ANNALES

London 2003

du 16e CONGRÈS

de l'ASSOCIATION INTERNATIONALE
pour l'HISTOIRE du VERRE

Couverture / Cover illustration:
The Kit-Cat Club Decanter. Height 280mm. This vessel celebrating a London dining club of the 18th century is discussed by Simon Cottle on p. 267.

Photo courtesy of Sotheby's

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CONTENTS

The Imperial Roman World – Glass Manufacture and Compositions

The Imperial Roman World – Vessels and their Patterns of Use

The Parthian and Sasanian Worlds

The Late Antique World

The Islamic World

Medieval and Early Post-Medieval Europe

The Seventeenth and Eighteenth Centuries – Studies in Composition

PRÉFACE

J'ai le grand plaisir de vous présenter les Annales du 16e congrès de l'Association Internationale pour l'Histoire du Verre et je tiens à remercier tous ceux qui ont fait que cette publication paraisse dans les meilleurs délais, les auteurs au premier chef, le comité de lecture, le maquettiste Peter Ellis, et surtout l'éditeur du volume, Hilary Cool, secrétaire générale de l'AIHV pour les années 2001–2003.

Le 16e congrès de l'AIHV s'est tenu à Londres du 7 au 13 septembre 2003 à l'Imperial College et il faut remercier ici chaleureusement le comité britannique qui a déployé tous ses efforts pour que cette rencontre unisse dans les meilleurs conditions science et amitié. Durant les vingt-quatre sessions organisées en parallèle, 87 contributions orales et 48 posters ont été présentés, montrant ainsi la vitalité de la recherche sur l'Histoire du Verre dans l'ensemble du monde scientifique. Grâce au dynamisme du comité britannique, des visites ont été organisées dans plus d'une quinzaine de musées et de galeries londoniens et les congressistes ont pu passer une pleine journée à découvrir les fouilles de Colchester ou bien les musées d'Oxford. Le comité d'organisation du congrès s'associe avec moi pour remercier de leur parrainage et de leur soutien les organisations, établissements et personnes suivants: Association for Cultural Exchange, Association for the History of Glass, AIHV, Mr Hugh Bayley MP, Bonhams, A.J.H. Boulay Charitable Trust, British Academy, Christie's, English Heritage, Mr Christopher Fish, Glass Association, Glass Circle, Guardian Industries Corp., Guild of Glass Engravers, Mallett & Sons (Antiques) Ltd, Sir Harry Pilkington Trust, Society of Antiquaries of London, Adrian Sassoon, Trustees et Director Wallace Collection, Rainer Zeitz Limited.

Ce volume réunit 92 contributions qui couvrent un arc chronologique très vaste depuis le deuxième millénaire av. J.-C. jusqu'à nos jours, et touchent à tous les aspects de l'histoire du verre, avec un accent particulier porté sur les données archéométriques. Une part importante est réservée aux débuts de l'histoire du verre au IIe millénaire et au début du Ier millénaire av. J.-C. avec des communications portant sur le Proche-Orient, l'Égypte, la Grèce et l'Italie et à ses développements dans la Méditerranée orientale hellénistique. Le monde romain est abordé selon deux axes: production du verre brut et détermination des compositions, étude de la diffusion à travers l'analyse d'assemblages de sites terrestres ou sous-marins ou de catégories techniques particulières. Le monde parthe et sassanide et l'Antiquité tardive sont illustrés par des contributions touchant aussi bien à l'archéométrie qu'aux aspects typo-chronologiques et économiques. Les communications sur le monde islamique s'inscrivent dans la lancée inaugurée au 15e congrès et attestent la vitalité de la recherche dans ce domaine. La présentation de découvertes et études portant sur la Grande Bretagne, l'Allemagne, les Pays-Bas, l'Italie, le Portugal et la Tchéquie alimentent le débat sur le verre à l'époque médiévale et post médiévale en Europe. Les XVIIe et XVIIIe siècles reçoivent un traitement de choix, avec une combinaison entre recherches archéométriques et études des influences entre les différents centres de production. XIXe et XXe siècle ne sont pas en reste, de même que les recherches portant sur la parure, le verre plat, les conditions de conservation des collections et l'identification des faux, imitations et remplois. Au total, un volume extrêmement riche, qui montre bien combien les recherches sur le verre s'intègrent dans les problématiques les plus nouvelles.

Lors de l'assemblée générale, le comité de l'AIHV a été renouvelé. Jennifer Price présidente, Hilary Cool, secrétaire générale, Anne Hochuli-Gyzel et Anne Vanlatum, que l'on doit toutes remercier pour leur efficacité, ont présenté leurs démissions. De nouveaux membres ont été élus: Marie-Dominique Nenna comme présidente, Jane Spillman comme secrétaire général et Ian Freestone comme vice-président. Déjà présents dans le comité, Jennifer Price, David Whitehouse, a été élu comme membres, J. Egberts a été réélu comme trésorier. Nous avons à déplorer le décès récent de David Grose, qui présent parmi nous à Londres, avait pu nous montrer une fois de plus, toute sa maîtrise de l'histoire du verre à ses débuts.

Les préparatifs pour le 17e congrès progressent bien. Le congrès se tiendra à Anvers du 3 au 10 septembre 2006 (pour plus de renseignements, consultez les sites web www.AIHV.org et le site de l'université d'Anvers). Nous fêterons alors, tous ensemble je l'espère, le 50e anniversaire de notre association et rendrons hommage à son fondateur Joseph Philippe.

Marie-Dominique Nenna
Octobre 2004

PREFACE

I have great pleasure in presenting you with the Annales of the 16th congress of l'Association Internationale pour l'Histoire du Verre, and I wish to thank all those who have ensured that this publication appears with the least delay: principally the authors, the academic committee, the production editor Peter Ellis and especially the academic editor of the volume, Hilary Cool, secretary general of the AIHV for the years 2001–2003.

The 16th congress of the AIHV was held in London from September 7th–13th, 2003, at Imperial College, and here we have to warmly thank the British Committee who expended all of their efforts to ensure the meeting ran smoothly in the best conditions of science and friendship. During the 24 parallel sessions, 87 spoken papers and 48 posters were presented, displaying the vitality of research on the history of glass in the scientific world. Thanks to the energies of the British Committee, visits had been organised to more than 15 museums and galleries in London, and the participants of the congress were able to spend a full day exploring the excavations at Colchester or the museums of Oxford. The congress organising committee join with me in thanking the following organisations, establishments and individuals for their sponsorship and their support: the Association for Cultural Exchange, the Association for the History of Glass, the AIHV, Mr Hugh Bayley MP, Bonhams, the A.J.H. du Boulay Charitable Trust, the British Academy, Christie's, English Heritage, Mr Christopher Fish, the Glass Association, the Glass Circle, Guardian Industries Corp., the Guild of Glass Engravers, Mallett & Sons (Antiques) Ltd, the Sir Harry Pilkington Trust, the Society of Antiquaries of London, Adrian Sassoon, the Trustees and Director of the Wallace Collection and Rainer Zeitz Limited.

This volume brings together 92 contributions which cover a vast chronological span from the second millennium BC up to the present day, touching on all aspects of the history of glass with a particular emphasis on the archaeometric discoveries. An important part is devoted to the beginnings of the history of glass in the second millennium and the beginning of the first millennium BC with papers covering the Near East, Egypt, Greece and Italy, and the developments in the eastern Hellenistic Mediterranean. The Roman world is approached from two directions: the production of raw glass and the determination of its composition, and the study of the spread of glass by analysing terrestrial and shipwreck assemblages or particular techniques. The Parthian, Sasanian and late Antique worlds are illustrated by papers touching on archaeometric approaches as well as those dealing with typology, chronology and economics. The papers on the Islamic world build on the start made at the 15th congress and show the vitality of research in this area. The presentation of discoveries and research coming from Great Britain, Germany, the Low Countries, Italy, Portugal and the Czech Republic fuel the debates about glass during the medieval and post-medieval period in Europe. The 17th and 18th centuries have a selective treatment with a grouping of archaeometric research and studies of the influences between different production centres. The 19th and 20th centuries are not ignored, and there are also studies dealing with jewellery, flat glass, the condition and conservation of collections and the identification of fakes, imitations and reuse. In sum, this is an extremely rich volume which well demonstrates how research on glass has engaged with new problems.

During the General Assembly the board of the AIHV changed. Jennifer Price (President), Hilary Cool (Secretary General), Anne Hochuli-Gyzel and Anne Vanlatum, to whom we extend all thanks for their work, submitted their resignations. The newly elected members were Marie-Dominique Nenna as President, Jane Spillman as General Secretary and Ian Freestone as Vice President. Jennifer Price and David Whitehouse were re-elected as members and Jan Egberts as Treasurer. We mourn the recent death of David Grose who was with us in London and who was able to show us one last time all his mastery of the history of glass from its beginnings.

The preparations for the 17th congress are progressing well. The congress will be held at Antwerp from September 3rd to September 10th 2006 (for more information see the web site www.AIHV.org and the site of the University of Antwerp). We will celebrate there, all together I hope, the 50th anniversary of our association and pay homage to its founder Joseph Philippe.

MARIE-DOMINIQUE NENNA
October 2004

EDITORIAL NOTE

In the papers that follow previous Annales are cited in an abbreviated form. The full publication details of the volumes cited are as follows.

Annales du 1ᵉ Congrès AIHV = *Annales du 1ᵉʳ Congrès des «Journées Internationales du Verre», Liège 20–24 août 1958* (nd [1960] Liège)

Annales du 8ᵉ Congrès AIHV = *Annales du 8ᵉ Congrès de l'Association Internationale pour l'Histoire du Verre, Londres-Liverpool 18–25 septembre 1979* (1981 Liège)

Annales du 9ᵉ Congrès AIHV = *Annales du 9ᵉ Congrès de l'Association Internationale pour l'Histoire du Verre, Nancy (France) 22–28 mai 1983* (1985 Liège)

Annales du 10ᵉ Congrès AIHV = *Annales du 10ᵉ Congrès de l'Association Internationale pour l'Histoire du Verre, Madrid-Segovia, 23–28 septembre 1985* (1987 Amsterdam)

Annales du 11ᵉ Congrès AIHV = *Annales du 11ᵉ Congrès de l'Association Internationale pour l'Histoire du Verre, Bâle 29 août–3 septembre 1988* (1990 Amsterdam)

Annales du 12ᵉ Congrès AIHV = *Annales du 12e Congrès de l'Association Internationale pour l'Histoire du Verre, Vienne-Wien, 26–31 août 1991* (Amsterdam 1993)

Annales du 13ᵉ Congrès AIHV = *Annales du 13e Congrès de l'Association Internationale pour l'Histoire du Verre, Pays-Bas 28 août–1 septembre 1995* (1996 Lochem)

Annales du 14ᵉ Congrès AIHV = *Annales du 14ᵉ Congrès de l'Association Internationale pour l'Histoire du Verre, Venezia-Milano 1998* (2000 Lochem)

Annales du 15ᵉ Congrès AIHV = *Annales du 15ᵉ Congrès de l'Association International pour l'Histoire du Verre, New York-Corning 2001* (2003 Nottingham)

In the cases of multiple authorship asterisks indicate the corresponding author.

Due to the large numbers of papers in this volume, strict word and illustration limits had to be imposed on the authors. This meant that some papers presented at the Congress will be published elsewhere at greater length than is possible here. I am pleased to inform members that one of these is now in press:

D. Foy, M. Picon, V. Thirion-Merle, M. Vichy, 'Contribution à l'étude des verres antiques décolorés à l'antimoine', to appear in *Revue d'Archéométrie.*

H.E.M. COOL

December 2004

DEVELOPMENTS IN THE SECOND AND EARLIER FIRST MILLENNIA BC

THE RAW MATERIALS OF EARLY GLASSES: THE IMPLICATIONS OF NEW LA-ICPMS ANALYSES

A.J. SHORTLAND

INTRODUCTION

The first man-made glass was produced in Mesopotamia and Egypt around 1500 BC (Nicholson 1993; Lilyquist and Brill 1993). It is probable that while the earliest production was in Mesopotamia, Egypt was producing glass within 100 years of its invention (Shortland 2000). Glass in this period was a prestige product and extensively 'traded' in a system of competitive gift-giving between neighbouring rulers and between the rulers and their satellite states. Since glass plays an important role in this exchange, the ability to trace individual glass objects back to the place where the glass of which they are made was first produced would add significantly to our knowledge of the economics and political systems of the period.

Unfortunately, provenancing this glass to its production site has proved to be more difficult than might have been expected at first sight since even under quite precise analysis, they all appear very similar. Glass of this period contains three main raw components: silica in the form of quartzite pebbles, a soda-rich plant ash and almost always a colorant (Turner 1956a; 1956b; Henderson 1985). To these deliberately added components there is the potential for accidental contaminants while manufacturing the glass, for example clay from the partial melting of crucibles, copper and bronze from tools and stirrers, and old glass from the reuse of these tools or vessels. No success has yet been achieved with the provenancing of the silica component of the glass. What little progress that has so far been made has been by looking at the colorants. For example, it is probable that most of the cobalt blue glass comes from Egypt since it contains a colorant sourced to Egypt (Kaczmarczyk 1986; Shortland and Tite 2000) (however, see Reade *et al.* this volume, for another opinion on cobalt colorants). Some success has also been achieved with the source of antimonate opacifiers for white and yellow (Shortland 2002) and with lead isotopes on lead antimonate glasses (Lilyquist and Brill 1993; Shortland *et al.* 2000). Other evidence has so far proved elusive.

This paper examines the third major component of the raw materials of the glass – the plant ash – in an attempt to distinguish glass manufactured in Egypt and that found in Mesopotamia. It then discusses briefly the use of copper colorant for the production of blue glasses.

SAMPLES AND METHODOLOGY

A collection of some 300 samples of early glass, mostly from Egypt and Mesopotamia has been assembled at Oxford. This paper concentrates on a subset of these samples from the sites of Malkata and Amarna in Egypt, both thought to be glassmaking sites in the 14th century BC (Nicholson 1995a; Nicholson and Jackson 1998; Nolte 1968; Keller 1983). These glasses are compared to glass from the site of Tell Brak in Syria, which is also likely to have been a glassmaking site (Oates *et al.* 1998; Henderson 1998).

The glasses from these three sites were analysed by SEM-WDS and LA-ICPMS following methodologies outlined in the appendix and elsewhere (Henderson 1988; Shortland 2002). The two techniques gave the possibility of analysing 23 elements by SEM-WDS, mostly major and minor elements and 57 by LA-ICPMS, mostly minor and trace elements. Since some of the elements were analysed by both techniques, a total of 64 different elements could be worked with (FIG. 1).

RESULTS

In a colourless glass, of the 64 elements that can be analysed, 34 elements are commonly found to be above the lowest limits of detection using these techniques (FIG. 1). A colourless glass should have only two raw materials: quartzite pebbles and a plant ash. Analysis of the quartzite pebbles has shown that they are a very pure form of silica contributing no significant amount of any other element to the glass (unpublished analysis by the author; Brill 1999a; Brill 1999b). Given that the quartzite pebbles therefore bring only one element (silicon) to the glass, then the remaining 33 elements must come from the plant ash or

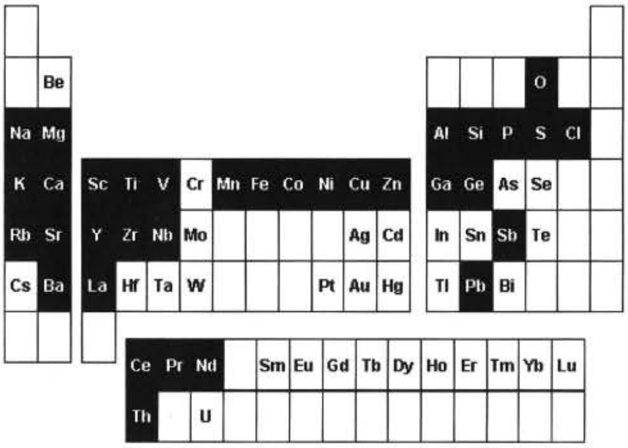

FIG. 1 Elements analysed in the study. All elements shown were analysed for with at least one of the two techniques. Those in a white font on a black background were detected in the colourless glasses

one of the possible sources of chance contamination. This is obvious for many of the major elements, for example Na, K, Mg, Ca, etc, and it has been realized for some time that ratios of these elements might give some indication as to the type of plant ash that might have been used (Lilyquist and Brill 1993; Turner 1956a; Turner 1956b; Weyl 1951), however the interpretation of the other minor and trace elements has not been attempted. In addition to the fact that these 33 elements seem to be present in the plant ash, further conclusions can be derived from the fact that some of the elements correlate with each other. FIGURE 2 shows a graph of Al against Fe for all colours of Egyptian glass except cobalt blue. As can be seen, there is a strong correlation between these two elements. This is true for a total of ten different elements: Al, Ti, V, Fe, Y, Zr, Nb, La, Ce, Pr and Nd – all are correlated to a greater or lesser extent. Furthermore, it is important to note that these elements are often those that might be associated with a clay. To test whether these correlations might be derived from clay being incorporated in the glass a graph of Al_2O_3 against ($FeO+TiO_2$) was plotted for the Cu blue glasses from Egypt (FIG. 3). These components correlated well, and when the trendline of the correlation was extended it passed through the values of Nile silt, the local clay. This suggests that the presence of these elements in the glass might be related to the influence, in some form or other, of Nile silt. However, it should be noted that not all the elements correlate so well, suggesting that, if Nile silt is involved, at least some of the elements must be fractionating relative to each other.

INTERPRETATION

Plant ash and clay

If Nile silt is involved, the question then arises as to how it is being incorporated into the glass. The first possibility is that it is derived from accidental contamination from the crucible. Excavations at the glass workshops at Amarna have shown that the vessels associated with glassmaking and glassworking on this site are made from Nile silt (Nicholson 1995b; Petrie 1894; Shortland and Tite 2000). It is possible that partial melting of the crucible in glassmaking leads to a Nile silt signature contaminating the glass. However, the amount of contamination required to produce this pattern would lead to a significant reduction and weakening of the crucible, probably too much to be a likely solution. The second possibility is that the clay was deliberately added, for some unknown purpose. This is possible, but again unlikely. The third and most likely solution is that the clay is somehow incorporated into the batch with the plant ash. This might be because the plant has been growing on the clay and taken up its chemical signature, or it might be that when the plant was burnt, the collecting of the ash incorporated some of the underlying clay into the ash; possibly both are a factor.

If these correlations represent clay contamination of the glass, then whatever way the clay has become incorporated, it would most probably be derived from the area around which the glass was made. Therefore if glasses are made in different areas then it is possible that different clays, with different chemical signatures, might be involved. If these different clay signatures were distinguishable, then there might be the potential to provenance the glasses. To test this, more plots of the Egyptian glasses were drawn and compared to Mesopotamian glasses from Tell Brak. In many cases the two trendlines produced were indistinguishable, since the clays of the two areas often have quite similar ratios. However, for some elements there is a significant difference in the element ratios. The best example of this is shown in FIGURE 4, where Ti is plotted against Fe for copper – and cobalt-coloured glass from Egypt and copper-coloured glasses from Tell Brak. As can be seen, all the Egyptian glasses lie on a tight line, trending towards the Nile silt values (Nile silt trendlines are shown, the actual points lying well off the field of the graph). This seems to indicate that the Egyptian copper and cobalt glasses have similar signatures and possibly similar clays. However, the Mesopotamian glasses (plus two of the Egyptian glasses) are distinctly different falling well below the trend of the others. The trendline for Tell Beydar clay (a source local to Tell Brak) is shown on the graph, and this also falls below the Egyptian values, however the fit of the Tell Brak values to the trendline is not very good. As always, further data are required to confirm the reality of this suggested pattern, but it seems that there is the potential to distinguish differences in the minor and trace element compositions of Egyptian and Mesopotamian glasses, differences that may be linked to the presence of local clay contamination in the glass.

Colorants: copper blue

Colorants in the glasses also show correlations between different elements. This has been demonstrated for yellow glasses, for example, where it has been observed that not only are the yellow glasses higher in the two elements, Pb and Sb, that make up the antimonate opacifier in the glass, but also in accidentally incorporated additional elements including Zn, As, Ag, Cd, Ba and perhaps Cr, Mo and Bi. Some of these elements are associated with the antimony component of the opacifier and have helped to trace the source of the antimony in these glasses to the Caucasus

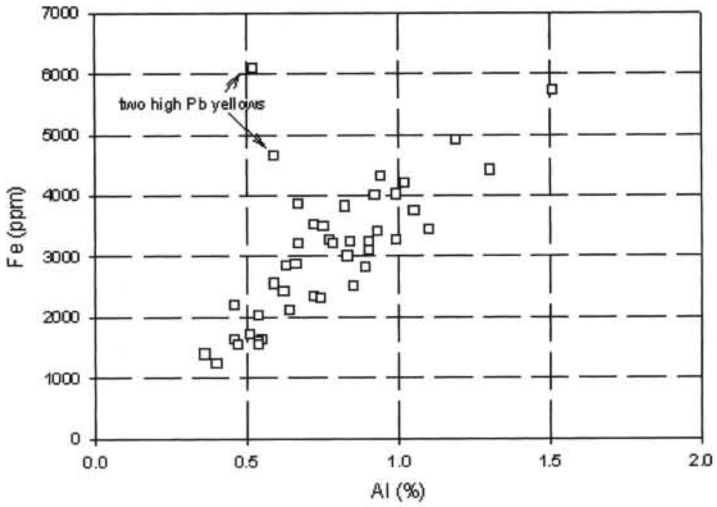

FIG. 2 Plot LA-ICPMS analyses of Al (%) against Fe (ppm) for Egyptian glasses of all colours except Co blue

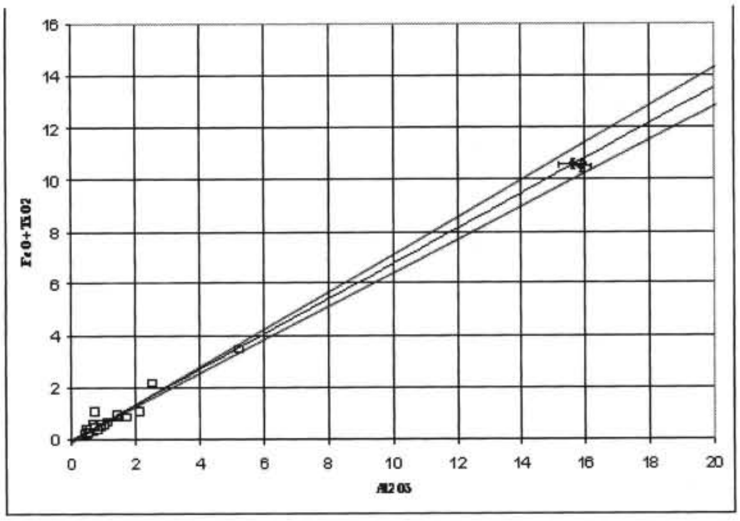

FIG. 3 Plot SEM-WDS analyses of Al_2O (%) against ($FeO+TiO_2$) (%) for Egyptian copper glasses (squares) with the trendline of this plot. Analysis of Nile silt (diamonds) for comparison

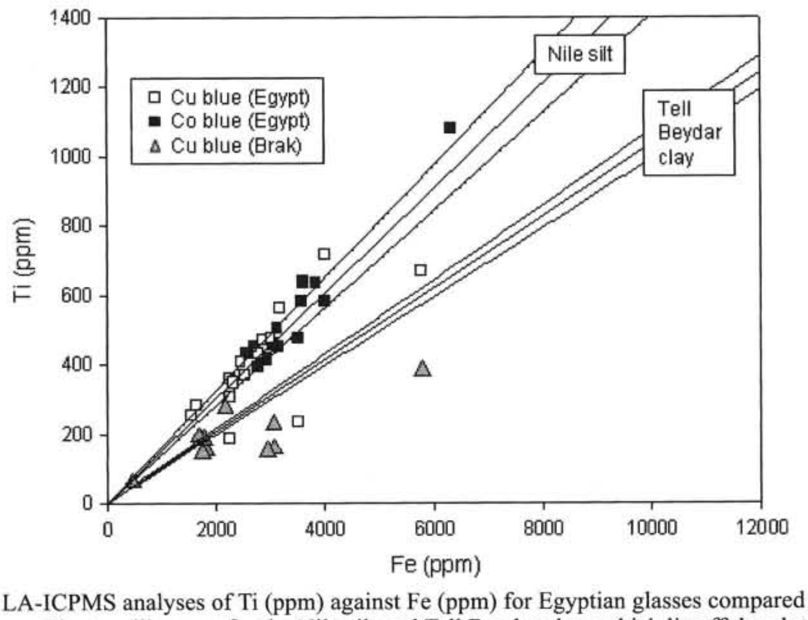

FIG. 4 Plot LA-ICPMS analyses of Ti (ppm) against Fe (ppm) for Egyptian glasses compared to Tell Brak glasses. The trendlines are for the Nile silt and Tell Beydar clays which lie off the plot area

(Shortland 2002). In the same way, it is possible to look for elements that may be incorporated in the glass when copper is added as a colorant. The most important of these in Egyptian glasses is tin which, when present, is usually in a ratio of about 1:10 with the copper, indicating that the colorant used was bronze or bronze scrap (Kaczmarczyk and Hedges 1983; Shortland 2000; Turner 1956b). The new analyses of Egyptian copper blue glasses have suggested that in some cases traces of As and Pb might also be included in the bronze, but this is still to be confirmed by further analyses. Of the 26 copper blue glasses from Egypt analysed in this study, 19 contained significant tin, indicative of a bronze colorant being used. Forty or so analyses of copper blue glasses from Mesopotamia were available, either from this study or previously published data (Brill 1999a; Brill 1999b; Henderson 1998; Oates *et al.* 1998). Although a small number of these glasses were analysed by SEM-EDS and therefore had high detection limits for tin, none of them contained detectable amounts of the element. This seems to suggest that in Mesopotamia a copper or copper compound was used as the colorant in contrast to Egypt where this was used less than 25% of the time, the majority being coloured by bronze or bronze scrap. Some difference in the procedures for using colorants are therefore evident between the two areas.

Conclusions

To conclude, this study of 14th-century BC glasses from Egypt and Mesopotamia has concentrated on looking at elements that might have thought to be associated with the plant ash component of the glass. It seems that of the 34 elements that are detectable in the glasses, ten of them appear to be correlated with each other to a greater or lesser extent. Some of the ratios of these correlated elements appear to be related to the ratios of the same elements in clays that were used in the crucibles and occur locally to the sites where these glasses are thought to be made. The most likely explanation for the occurrence of this clay signature in the glass is that the clay was somehow incorporated into the glass batch with the plant ash, either because the plant had taken on the chemical characteristics of the ground in which it grew, or because it was burnt on a clay surface and some of that clay was incorporated into the plant ash when it was collected up. Either way, there seems to be detectable differences in some of these elements between Egyptian and Mesopotamian glasses, suggesting that, with further analysis, there is a potential to provenance. Similarly, the colorant used in copper-coloured glasses appears to be different between the two areas. In Mesopotamia, no tin has yet been identified in the glasses suggesting a copper colorant was used. However, in Egypt over 75% of the copper blue glasses analysed were found to contain tin, suggesting that in Egypt the norm was to use a colorant based on bronze or bronze scrap. Further work on the analysis of these ancient glasses and particularly on the composition and production of plant ashes is necessary for further progress to be made.

Acknowledgements

The author would like to thank Jennifer Mass (Winterthur Museum), Christine Lilyquist (Metropolitan Museum of Art), Joan Oates (McDonald Institute) and Paul Nicholson (Cardiff) for loaning parts of their sample collection to this study. It would not have been possible without access to museum collections in Victoria Museum of Egyptian Antiquities (Uppsala), Nationalmuseet (Copenhagen), Metropolitan Museum of Art (New York), The British Museum, National Museum of Scotland, Ashmolean Museum (Oxford), Fitzwilliam Museum (Cambridge), Petrie Museum of Egyptian Archaeology (UCL) and the Liverpool University Museum. Norman Charnley (Microprobe Unit, Earth Sciences, Oxford), Jo Greenwood (NERC ICPMS Facility, Kingston University) helped greatly with the analyses and Professors Mike Tite (Oxford) and Thilo Rehren (UCL) in discussion and reading of drafts. Marc Walton kindly allowed access to his unpublished analyses of Tell Beydar clays.

Appendix

Microprobe analyses were conducted on polished sections through the samples which were examined in the Cambridge Microscan 9 microprobe in the Department of Earth Sciences, Oxford. The chemical compositions of the glasses were determined using the attached wavelength dispersive spectrometer following the methodology laid down by Norman Charnley and Julian Henderson (Henderson 1988). Regular runs on a Corning glass standard were used to check for machine drift. LA-ICPMS analysis was conducted at the NERC facility at the University of Kingston, Surrey. The widest range of elements, routinely measured at the facility was included, amounting to some 57 elements in all. Each time a new block was put into the sample chamber, two gas blanks (each of five runs) and two analyses each of standards NIST610 and NIST612 (each of three runs) were completed with a rastering laser. Each analysis of an unknown was the mean of three runs. Results were calibrated by using ^{43}Ca as an internal standard and standardising it against the CaO values obtained by WDS microprobe. An ablation volume correction factor was therefore obtained and applied to the other elements. LLD values (lowest level of detection) were obtained using the gas blank and NIST610 results.

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A STUDY OF CORE-FORMED GLASS VESSELS PRODUCED IN EIGHTEENTH-DYNASTY EGYPT: A COMPARISON OF THE GLASS VESSELS FROM GHURAB AND AMARNA

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AIMS AND METHODS

A major study was undertaken by Nolte (Nolte 1968) in the 1960s to interpret glass vessels comprehensively in the framework of the history of ancient Egypt. In recent years, based on new excavation results from the ruined cities such as Amarna and Qantir (FIG. 1), reconstruction studies of the glass furnace have been made, and these researches have started to reveal international aspects in the evidence of actual export and import (Jackson *et al.* 1998; Rehren *et al.* 2001; Shortland 2001a).

In addition, as a result of excavation and investigation in the Memphite necropolis in recent years, it has become very clear that Memphis was functioning as a political base in those days (Zivie 1988), and it is now time to reconsider the production system of glass in Egypt.

Although many glass vessel fragments were excavated from the ruins of Medinet el-Ghurab in the hinterland of Memphis, where it is believed that the glass factory would have existed, these were not described in detail in the report (Brunton and Engelbach 1927, 2). Glass vessels excavated from Malqata and Amarna, the sites of Upper Egypt which have received comparatively wide recognition, are considered to be typical of core-formed glass vessels in ancient Egypt. The typical characteristics are well illustrated by an unprovenanced vessel now in the Victoria and Albert Museum, London (COLOUR PLATE 1). It is unclear, however, how glass vessels from Ghurab differ from those of Malqata in Upper Egypt or those of Amarna which are considered to be the standard type.

Provenanced pieces from excavations are very informative, even if they are fragmentary, in clarifying aspects of glass vessel production in each region. I have researched at the British Museum (Cooney 1976) and the Petrie Museum (Thomas 1981) which possess many pieces of glass vessels excavated from Ghurab and Amarna. In this paper, I would like to list the characteristics of the glass vessels excavated from Amarna first; and then clarify the special characteristics of the glass vessels excavated from Ghurab. Finally, by comparing the two, to consider the production activity of the glass factory at Ghurab in the light of this research.

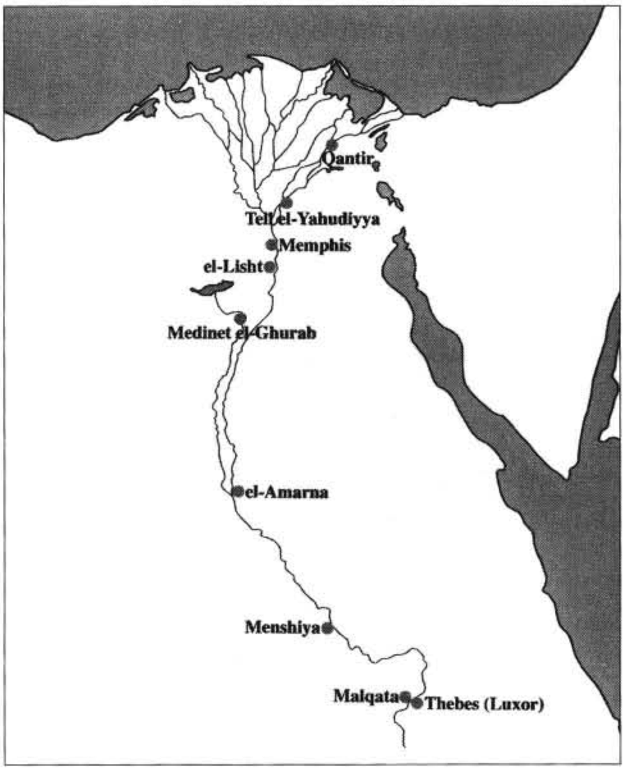

FIG. 1 Map of Egypt

THE CHARACTERISTICS OF THE GLASS VESSELS FOUND AT AMARNA

Amarna, located about 280km south of Cairo, was founded by King Akhenaten (*c.* 1352–1336 BC). The city was abandoned soon after his death, having been occupied for only about 20 years. Numerous glass vessels, as well as glass furnaces, were unearthed at this site (Petrie 1894, 25; Nicholson 1995), and because of their number have been considered the standard type at Amarna. Characteristics 2, 3 and 4 have already been pointed out by Kozloff (1992, 376).

1 Forms: Most of the vessel shapes are *krateriskos* and *amphoriskos*, and the former are larger in number than the latter. Lentoid flasks are also present.
2 Colours: Blue coloured with copper is as common as the cobalt blues.
3 Decorations: Neck; mostly chevron or simple festoon pattern. Body; mostly clustered festoon or another kind of pattern decorations.
4 Generally no decoration on the handles.
5 Most of the rims and feet are encircled by colour thread or have no decorations.

Glass vessels found at Medinet el-Ghurab

Medinet el-Ghurab, located in the hinterland of Memphis, was established by Thutmosis III (*c.* 1479–1425 BC) as a royal *harim* and appears to have functioned for about 300 years until the reign of Rameses V (Kemp 1978). Petrie excavated this site from 1888 to 1890, and many pieces of core-formed glass vessels have been unearthed in the town of Ghurab (Petrie 1890, 38; 1891, 16–17). Subsequently, Brunton and Engelbach argued that glass factories and kilns had existed in Ghurab (1927, 3). Though the detailed provenances of glass vessels which I have researched in the museums are not known, the glass vessels stored in the British Museum were excavated by Petrie according to Cooney (Cooney 1976, 49). My research focused on the 48 pieces of fragmented material stored in the Petrie Museum and the British Museum in order to study in detail the glass vessels excavated from Ghurab.

The points considered to be the special features of core-formed glass vessels from Ghurab compared to those of Amarna are explained in detail below.

EA64338 (colour plate 2.1) Lentoid flask; The lentoid flask is the most popular form in Ghurab. Vertical handles decorated with fine parallel lines from the neck to the body are considered to be a feature of core-formed glass vessels from Ghurab. This pattern is exquisite and needs an advanced technique because the lines are parallel at intervals of about 1mm without any overlapping, and the handles are only about 10mm wide. Some of the vessels are decorated with this pattern not only on the surface of the handles, but also on the back which is not usually visible. It is a notable point that this characteristic decoration does not connect with the decorative composition of the whole vessel, nevertheless this elaborate decoration is adopted. On the body there is a feathered pattern as a main decoration in the middle between horizontal lines. The feathered pattern that we recognize in the vessels is characteristic. It is considered to have been decorated by a pointed tool drawn with a single stroke up and down. It is noticeable that the same characteristic technology of the feathered pattern was frequently used in the vessels excavated from Ghurab.

EA67027 (colour plate 2.2) The *amphoriskos* is the second most popular form amongst the core-formed glass vessels from Ghurab. Many of the handles of *amphoriskoi* from Ghurab were fixed vertically on the neck and the body, but those from other sites were usually fixed horizontally on the body. There are vessels which were edged with monochromatic glass on the rims and feet in Amarna, but in Ghurab there are many vessels which were edged with a gorgeous twist pattern on the rims and feet. The twist pattern was created from a prefabricated glass rod, which was twisted together with two or more coloured glass rods. The handles explained above are also prefabricated. Thus one of the features of vessels from Ghurab is elaborate decoration.

EA65661 (colour plate 2.3) Lentoid flask. The random spot pattern adopted for these vessels is unusual. Almost all of the core-formed glass vessels of Ancient Egypt are decorated with festoon or feathered cord patterns. It is notable that many vessels which have a similar spotted patterns were unearthed in Ghurab. Two different coloured glass rods are joined to each other (colour plate 2.3, upper right) and fixed from the neck to the body. This type of handle is another feature of Ghurab in cases where the parallel multi-colour threads are not used.

EA64339 (colour plate 2.4): Miniature lentoid flask; The spot pattern was adopted on the middle of the body. The horizontal lines and twist patterns were set on the body above and below the main spot pattern. The twist patterns were adopted abundantly not only on the edge of the rim and the base but also dividing the line of the main pattern on the vessels from Ghurab. So core-formed glass vessels from Ghurab impress us as more attractive than those of Amarna.

The characteristics of the glass vessels excavated from Medinet el-Ghurab are as follows. Nos 1–3 and 9 have already been pointed out by Cooney (1976, 149–52).

1. Forms: mostly lentoid flask but including *amphoriskoi* and others (see lentoid flasks; colour plates 2.1, 3, 4; 3.3, 7, *amphoriskoi*; 2.2; 3.1).
2. Most of the handles are attached vertically on the vessel regardless of its form (colour plates 2; 3.2).
3. Frequent use of decoration on the handles overlaid with parallel multi-colour threads (colour plates 2.1, 2; 3.2).
4. A few handles are formed by joining several coloured glass rods side by side (colour plate 2.3).
5. Frequent use of twist patterns as decorative rims and feet (colour plates 2.1, 2, 4; 3.4, 6).
6. Feathered patterns drawn with a single stroke on the body (colour plates 2.1, 2; 3.1, 3, 7).
7. Feathered and other patterns enclosed by lines or twist patterns on the body (colour plates 2.1, 2, 4; 3.2, 3, 5, 7).
8. A few vessels have spotted decorations on the body (see colour plate 2.3, 4).
9. There are some miniature lentoid flasks (see colour plate 2.4).

It is clear that the glass vessels from Ghurab have specific characteristics different from those of the vessels from Amarna (table 1). Those from Ghurab appear to be splendid with colourful patterns which required skilled workmanship, suggesting that, as one possibility, another group of glassworkers had existed in addition to those from Amarna. There is a possibility that a glass factory had existed in Memphis, which was a centre of administration influencing Ghurab, because there is not much detail of glass factories in Ghurab mentioned by Brunton and Engelbach, and glass factories existed at the contemporary religious sites of Amarna and Malqata. Having taking into consideration that many of the glass vessels with the unique characteristics described above have been extensively excavated from Ghurab, these groups of vessels probably were produced at this site or at Memphis.

Fragmented pieces from Amarna produced in Ghurab or around the Memphite area

It can be argued that the glass vessels considered to have been produced in Ghurab or the Memphite area have a

Table 1 Comparison of glass vessels from Ghurab and Amarna

Provenance	Form	Pattern of rim and foot	Pattern of handle	Pattern of body
Amarna	crater, *amphorisk*	edged with monochromatic glass rod	plain	clustered festoon etc
Ghurab	lentoid flask, *amphorisk*	edged with a gorgeous twist	gorgeous cord	feathered – drawn with a single stroke enclosed by lines etc

unique style to them. Therefore, to pinpoint the period when the factory that produced vessels from Ghurab functioned, I looked for vessels with characteristics of the decorations seen in the vessels from Ghurab, among the 175 pieces excavated from Amarna. These cover the period from the foundation to the abandonment of the city. I found the following.

• Handles overlaid with parallel multi-colour threads: EA66972, EA66973 (colour plate 4.1), EA68419 (colour plate 4.2), EA68421 (colour plate 4.3).

• Twist patterns as decorative rims and feet: EA68423 (colour plate 4.4), EA68426 (colour plate 4.5).

• Feathered patterns drawn with a single stroke on the body: EA66984, EA68423, EA68447 (colour plate 4.6).

• Feathered and other patterns enclosed by lines or twist patterns on the body: EA66979 (colour plate 4.7), EA67003 (colour plate 4.8), EA68424 (colour plate 4.9).

Thus, glass vessels which have obvious features of those unearthed from Ghurab and are considered to have been produced around the Memphite area, have been excavated at Amarna. This clearly shows that the factory which produced vessels unearthed from Ghurab was making and exporting these vessels to Amarna at least in the period when the city of Amarna was functioning.

In addition, the vessels excavated from Ghurab have characteristic handles overlaid with parallel colour-threads attached vertically on the vessels, while those of Amarna are attached horizontally in many cases. Furthermore, multi-coloured handles without evidence of attachment to the vessels were also excavated from Amarna (EA68421). This evidence indicates that not only finished vessels but also prefabricated parts were brought to Amarna from around the Memphite area.

Conclusion

This study has focused on the core-formed glass vessels excavated from Medinet el-Ghurab in the hinterland of Memphis, in order to consider the problem of how glass vessels had been produced in other regions of the country aside from those from Amarna and Malqata which have been considered as the standard of ancient Egyptian core-formed glass vessels.

From a comparison of the glass vessels from Ghurab with those of Amarna stored in the British Museum and the Petrie Museum in London, it can be concluded that there were specific characteristics – such as the frequent use of twist patterns, meticulously decorated handles attached vertically on the body and the feathered pattern drawn with a single stroke – found on the glass vessels excavated from Ghurab. These characteristic decorations appear splendid and required skilled workmanship, and large numbers of glass vessels with these unique characteristics have been extensively excavated from Ghurab, suggesting a strong possibility that they were produced at this site or Memphis and not elsewhere.

In addition, with regard to the chronology of the working periods of the glass factory in Ghurab or the Memphite area, I would argue that the factory was already working when Amarna was occupied, and that the glass vessels and prefabricated parts produced in this factory had been exported to the city of Amarna, because several glass fragments with the characteristic decorations seen in the vessels from Ghurab have been discovered at Amarna. To clarify the detailed activities of each glass factory across the whole country, including the circulation of glass vessels themselves and the diffusion of specific workmanship, further studies will be needed in the future.

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RAW MATERIALS USED TO PRODUCE AEGEAN BRONZE AGE GLASS AND RELATED VITREOUS MATERIALS

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Introduction

In addition to glass, the vitreous materials considered in this paper are faience and Egyptian blue frit. Faience consists of a quartz sand or crushed quartz body coated with an alkali glaze (Tite and Bimson 1986) that was coloured initially by copper or manganese and later by cobalt. Egyptian blue frit is a polycrystalline material, produced by firing a mixture of quartz, lime, a copper compound and alkali (Tite *et al.* 1984). It is coloured blue throughout and is without any glaze layer. It consists of copper calcium silicate crystals, that produce the blue colour, and partially reacted quartz particles bonded together by a small amount of glass phase.

Faience, mainly as beads but also including the occasional vessel, first appeared in the Aegean in Minoan Crete (Foster 1979; Panagiotaki 1999a, 618) and in the north of Greece (Mirtsou *et al.* 2001) during the 3rd millennium BC, with Egyptian blue frit appearing by the beginning of the 2nd millennium BC (Panagiotaki 1999b, 40–1). During the period 1700–1425 BC, the manufacture of faience reached a peak with the production of inlaid plaques, human and animal figures in low relief as well as in the round (Evans 1921, 350; Foster 1979; Panagiotaki 1999b). At the same time, the small-scale production of Egyptian blue frit, mainly in the form of beads, continued (Panagiotaki 2000, 454).

During the 16th century (MM IIIB–LM IA or LM IA in Cretan terms, see Warren and Hankey 1989, 96), faience was introduced to the Mycenaean mainland (evidenced in the Shaft graves at Mycenae). In the 15th century or a little earlier glass appears in the form of beads and vessels in both Crete and the mainland. By 1450 BC, the Mycenaean mainland became dominant over Minoan Crete and among the Minoan arts and crafts adopted by the Mycenaeans was that of making relief beads. However, the Minoan relief beads were made of faience or gold but the favourite material for such beads in the Mycenaean world was glass, often enveloped in gold leaf. Glass relief beads and decorative plaques continued to be produced for almost three centuries together with beads made from faience, Egyptian blue frit and, new to the Aegean, cobalt blue vitreous (or glassy) faience (Panagiotaki *et al.* 2004).

The technologies for the production of faience, Egyptian blue frit and glass were almost certainly introduced from Egypt or the Near East (Panagiotaki 1999a). However, as already stressed by Foster (1979, 173), the Aegean faience has characteristics that make it strongly Aegean and therefore must have been made locally in the Aegean from its constituent raw materials (i.e. quartz, alkali and colorant). However, for Egyptian blue frit and glass, the situation is more complex since these materials are first produced from their respective constituent raw materials as 'primary' blocks or ingots which are then worked to produce objects. Therefore, Egyptian blue frit and glass objects of Aegean type could have been produced either from locally available constituent raw materials or by local working of imported primary blocks or ingots.

The primary aim of the research presented in the current paper has been to characterize, and thus attempt to identify, the sources of the alkali and cobalt colorant, and so contribute to our understanding of where and how Aegean vitreous materials were produced. However, the conclusions drawn are only preliminary since further analyses of Aegean vitreous materials are planned, together with a programme of plant ashes analyses.

Experimental procedures

Small samples of Egyptian blue frit, faience and glass were prepared as polished sections in resin blocks. The chemical compositions of any glass phase surviving in the Egyptian blue frit and faience, and of the glass itself, were then determined using wavelength dispersive spectrometry (WDS) in an analytical scanning electron microscope (SEM) (Table 1). The bulk compositions of the faience and frit as well as the glass compositions were also determined using energy dispersive spectrometry (EDS) in an SEM. However, these latter data are not included in the present paper.

A major problem with the analysis of vitreous materials from the Aegean is that a very high proportion has suffered severe weathering. As a result there has been only limited survival of glass phase. In the case of the faience and the Egyptian blue frit, unweathered glass phase was found in only 3 out of some 50 objects analysed. However, for the much less porous glass and vitreous faience, it was normally possible to locate at least small areas of unweathered glass phase.

Egyptian blue frit

In Egyptian blue frit from Minoan Crete, unweathered glass phase has been found only in the bead (KF31) selected from the 2000 or so found in the Vat Room Deposit at the Palace of Knossos, dating to the 19th century BC (Panagiotaki 1999b, 40–1). Analysis (TABLE 1) showed that the alkali used in producing this frit was richer in potash than soda (Na_2O/K_2O=0.6). Similarly, analysis of the surviving interstitial glass in the brown inlay of one of the Town Mosaic house façade plaques from the Palace of Knossos, dating to the period 1700/1650–1640/1630 BC (Panagiotaki 1995, 143–4; 1999a, 618) showed that an alkali richer in potash (Na_2O/K_2O=0.9) was again used. In contrast, the alkali used in the production of both Egyptian blue frit and faience from Egypt and the Near East was richer in soda than potash (eg Na_2O/K_2O=9.2 for Egyptian blue frit from Egypt).

This use of a distinctive potash-richer alkali strongly suggests that the Egyptian blue frit, like the faience, was produced on Crete from locally available component raw materials and was not imported as primary blocks from Egypt or the Near East. Since, although richer in potash, the alkali still contained a significant proportion of soda, its source was most probably a plant ash produced by burning a halophytic plant, such as *Salsola kali* which is currently found growing in Crete. Analysis of plant ash produced by burning *Salsola kali* collected from west Crete (from the beach at Georgioupolis) indicated a large excess of potash over soda (Na_2O/K_2O=0.1) far greater than that in the Minoan frit and faience. However, the analytical data for other *Salsola kali* plant ashes indicate a wide variation in composition including ashes with equal potash and soda contents (Na_2O/K_2O=0.9 for ash from the Levant (Ashtor and Cevidalli 1983)), and those richer in soda than potash (Na_2O/K_2O=1.9 for ash from Sicily (Verita 1985)).

In contrast to the Minoan Egyptian blue frit and faience, the unweathered glass phase found in one of the Egyptian blue frit fragments (Artisan's Quarter) from Mycenae was richer in soda than potash (Na_2O/K_2O=3.7). Since Egyptian blue frit found on the Mycenaean mainland is distinctive in having an unusually coarse texture with considerable unreacted copper, it is thought to have been produced on the Greece mainland using locally available raw materials. Therefore, it seems probable that, in this case, the alkali source was the halophytic plant *Salsola soda* which yields soda-rich ash (Na_2O/K_2O=6.4 for a *Salsola soda* ash from the Levant (Ashtor and Cevidalli 1983)) and which is found on the mainland but not on Crete.

Glass

The cobalt blue glass from Mycenae (Brill 1999, vol. 2, 57), and from Crete, analysed in the present project (TABLE 1), are comparable in composition both to cobalt blue glass from Amarna, Egypt (Shortland 2000, 17; Tite and Shortland 2003) and the cobalt blue glass ingots from the Uluburun shipwreck (Brill 1999, vol. 2, 53–4). All these cobalt blue glasses are characterized by alumina, manganese oxide, zinc oxide and nickel oxide contents that are higher than those observed in copper blue glasses, indicating that the source of the cobalt colorant was, in all cases, the cobalt rich alum from the Dakhla or Kharga Oases in the Western Desert of Egypt (Kaczmarczyk 1986). Therefore, the cobalt blue glass found in the Aegean was almost certainly imported from Egypt as primary ingots that were worked locally to produce the characteristic Aegean relief beads and plaques.

Similarly, the copper blue glass from Mycenae (Brill 1999, vol. 2, 57) and Crete, which is comparable in composition to that produced in both Amarna, Egypt

TABLE 1 GLASS PHASE ANALYSES FOR VITREOUS MATERIALS

Sample	Object type	SiO_2	Na_2O	K_2O	Na_2O/K_2O	CaO	MgO	P_2O_5	Al_2O_3	FeO	CuO	SnO_2	PbO	CoO	MnO	ZnO	NiO	Sb_2O_3	As_2O_5
KF31	Eb bead	64.48	4.64	7.20	0.6	4.08	1.02	0.33	3.85	3.97	9.17	0.00	0.01	0.09	na	na	na	na	na
Town mosaic	Fa plaque	80.68	4.31	5.07	0.9	1.45	0.68	na	2.91	2.88	0.74	na	na	na	na	na	na	na	na
Amarna (Av)	Eb	65.93	16.18	1.75	9.2	6.18	3.52	0.11	0.16	2.06	0.59	1.66	0.66	0.06	0.22	0.09	0.05	0.01	0.08
Artisan Quart	Eb fragmt	67.61	6.55	1.78	3.7	1.85	1.60	na	4.05	1.20	7.05	1.95	0.11	na	na	na	na	na	na
Crete	Co glass	67.62	17.22	0.65	26.5	5.65	2.10	0.13	3.24	0.50	0.26	0.01	0.04	0.10	0.49	0.26	0.14	0.31	0.02
Mycenae (Av)[1]	Co glass	64.30	19.67	1.27	15.5	7.60	3.57	na	2.17	0.73	0.08	na	na	0.08	0.15	na	na	na	na
Amarna (Av)[1]	Co glass	63.80	19.60	1.10	17.8	7.60	4.30	0.12	2.50	0.60	0.18	0.02	0.00	0.13	0.19	0.12	0.07	na	0.02
Uluburun (Av)[1]	Co glass	65.93	19.47	0.93	21.0	6.90	2.93	na	2.00	0.66	0.21	na	na	0.05	0.15	na	na	na	na
Crete	Cu glass	65.11	17.09	3.23	5.3	5.04	5.68	0.19	0.96	0.35	1.14	0.01	0.02	0.03	0.02	0.02	0.02	0.00	0.07
Mycenae (Av)[1]	Cu glass	64.80	19.35	2.10	9.2	7.10	4.00	na	0.81	0.55	0.94	na	na	nd	0.04	na	na	na	na
Amarna (Av)[1]	Cu glass	64.10	17.80	2.30	7.7	8.40	4.20	0.18	1.10	0.60	1.30	0.13	0.13	0.01	0.16	0.03	0.01	na	0.02
Near East (Av)[1]	Cu glass	67.33	15.53	2.27	6.9	7.83	3.85	na	0.55	0.25	1.47	na	na	nd	0.03	na	na	na	na
Uluburun (Av)[1]	Cu glass	68.50	18.80	1.55	12.1	6.35	2.70	na	0.73	0.49	0.48	na	na	nd	0.02	na	na	na	na
Isopata 4	Vf bead	72.84	12.43	2.39	5.2	1.59	1.89	0.23	3.60	0.45	1.66	0.03	0.17	0.36	0.88	0.54	0.23	0.00	0.01
Amarna (Av)[1]	Vf rings	75.21	11.31	2.61	4.3	1.22	1.74	0.08	5.34	0.37	0.05	0.00	0.01	0.45	0.19	0.46	0.20	0.00	0.03
Mesara 4	Vf bead	73.39	11.05	0.85	13.0	2.06	0.60	0.11	0.73	3.99	2.57	0.03	1.59	1.23	0.04	0.01	0.30	0.78	0.07
Mesara 5	Vf bead	71.51	12.16	0.92	13.2	2.38	0.54	0.10	0.95	3.78	1.72	0.02	2.29	1.71	0.01	0.03	0.32	0.89	0.05
Psara K006	Vf bead	70.99	11.46	0.79	14.5	1.67	0.67	0.09	0.71	4.90	2.56	0.01	2.82	1.55	0.04	0.00	0.25	0.92	na
Poviglio P3b[1]	Vf bead	67.80	12.50	1.05	11.9	1.60	1.00	0.05	0.60	6.60	1.60	na	2.70	1.60	na	0.10	0.40	1.20	0.04
Poviglio PV960[1]	Vf bead	75.48	8.60	1.87	4.6	2.22	0.71	0.08	0.67	3.17	2.70	0.01	2.15	0.84	0.02	na	0.09	0.75	na

Fa – faience; Eb – Egyptian blue frit; Vf – vitreous faience
na – not analysed for
[1] Previously published analyses: Amarna (Av) (Shortland 2000; Tite and Shortland 2003); Mycenae (Av), Near East (Av), Uluburun (Av) (Brill 1999); P3b (Santopadre and Verita 2000); PV360 (Angelini *et al.* this volume)

(Shortland 2000, 17) and the Near East (Brill 1999, vol 2, 39–42), was also most probably imported into the Aegean in the form of primary glass ingots that were worked locally. In this case, because there are no obvious compositional differences between copper blue glass from Egypt and the Near East, it is not possible to suggest from which of these two regions the primary ingots originated. However, the discovery of both cobalt blue and copper blue glass ingots on the Uluburun shipwreck (Bass 1991) provides clear evidence that both types of glass were being traded.

Vitreous faience

Vitreous faience beads are found on both Minoan Crete and the Mycenaean mainland from about 1400 BC onwards but are far more abundant on the mainland. The beads are of two main types, grain-of-wheat shaped or melon-shaped with collars. Typologically similar beads are also found in the Near East and Egypt (Beck 1928, 7, 10; Oates *et al.* 1997, 86–9, 242–7; Maxwell-Hyslop 1971, 125–7).

The microstructure of the vitreous faience beads, as seen in the SEM, consists of fine quartz particles in a more or less continuous glass matrix. The glass phase is coloured primarily by cobalt so that, where unweathered glass phase has survived, the body has a bluish-grey colour throughout. Although no glaze had survived on the samples examined in the SEM, there are specks of dark blue glaze visible on some beads. In terms of microstructure and the use of cobalt colorant, the Aegean vitreous faience is similar to that produced in Egypt from the late 15th century onwards.

On the basis of the compositions of the glass phase, the four vitreous faience beads analysed (three from Crete and one from the island of Psara, near to Chios), fall into two groups. One bead (Isopata 4), which is grain-shaped, is characterized by the use of a soda-rich alkali (Na_2O/K_2O=5.2) together with the high aluminium, manganese, zinc and nickel contents associated with the use of the cobalt rich alum from the Western Desert of Egypt as the source of the cobalt colorant. However, as in the case of the vitreous faience from Egypt (Tite and Shortland 2003), the cobalt oxide content (0.36% CoO) of the Aegean vitreous faience is too high for it to have been produced by adding crushed cobalt blue glass (average 0.13% CoO) to a quartz body. Therefore, this bead was most probably imported from Egypt where typologically similar beads are found.

The three beads in the second group (Mesara 4 and 5, Psara K006), which are also grain-shaped, are very different in composition to the Isopata bead, being characterized by higher cobalt, and high iron, copper, lead, nickel and antimony contents. Their low aluminium, manganese and zinc contents indicate that the cobalt-rich alums from the Western Desert of Egypt were not the source of the cobalt colorant in these beads. Instead, the source of the cobalt colorant is most probably characterized by high iron and nickel contents with the copper and, probably also, the lead and antimony more likely being added as separate components. This second group of Aegean beads is similar in composition to two contemporary cobalt blue vitreous faience beads from Poviglio in northern Italy (Table 1), one of which has an openwork, spoked-wheel structure (Santopadre and Verita 2000) and the other is described as a biconical radially grooved bead (see Angelini *et al.* this volume). However, other cobalt blue vitreous faience beads from Italy (see Angelini *et al.* this volume) differ in composition from both groups of Aegean beads.

Identification of the cobalt source used in the production of this second group of Aegean vitreous faience beads is difficult since there are very few analytical data for cobalt ore sources. On the basis of geological surveys (Andrews 1962; Gratuze *et al.* 1992), the low arsenic content of the vitreous faience rules out the high arsenic cobalt ores from the Erzgebirge in Germany which is suggested as the source of the cobalt used in the late Bronze Age fragment of vitreous faience from Frattesina in northern Italy (Santopadre and Verita 2000); from Kashan in Iran which was certainly being used by the 14th century AD (Allan 1973); and from the Transcaucasus. Cobalt ore sources in Bulgaria and Anatolia also appear to be ruled out because they do not contain the characteristic high nickel content of the vitreous faience. Instead, the most probable sources of high nickel-iron cobalt ores are in Greece (Laurium and Larymna) and Italy (in the region of Lake Maggiore).

It is possible therefore that this second group of beads found in the Aegean was produced in the Aegean, most probably on the Greek mainland, using cobalt from either Laurion or Larymna. The fact that the alkali used in the vitreous faience is soda-rich is not necessarily inconsistent with production on the Greek mainland since soda-rich plant ash appears to have been used in the production of Mycenaean Egyptian blue frit. However, it must be borne in mind that the soda to potash ratio in the plant ash used in the Egyptian blue frit was significantly lower than that in the vitreous faience (Na_2O/K_2O = 5.3 as compared to 13–14.5).

Conclusions

Although the technologies employed in the production of vitreous materials were brought to the Aegean from the Near East and/or Egypt, the great majority of the objects were most probably made in the Aegean. In the case of faience and Egyptian blue frit, the objects were almost certainly made using locally available component raw materials. In contrast, it is much more likely that glass was imported into the Aegean from Egypt and, possibly also, the Near East as primary ingots that were worked locally to produce the characteristic Aegean beads and plaques. If the hypothesis that the primary glass was imported is correct, then this probably reflects a combination of a more complex production technology and the greater central control of the secrets involved in the production of this high value, high prestige material.

The vitreous faience bead containing the cobalt-rich alum from the Western Desert in Egypt was most probably imported from Egypt as a finished object. However, it is possible that the other three vitreous faience beads from the Aegean were made on the Greek mainland from locally available raw materials – this is not at present proven. In order to resolve this question, more information is required on the location, compositional characteristics and exploitation in antiquity of cobalt sources in the Mediterranean and Near East. In addition, in order to fully understand the observed variation in the soda to potash ratios (ie, from $Na_2O/K_2O=0.1$ for the potash rich ash from the *Salsola kali* collected from Crete, to 13–14.5 for the second group of Aegean vitreous faience) more information is required on the compositions of the ashes that can be produced from different species of halophytic plants growing in different locations on Crete and mainland Greece.

Finally, it should be emphasized that, in trying to resolve the origin of the vitreous faience beads from the Aegean, their similarity in composition to some, but not all, of the contemporary cobalt blue vitreous faience beads found in Italy must be taken into account.

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A GLASS WORKSHOP AT THE MYCENAEAN CITADEL OF TIRYNS IN GREECE

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Ich erwähne weiter eine Perle von kobaltglas und einige kleine Gegenstände aus einer Glasmasse

These are the words Schliemann (1885/6, 176; 1886, 199) used to refer to glass he found in his excavations at the Mycenaean citadel of Tiryns, in the Peloponnese in Greece in AD 1884–1885. The 'Perle' of cobalt blue glass is exhibited in the National Museum in Athens together with decorative inlays: plaques, strips and knobs (COLOUR PLATE 5). More inlays exist in the Museum storerooms under the same Museum inventory number (1615–19) and there is no doubt that they come from Schliemann's excavations at Tiryns. Though there are no proper excavation data, we believe that this material is what Schliemann called 'einige kleine Gegenstände aus einer Glasmasse'. Closer examination of the material in the Museum storerooms by M. Panagiotaki proved that it comes from a glass workshop since glass waste exists alongside the finished products.

Products of the workshop

Decorative inlays and beads seem to have been produced at the Tiryns workshop as far as we can tell from the surviving material. All the inlays are made of opaque, turquoise glass, the surface of which has now faded as a result of weathering, to off-white or a mixture of off-white and turquoise – the white surface layer is characteristic of weathered Late Bronze Age glass (Spaer 2001, 55). The beads comprise: a fragmentary spherical one of exactly the same turquoise glass of the inlays, another spherical example (inventory number 1599) of dark blue (cobalt blue) – maybe the one described by Schliemann, and finally an almond-shaped one (inventory number 1566) of an iridescent nature coloured a very dark blue, almost black (COLOUR PLATE 5, top row). The latter may be identified with the one Schliemann found in the longitudinal trench of the lower citadel (Schliemann 1885/6, 82, fig. 17; 1886, 92, fig. 17). A number of glass beads are also known from the more recent excavations at Tiryns (Haevernick 1979, 44–7). A lump of Egyptian blue (inventory number 1606) among the Tiryns glass material suggests that Egyptian blue was worked as well (COLOUR PLATE 5, top right).

The inlays comprise rectangular plaques, strips and knobs. The rectangular plaques have two flat surfaces and clear-cut edges. The strips are of three types: (a) elongated with two flat surfaces and clear-cut sharp edges, (b) elongated with two flat surfaces but no sharp edges (of a more rounded section), (c) much shorter strips with a slightly raised upper surface, flat underside and clear-cut edges. The knobs are round, disk-like with a raised upper surface and flat or slightly concave underside.

Glass waste

Glass waste was found together with the finished products: (a) elongated or pear-shaped drops of glass with the thread in position (often curled over at the end – COLOUR PLATE 6) and with a flat underside, the last feature indicating that the drops had fallen on a flat and cold rather than hot surface (when drops fall on a cold surface they do not adhere, though they will do so on a hot surface; on such technical details, see Lierke 2002, 182); (b) drops which have a rounded section (and the thread in position), suggesting that they either solidified in the air or they fell on a thick and yielding layer of ash; (c) round drops without a thread, but with a flat underside; they may have been formed accidentally by shards of raw glass melting near the fire (Lierke 2002, 181, fig. 3.4); (d) a rectangular plaque with a small pear-shaped drop (with thread attached) accidentally formed or stuck on one surface; (e) strips that are bent (the largest one may have been bent intentionally) or deformed, perhaps as they were taken out of the mould (COLOUR PLATE 7); (f) strips stuck together in a mass; (g) strips and drops stuck together; (h) strips, plaques and drops all amalgamated (COLOUR PLATE 8).

Some of the strips and plaques fused together seem to have been finished pieces. The fact that such objects are mixed up with both unfinished bits and waste-drops indicates maybe that something went wrong while they were being made and the craftsman, perhaps with an angry gesture, just pushed them all aside, causing them to stick to each other and be turned into a 'mass', in which nonetheless the individual components are still identifiable.

Glassworking procedure

No objects found with our glass permit detailed inferences on the glass technology (compare with the glass workshops in north Italy, especially that of Frattesina, where besides finished products and waste, glass ingots, tools and fragments of crucibles were found, see Bellintani 1997, 126–7, fig. 8; Towle *et al.* 2002, 19–20, figs 1, 3.10, 5; and for the chemical analyses Angelini *et al.* 2002).

However, the clear-cut edges of the strips and plaques point to the use of moulds (open-face moulds would be more appropriate) and the existence of drops makes it clear that the raw glass was not placed in the moulds in the form of chips (Lierke 1999, 23–4, fig. 41) and subsequently heated, but it was rather softened in a crucible and the liquid/fluid glass was either poured into the moulds or transported from one to the other using a tool (on glassworking see Grose 1989, 31–3; Evely 2000, 445–56, fig. 179). The strips with the rounded section may have been made by pulling a cob of soft glass until it formed a strip – an action similar to forming a cane.

It is thus possible that in the Tiryns glass workshop two techniques were used to make the inlays: liquid glass poured into moulds and softened glass worked by pulling. The moulds could have been made of stone, clay, plaster or wood (on moulds see, Tournavitou 1997, 209–56; Chatzi-Spiliopoulou 2002, 70–7; Triantafillidis 2002, 45, n. 58; Panagiotaki forthcoming). Stone moulds have been mostly found in the Aegean world, although clay ones have recently been reported (Demopoulou 1997, 436, pl. clxxi.c). The knobs may have been made by heating shards of raw glass (perhaps recycled) on a flat surface; after solidifying, polishing may have followed to make their edges more regular (perhaps the same polishing techniques used for Mycenaean beads, see Nightingale 2002, 48–50).

No crucibles, ceramic platforms or glass ingots have been recorded in the Museum inventories nor were identified by the excavators: any such artefacts relating to glass production/working may exist elsewhere among the objects that were recovered at Tiryns. Pieces of clay were, however, recorded in the National Museum inventories (together with the glass material, inventory number 1619) and indeed small pieces of badly burnt clay were found among the glass waste; these may have been pieces from the clay lining of the kiln rather than from crucibles. A stone 'rod' with a pointed end (inventory number 1614), which Schliemann also mentioned (Schliemann 1885/6, 176; 1886, 199), may have been used as a tool, to take the liquid glass out of the crucible or to work it somehow (COLOUR PLATE 5, top right).

No direct evidence of glassmaking exists at Tiryns. This is not surprising. The workshop may have been using imported raw glass: an idea supported by the glass ingots discovered in the shipwreck of Uluburun (Kas) off the coast of Asia Minor (Bass 1986, 281–2). All the more so since the Uluburun glass ingots were found to be compositionally similar to both Mycenaean and Egyptian glass (Brill 2002, 11; see also Panagiotaki *et al.*, 2004, 174–5). It is important that two different kinds of glass were worked at Tiryns: dark blue (coloured by cobalt) and turquoise (coloured by copper), both kinds also found as ingots in the Uluburun wreck.

In the National Museum inventories together with the glass material (inventory number 1619) were also recorded two irregular pieces of gypsum, one of quartz stone, and three of bronze – all perfect ingredients for the production of glass! For a time we entertained the idea that we might actually have a glassmaking and glassworking workshop (on the distinction see Stern 1999, 23–4, 35). Alas, when we located the above potential raw materials they were but tiny fragments (whether they once belonged to bigger objects that were indeed used for glassmaking cannot now be said). The Tiryns workshop would thus have to be seen as involved with glassworking rather than glassmaking.

Location of the workshop

We do not know the exact findspot(s) of this material, but we know that Schliemann (1886, plan 1) excavated mainly on the upper citadel and dug only one trench in the lower. Iakovidis (1983, 15) suggested that Rooms 30–34 (in his plan 2 – of the upper citadel) may have been used as storerooms or workshops ('since three cylindrical vessels, 0.30 m. in diameter and ca. 1 m. high, found in one of the smaller rooms (Plan 2, 33), would have had no place in a residential area'). Being near two courtyards, they could have been ideal for craft activities. It should be noted that Kilian (1984; 1988, 111) unearthed a bronze workshop in building XI (of LH IIIB2 date) and he also found evidence for bronze and leadworking in the lower citadel. Among the objects he found are gold foil and a piece of glass of indefinite shape (could this be explained as a piece of raw glass, part of a glass ingot?). If so, the possibility of glassworking in the lower citadel along with the other industrial activities cannot be ruled out (see also Rahmstorf 2001, 313–15).

But it seems that at present we have to be satisfied with just the industrial waste, which nonetheless identifies the earliest known glass workshop on mainland Greece. Within the Aegean the earliest glass workshops identified on the basis of finished products and glass waste are at Knossos, in a building by the Royal Road, immediately west of the palace and of LM IB date (Cadogan 1976), with another probable example at the palace itself where dark blue pieces of glass (cobalt blue) of indefinite shape (perhaps waste) were identified among unpublished faience material from the excavations of A. Evans (Panagiotaki 1997, 307; for the earliest glass objects from the same palace, see Panagiotaki 1999, 621); yet another has been suggested at Mycenae, on the basis of a large concentration of stone moulds that may have been used for glass relief beads (Nightingale 2002, 50). The Tiryns workshop seems to be the only one though with so much waste and so many misshapen pieces.

The stone relief frieze inlaid with glass from the porch of the palace at Tiryns

The Tiryns workshop becomes even more important when we compare the finished pieces (plaques, strips and knobs) with the glass inlays embellishing the known stone relief frieze of half rosettes and triglyphs that decorated the west wall of the porch of the palace at Tiryns (FIG. 1; Schliemann 1886, pl. iv; Müller 1930, 139–43, figs 68–9, pl. 41; National Museum inventory number: 1744-6) – the shape, colour and the sizes of the items are certainly comparable.

> The triglyph shows in its lower edge a row of rectangular pieces of glass, each 19 mm. broad and 24 mm. high; over it is a continuous strip of glass, 9 mm. broad. The upper part is divided by four vertical

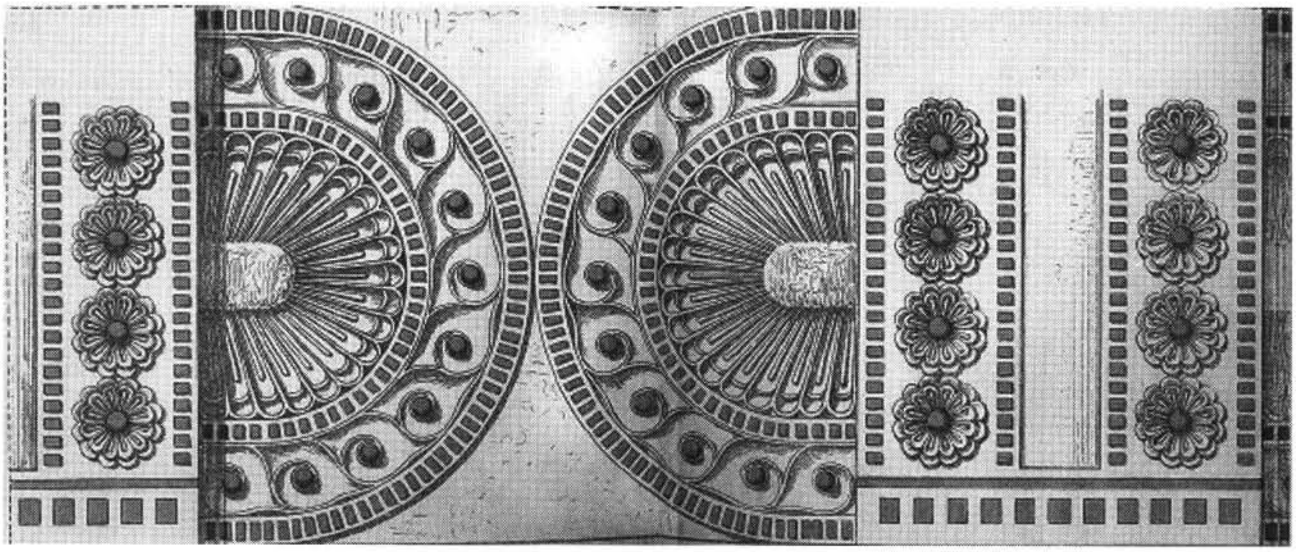

FIG. 1 The stone frieze from Tyrins (after Schliemann 1886, pl. iv)

> rows of little pieces of glass (10–13 mm.) into three fields, of which the two outer ones are adorned with rosettes. … The middle of each rosette is occupied by a round piece of glass of 26 mm. in diameter. … The metopes are even more richly adorned than the triglyphs. Two semi-ellipses, which touch in the middle, occupy the whole field. … The rosette is surrounded by a broad band, which consists of a band of spirals encompassed by two bands of inlaid pieces of glass. The pieces of glass of the inner row are rectangles, of 9 by 16 mm., the outer, 9 by 18 mm. The eyes of the spirals are also formed of round pieces of glass paste, inlaid. (Schliemann 1886, 285).

A similar frieze adorned with blue glass had decorated the palace of Alkinoos as described by Homer (*Odyssey* VII. 86-7: 'Χάλκεοι μεν γάρ τοίχοι ερηρέδατ' ένθα και ένθα, Εςμυχόν εξ ουδού; περί δε θριγκός κυάνοιο' ('bronze walls ran this way and that from the threshold to the inmost chamber, and round them was a frieze of *Kyanos*'). And similar coloured glass inlays were part of the architectural embellishments of the Greek temples, especially during the last decades of the 5th century BC. Pheidias made use of such inlays in both the Athenian Parthenon and the ivory statue of Zeus in Olympia (for drawings, by 19th-century travellers, of glass inlays decorating some of the stone friezes at the Athenian Acropolis, see Stern 2002, 355–6, figs 6–7, and for the glass drapery of the statue of Zeus at Olympia, *ibid,* 60–3).

The frieze inlays from the palace at Tiryns were analysed chemically by Professor Virchow: 'The glass-paste consists of a calcium-glass, which is coloured with copper; it contains no admixture of cobalt' (Schliemann 1886, 291) – the results are definitely comparable with the results of our scientific analysis (see below).

The date of the frieze is problematic since the excavators believed that it was transferred to the porch from elsewhere (Schliemann 1886, 291–2). If the results of more recent research on the porch and the palace in general are accepted – namely that they can be attributed to the end of the 13th century (to the third building period, Iakovidis 1983, 4–5) – the stone frieze was either made then or slightly earlier.

The date of the workshop

As we do not know where exactly the glass material (beads, plaques, strips and knobs) and waste come from, it is tempting to date the workshop based on the clear similarities between them and the glass inlays of the above described stone frieze. An approximate date will thus be given. If the stone frieze *was* made during the last renovations of the citadel at the end of the 13th century and if it could be *proven* that the Tiryns glass workshop was producing inlays (at the time of its destruction) for this particular frieze or a similar one, then the end of the 13th century can be seen as the *terminus ante quem* for the workshop. It is, however, possible that the workshop material was found in a LH IIIB rubbish dump 'containing sherds, fresco fragments and other material deriving from a renovation of the palace after a fire' (Iakovidis 1983, 12–13), in which case the material could be given a slightly earlier date (fresco fragments are recorded together with the glass material in the National Museum inventories which is why we are considering the possibility of its being found in the above dump (inventory number 1619)).

Chemical analysis

Six samples of glass from Tiryns were analysed using both atomic absorption spectrometry (AAS) and wavelength dispersive spectrometry (WDS) in an analytical scanning electron microscope (Jeol 8800) (TABLE 1). No regions of unweathered glass could be found for analysis by WDS in the two samples (1619a and 1619b) for which the soda contents as determined by AAS were low (~5% Na_2O). However, with the exception of the antimony oxide contents in sample 1617, there was reasonable agreement between the two methods of analysis for the other four samples, the differences probably being, in part, the result of some slightly weathered glass being included in the bulk AAS analyses. The compositions of the Tiryns glass indicate that they are of the soda-lime type, produced using plant ash, coloured with copper and opacified by calcium antimonate. Thus the Tiryns

TABLE 1 ANALYSES OF GLASS OBJECTS FROM TIRYNS

Sample	Description	Method	SiO_2	Na_2O	K_2O	CaO	MgO	Al_2O_3	Fe_2O_3	CuO	Sb_2O_5
1615a	roundel	AAS	70.1	13.1	3.7	6.9	4.4	1.1	0.6	0.97	0.93
		WDS	62.60	16.22	3.08	8.61	6.07	1.18	0.36	0.64	1.25
1615b	rod	AAS	77.2	11.4	1.2	5.5	3.1	0.4	0.4	0.44	0.46
		WDS	62.64	16.28	3.04	8.94	5.87	1.14	0.36	0.73	1.00
1616	roundel	AAS	67.6	15.5	3.0	6.9	5.0	1.1	0.4	0.86	0.88
		WDS	62.90	15.99	3.06	8.68	5.96	1.16	0.38	0.65	1.22
1617	rod	AAS	66.9	13.7	2.6	8.2	5.4	0.9	0.8	0.5	0.88
		WDS	61.44	20.00	2.74	8.53	5.83	0.81	0.33	0.32	0.00
1619a	rod	AAS	73.6	5.1	2.1	12.5	4.2	0.9	0.7	0.37	0.56
1619b	drop	AAS	78.7	5.4	1.2	8.2	4.8	0.4	0.4	0.29	0.56
Egypt (Av)	Copper blue	WDS	62.7	17.4	2.2	8.2	4.1	1.1	0.6	1.23	1.16

glass is comparable in composition to that of contemporary glass from Egypt and the Near East and, therefore, was probably imported into the Aegean as primary ingots. In view of the comparatively high potash and magnesia contents (TABLE 1), and low manganese, tin and lead oxide contents (<500 ppm MnO, <200 ppm SnO_2 and <350 ppm PbO), the Near East is a more likely source of these ingots than Egypt

TIRYNS PALACE: A GLASS PRODUCTION CENTRE – SOCIO-ECONOMIC AND POLITICAL INFERENCES

The existence of a glass workshop in the palatial centre of Tiryns (besides the ones at Knossos and the possible one at Mycenae) emphasizes the idea that glass, a precious commodity, was imported and worked by the elite or under the auspices of the elite (the actual palace). At the same time, because of its religious and magical connotations as a material it was available to all – as it is evident from the many items made from it discovered in tombs (Panagiotaki 2000, 158–60; 2004, 168–70). The Mycenaean elite concentrated on the production of glass embellishments (the case of the Tiryns workshop) and even more so on glass relief-beads which were in both material and shape connected with cult and magic (Hughes-Brock 2000, 123–6; Panagiotaki 2000, 158–60; 2002, 51–3) and they kept these beads close to their world – they were not exchanged with any other material from Egypt or the East. It was a Mycenaean product made for Mycenaeans/Aegeans.

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THE MYCENAEAN GLASS WARRIORS

GEORG NIGHTINGALE

In Late Bronze Age (Mycenaean) Greece glass was mainly used for beads (Bielefeld 1968; Higgins 1980; Harden 1981; Wiener 1983; Xenaki-Sakellariou 1985; Effinger 1996; Nightingale 1999; Nightingale 2000). Other glass objects were inlays, glass pins (Effinger 1996, 55, 354), glass seals (Pini 1981) and gaming pieces (Harden 1981, 50, nos 75 and 76, pl. vi, fig. 3.75). The few glass vessels are considered to be imports with the exception of the little glass bowl from Kakovatos (Müller 1909; Weinberg 1992). This paper examines a less well known aspect of the use of glass; its use in and together with weaponry amongst the Mycenaean elite.

A very well-preserved sword hilt (135mm long), which was found in chamber tomb 102 of the Third Kilometre Cemetery at Mycenae, belongs with the most spectacular finds of glass (FIG. 1; Xenaki-Sakellariou 1985, 279, 281, pl. 137; Bosanquet 1904, 324; Evans 1935, 852; Wace 1932, 188, 189; Sakellariou 1984; Sandars 1963, 124, 128, 129; Foster 1979, 147). It is of the cruciform type (type Sandars Di, Kilian-Dirlmeier Kreuzschwert Typ 1). The hilt consists of a large mushroom-shaped pommel which is separated from the grip by a golden ring. The grip tapers towards the shoulder, which is drawn out into horizontal bars. The oval opening in the shoulder is typical of type Di swords. There is a double relief band around the grip which is curved towards the oval opening. A large circular depression with an inlaid golden disk with a granulated border imitating a large rivet head is placed on the grip. A similar, smaller disk is preserved in the pommel at the point where, in other swords, the rivet is situated which secures the pommel to the hilt. Two more circular depressions are found on the shoulder on both sides of the oval opening. A large opening or slot is in the shoulder which looks as if it was cut by some tool. However the slot does not seem to reach the oval opening. Nevertheless there is a circular hole entering from inside the oval opening up into the grip, as if meant for the tang of a blade.

A second smaller sword hilt was found on the Acropolis of Mycenae (Tsountas 1897, 109, pl. 8.6; Bosanquet 1904, 322; Evans 1935, 852, n. 2, fig. 836; Haevernick 1981a, 79, pl. 4.1; Haevernick 1981b, 111, fig. 5; Foster 1979, 147, fig. 101; Harden 1981, 40, n. 33). The dark blue glass is very well preserved. It is nearly identical to the first example. The grip is broken at the middle of the circular depression for the imitated, large rivet head.

In addition to these more or less complete hilts there is a hilt-plate of glass from one of the tombs of Mycenae (without provenance, Xenaki-Sakellariou 1985, 139, pl. 39). It is an oblong bar with a semi-circular cross-section (preserved length 50mm). Again, there are circular depressions in imitation of rivet heads.

Two glass pommels for swords or daggers were found in the same tomb (chamber tomb 102) as the large glass sword hilt (Xenaki-Sakellariou 1985, 279, 281; diameter 20–37mm). A fragment of another glass pommel from Mycenae is without further provenance (Xenaki-Sakellariou 1985, 139). Wace called the material of a pommel from Mycenae chamber tomb 529 faience. It has circular depressions for inlays (Wace 1932, 101, 105, 187, 220, pl. li; Foster 1979). A small pommel (or sceptre head: M. Panagiotaki, pers. comm.) from the Palace of Knossos with a diameter of 30mm is decorated with a complicated running spiral (Panagiotaki 2000, 98, pl. 71).

Two large golden covers for rivet heads in the grip of the hilt of a bronze sword from chamber tomb 78 in the Kalkani cemetery of Mycenae are decorated with a rosette in cloisons filled with dark blue glass (Tsountas 1897, 105–6, pl. 7.3; Sakellariou 1984, 130–1; Sandars 1961, 26, no. 70; Sandars 1963, 124; Xenaki-Sakellariou 1985, 216–18, pl. 101, ix; Hood 1994, 158). A large golden ring, which separated grip and pommel, was decorated likewise, as were three preserved rivets with golden heads, a granulated edge and traces of dark blue glass in the middle.

In addition to the swords, glass was also used for helmets. About 50 glass imitations of boar's tusk plates from a boar's tusk helmet were found in a rich chamber

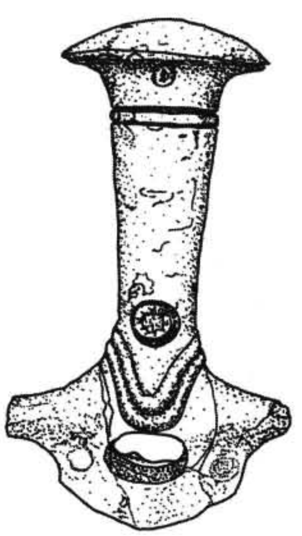

FIG. 1 Glass sword hilt from Mycenae (Xenaki-Sakellariou 1985, pl. 137, redrawn by the author); scale 1:2

tomb at Spata in Attica (Haussoullier 1878, 203, 224, 225). In the same tomb real boar's tusks were also found. The glass boar's tusks are wider then the real ones, but they have the same slight bend and the same alternating curvature. Each plaque has two perforations. No closer date is available for the helmet parts themselves (other finds from this tomb date to LH IIIA1 to LH IIIB and even LH IIIC – *c.* 1420 to 1200 and beyond).

Another helmet with glass parts was reported from the Tholos of Dendra in the Argolid, from the so-called burial of the 'King' in pit I (Persson 1931, 14–18, 64–5, 36 nos 13a, 13b, 13c, 13d, pl. viii, xxv, xxvi, figs 41.7, 43, 44; Nilsson 1950, 36, 37, n. 10, figs 2, 3; Bielefeld 1968, C 15, C 16; Karo 1935, col. 591; not in Borchardt 1972). Several glass items were found around the head of the king. They are eleven curls of turquoise blue glass with a lot of pitting (fragments of two more curls were found in another pit – pit IV), nine narrow, slightly curved triangles of similar glass, eight heavily corroded turquoise or dark blue rectangular plaques decorated with the scene of possibly a woman riding sideways on an animal (Perrson: 'Europa and the bull'), and three more dark blue rectangular plaques showing a multi-figured scene (Persson: 'Chimaira and Bellerophon'). In all glass elements there are holes for fastening them onto a background. The context of pit I is dated to LH IIIA1 (1420–1380 BC).

Another use of glass with weapons is shown by a find from chamber tomb 2, the so called cenotaph at Dendra (Persson 1931, 79, 106, pls xxviii.2, xxxv). To the right of the entrance into the chamber hundreds of thin, blue and white glass disk beads were found together with the hilt of a broken bronze sword (Persson 1931, 79, no. 50, 106, pls xxviii.2, xxxv). This find context was interpreted by the excavator as a kind of beadwork on the hilt. To the left of the entrance of this tomb another beaded garment was preserved which still showed a zigzag pattern in yellow, brown, black, blue or white (Persson 1931, 79, no. 51, 106, pls xxxv, xxxvi.4; for the use of beads with garments and beaded garments *cf.* Barber 1991, 154, 172). The context of this tomb was dated both to LH IIIA1 or LH IIIB (*c.* 1400 or 13th century BC). Besides these exceptional finds from Dendra there are several contexts of warrior burials which were accompanied by beads of gold, glass, faience and other materials (*cf.* the beads noted as accompanying finds in the catalogue of the swords in Kilian-Dirlmeier 1993).

Our glass hilts conform exactly to the cruciform sword – Sandars Di/ Kilian-Dirlmeier Kreuzschwert Typ 1 (same shape, identical placement of rivets or imitated rivets, separate pommel). The use of glass is attested for the cruciform type DI swords only, though the pommels and the separate glass grip plate could have been used for other sword or dagger types as well. Cruciform swords first appear in LM II (1455–1420 BC), they are frequent in LM/ LH IIIA1-2 (1420–1320 BC), and some are still found in LH IIIB (1330–1200 BC). The dates available for our glass weapon parts are possibly LH IIA for the complete sword hilt and two of the pommels, LH II for another pommel from Mycenae and LM IB for the pommel from Knossos. These dates fit well into the chronological range of the type Di swords. We can therefore date, with some confidence, the glass weapon parts without a documented find context to LH II or LH IIIA as well. Most of the cruciform swords were found around Knossos and Mycenae. Therefore a leading role of the workshops of Knossos and Mycenae has been assumed for the development and production of the cruciform swords and they may well have produced our glass weapon parts (Kilian-Dirlmeier 1993; Sandars 1963; Sakellariou 1984).

The exceptionally rich embellishment of sword hilts does concentrate on the cruciform type Di/Kreuzschwert Typ 1 swords. Luxurious decorations for type Di sword hilts were not only made of glass. The material most frequently used is gold or ivory. Rock crystal (Knossos: Kilian-Dirlmeier 1993, 64, no. 153, pl. 27; Evans 1935, 853-5, fig. 837), agate (Mycenae, Panagia, T. 81: Xenaki-Sakellariou 1985, 230f. no. L 3110, pl. 107) and different sorts of marble were used as well. According to Sakellariou the hilts made of agate or glass from the tombs are models of sword-hilts (Sakellariou 1984, 129–30; and relevant catalogue entries in Xenaki-Sakellariou 1985). She thinks that the grip-plates of glass or rock crystal could not have been used for serviceable weapons.

A fragment of a cruciform marble hilt was found at the Unterburg of Tiryns (FIG. 2; Kilian 1983, 328, 299, 304, 306, fig. 22.1, fig. 32a, b; Tiryns-Unterburg, Room 191, no. LXII 42/59 VIII; date of the find context LH IIIB, 1330–1200 BC). This fragment is very important as the preserved hole in the grip for the blade, with an oblique perforation for a rivet to fix the hilt to a blade, clearly demonstrates that this hilt was functional and was intended to be mounted on a blade.

A certain basic stability seems to be necessary even for a prestigious or ceremonial weapon. Grip-plates or pommels of glass and other materials certainly do not diminish the stability of a sword. From the development of the horned and cruciform swords onwards the mechanical stress was taken by the metal hilt. The additional grip-plates provided only a comfortable grip and decorated the sword (Kilian-Dirlmeier 1993, 50, 64–6, 70). The only function of the rivets now was to fix the grip-plates to the bronze grip of the sword. Nevertheless large rivet heads or the imitations of rivet heads were kept as a decorative and archaizing feature.

The weapons with hilts entirely made of glass/faience or semi-precious stone would have been less usable. As the opening/slot in the shoulder of the complete glass hilt does not seem to penetrate it completely it may well have only been partly finished (Sandars 1963, 124, 127). Nevertheless, with the marble hilt from Tiryns it is quite clear that such precious hilts were meant to be mounted onto a blade. The standard grip plate of a Di sword would have been replaced by a narrow tang which fitted into the narrow opening. The stability of such a sword is indeed seriously weakened. However, it is still a usable weapon (at least for representational purposes) presumably with about the same stability as the older type A swords with their short, narrow tang. Thus a general interpretation of such hilts and hilt-parts as mere models is not justified.

The glass helmet from Spata was not just a precious and prestigious item of shining, dark blue colour, but could be used as a real helmet as well since protection for the head does not derive from the plaques alone – either real or imitated – but rather from the leather helmet on which

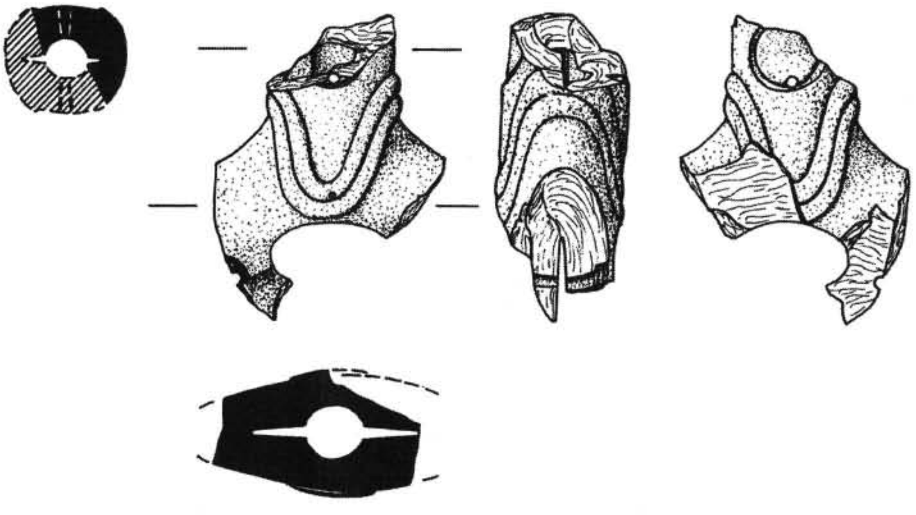

FIG. 2 Marble hilt from Tyrins (Kilian 1983, fig. 22.1)

they were sewn. In Persson's opinion the glass parts from Dendra were sewn onto a leather helmet: the curls like curls of hair along the edge of the helmet and the triangular and rectangular plaques alternating in a band. Bielefeld (1968, C 15) accepts Persson's interpretation as a helmet, Karo (1935, 591) does so only for the curls. He would like to associate the plaques with a necklace of agate and rock crystal. Wace (1932, 193) combines the triangles and curls to a curled leaf ornament forming an ornament on the head.

All these glass items can certainly be interpreted as precious weapons only to be found with people of high status or even as possible insignia of rank or status or as weapons with a religious or ceremonial meaning (Kilian-Dirlmeier 1993, 70, 145, 148; Sakellariou 1984, 129: 'emblème ou d'un insignium dignitatis'; Haevernick 1981a, 79; Haevernick 1981b, 111: a 'Prunkwaffe', a sword which was carried on state occasions only; for the reproduction of practical items in luxury materials see Foster 1979, 148; Sandars 1963, 127). Glass as a material must have enjoyed considerable appreciation by the highest ranks of the Mycenaean society of palatial times (*cf.* Schweizer 2002). As the dates of the glass weapon parts seem to fall into LH II or LH IIIA (1450–1330 BC) the contemporary glass bowl of Kakovatos is not an isolated piece but rather belongs to a whole group of large, precious glass objects. From a technological point of view these glass objects are quite remarkable achievements and form the acme of Mycenaean glassworking. Some of the Mycenaean warriors can indeed be labelled as 'Glass Warriors'.

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INNOVATION OR CONTINUITY? EARLY FIRST MILLENNIUM BCE GLASS IN THE NEAR EAST: THE COBALT BLUE GLASSES FROM ASSYRIAN NIMRUD

Wendy Reade, Ian C. Freestone and St John Simpson

Introduction

Glassmaking traditions of the early 1st millennium Near East have been little investigated and are therefore poorly understood. However, this is arguably one of the key periods in the development of glassmaking. What little remains of this glass represents an important chronological and geographical link between the Late Bronze Age glassmaking technologies of Egypt and Mesopotamia and the beginning of the long Greco-Roman tradition towards the end of the 1st millennium.

There are several key issues which need to be addressed. Does the early Iron Age Near Eastern assemblage represent a continuity of tradition or do we find the beginnings of the technological innovations that have emerged so clearly by Hellenistic times, such as the use of natron as a flux? Did exploitation of 2nd millennium raw material sources continue, or had new sources of colorants, opacifiers and silica been adopted? Had glassmaking diversified and to what extent?

The glass assemblage from Nimrud, Iraq, a significant proportion of which is housed at The British Museum, offers the possibility to address some of these questions. Nimrud was established in 879 BCE by king Ashurnasirpal II (883–859 BCE) as the new capital of the Neo-Assyrian empire, situated on the east bank of the Tigris river and north of the previous capital at Assur. The capital was later moved to Khorsabad and then Nineveh at the end of the 8th century BCE, and Nimrud declined until it was finally destroyed in 612 BCE by a combined Babylonian and Median army. As a great and relatively short-lived centre with a large corpus of glass principally dating to the 9th–8th centuries, Nimrud provides a fascinating and important piece in the jigsaw of ancient glass research.

The site has been extensively excavated since the mid-19th century, with finds in the British Museum deriving from excavations made by Layard and his successors and those conducted by M.E.L. Mallowan during the 1950s and 1960s on behalf of the British School of Archaeology in Iraq (Mallowan 1966; Reade 1982). The corpus of glass consists of small cobalt blue inlay pieces and a piece of a beard from a statuette; translucent turquoise, purple and colourless hemispherical bowls; and turquoise opaque ingots (von Saldern 1966; Barag 1985). More recently, excavations resumed by the British Museum in Fort Shalmaneser in 1989 confirmed the frequency of blue glass inlays at the site (Curtis 1999).

All of these luxury objects are found in royal contexts or contexts associated with senior officials, specifically at Fort Shalmaneser, the North-West Palace and the Burnt Palace. The mechanisms by which these items reached Nimrud presumably included booty, tribute and trade.

Previous analyses of glasses from Nimrud have been published by Turner (1955; 1956), and Bimson and Freestone (in Barag 1985) but these studies were based on a limited number of samples. Brill (1999, vol. 2, 47–9) has published analyses of 24 glasses, covering a range of colours but focusing particularly on red, yellow and blue opaque glasses. Our current work covers a range of glasses, mainly blue and colourless, and adds a further 45 analyses to the Nimrud corpus. In the present paper, however, we focus in particular upon a subset of these glasses, the opaque dark blues. In terms of both their colorant and base glass compositions, the opaque blues are particularly pertinent to the question of continuity *versus* change in the Late Bronze to Early Iron Age transition.

Samples analysed and analytical method

The 13 cobalt blue glasses analysed here are derived mainly from small inlay plaques, frequently square plaques with central white rosettes. These inlays were set within glass or copper alloy frames which often were attached to ivory inlays set into furniture (von Saldern 1966, 625; Barag 1985, 71–2), but other glass inlays appear to have been hammered onto beds and/or other furniture with bronze tacks (Curtis 1999; Oates 2001, 239–40), and an 8th to 7th-century 'Phoenician' glass bowl also excavated at Nimrud was decorated below the rim with plaques of this type (Barag 1985, 65–6, fig. 3, nos 40–40A; *cf.* also Oates 2001, 240). It has been proposed that these inlay plaques are Phoenician (Mallowan 1978). However, similar square inlays with white rosettes have also been excavated at Arslan Tash and Samaria, and are suggested to have been the products of a south Syrian centre such as Damascus (Winter 1981). Furthermore, glass plaques inlaid into an alabaster cup excavated at Hasanlu in north-west Iran pose further questions over the origin and function of these inlays (de Schauensee 2001). Spaer (this volume) considers these inlays further.

The analyses of the blue glasses are compared with the analyses of other colours from Nimrud, and with those of blue glasses from Egypt and Mesopotamia of the 2nd and early 1st millennia BCE.

Analyses were performed by X-ray microanalysis using an Oxford Instruments ISIS energy-dispersive spectrometer in a JEOL JSM 840 scanning electron microscope. The

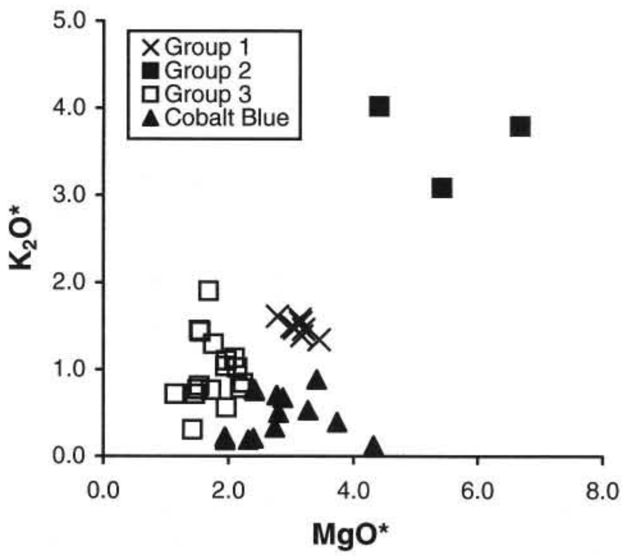

FIG. 1 Scatter plot of magnesia *versus* potash for Nimrud glass groups 1–4; * indicates reduced composition

accuracy and reproducibility for this method is in general about 1–2% relative for major elements and 10–20% for elements near the limit of detection, which is close to 0.1% for most elements (see Freestone *et al.* 2000 for details).

RESULTS

Analysis defined four reasonably coherent compositional groups of glass, with a small number of outliers. The main groups are shown in FIG. 1, according to their concentrations of magnesia and potash, and average compositions of the groups are presented in TABLE 1.

Group 1 glasses form a tight compositional group with potash around 1.5% and magnesia around 3%. The magnesia more or less conforms to a plant ash glass, but potash falls at the lower end of the range for this type of glass. These glasses consist of colourless, weakly coloured to pink/purple hemispherical bowls.

Group 2 is a small group of three standard plant ash glasses with high potash and magnesia. Four outliers (three turquoise opaque or translucent, and one colourless glass) are also rich in potash and magnesia but do not conform well to this grouping in other respects.

Group 3 is a large group of vessels, mainly copper blue with some colourless. Components considered markers of plant ash are generally low, with mean magnesia of 1.7%, mean potash of 0.95%, and mean phosphate of 0.1%. This suggests that the soda came from a natron type evaporitic source. These copper blue glasses have fairly high calcium contents which, if not plant ash, probably reflect a limestone source, added either separately or in conjunction with quartz sand.

Cobalt blue glasses comprise 13 cobalt-coloured glasses which have particularly low potash, averaging only 0.5%, strongly suggesting that these are natron-based glasses. The low lime contents of these glasses (averaging 2.9% and as low as 1%) support this view, as lime is a major constituent of plant ash and the use of plant ash soda alone would typically yield a glass with 5% lime or more. Low P_2O_5 contents, at around 0.1% also appear to preclude plant ash as a source of the soda. These cobalt blue glasses are mainly inlay pieces opacified with calcium antimonate.

The Nimrud glasses therefore are not all typical Mesopotamian plant ash glasses as might have been expected. Plant ash glass is present but the compositions of two, possibly three, of the four main groups have low potash contents, closer to glasses made with mineral soda, this being particularly so for the cobalt blue glasses. The importance of this is that natron-based, non-cobalt glasses occur here somewhat earlier than has generally been documented, although Schlick-Nolte and Werthmann (2003) have recently reported natron-based glasses not coloured with cobalt dating to the 10th century BCE from the tomb of Nesikhons in Egypt.

THE NATURE OF THE COBALT COLORANT

The lime–alumina plot (FIG. 2) emphasizes the distinctive character of the cobalt blue glasses. Not only are the lime contents particularly low, but alumina is consistently high, ranging from 4 to 7.7%. The high alumina contents associated with the cobalt blue colorants immediately bring to mind the cobalt blue glazes of New Kingdom Egypt, which Kaczmarczyk (1986) argued were coloured by cobalt-bearing alum obtained from the Kharga and Dakhla Oases of the Egyptian Western Desert, a view which has come to be widely accepted (eg Nicholson 1993; Henderson 2000; Shortland and Tite 2000; Tite *et al.* 2002).

TABLE 1 AVERAGE COMPOSITIONS OF NIMRUD AND EGYPTIAN GLASSES IN WT%

Nimrud	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	FeO	CoO	CuO	ZnO	SnO_2	Sb_2O_3	NiO
Group 1	13.90	3.07	1.00	69.69	0.15	0.53	1.46	8.66	0.14	0.43	0.48	<0.1	<0.1	<0.1	<0.4	<0.4	<0.1
Group 2	15.98	5.18	1.01	60.84	0.18	0.52	3.40	6.32	<0.1	<0.1	0.57	<0.1	2.97	<0.1	<0.4	2.69	<0.1
Group 3	16.94	1.70	0.55	69.85	0.10	0.54	0.95	6.15	<0.1	0.10	0.28	<0.1	1.74	<0.1	<0.4	0.92	<0.1
Group 4	18.12	2.72	5.50	66.28	<0.1	0.56	0.45	2.88	<0.1	0.38	0.85	0.16	<0.1	0.13	<0.4	1.71	0.13
Egyptian Cobalt Glass											Fe_2O_3					Sb_2O_5	
Pre-Malkata[1]	19.70	4.29	2.95	61.76	–	0.51	1.21	6.61	0.06	0.27	0.48	0.17	0.17	0.20	0.00	1.47	0.14
Malkata[2]	20.28	3.89	1.82	61.95	–	–	1.53	7.53	0.12	0.10	0.91	0.07	0.02	–	0.00	0.00	0.05
Amarna[3]	18.22	4.06	2.07	64.15	0.16	–	1.1	8.24	0.11	0.15	0.7	0.04	0.4	0.02	0.01	0.1	0.06

[1] calculated from Lilyquist and Brill 1995
[2] calculated from Lilyquist and Brill 1995, 41
[3] calculated from Brill 1999, 27–30

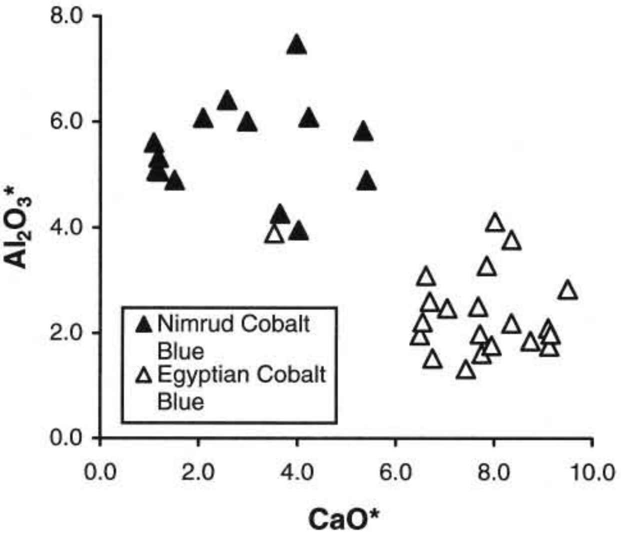

FIG. 2 Scatter-plot of lime *versus* alumina for Nimrud and Egyptian New Kingdom cobalt blue glasses

Other characteristics of glasses coloured with this cobalt alum include high concentrations of magnesium, manganese, iron, nickel and zinc. According to Kaczmarczyk, these elements are invariably associated in New Kingdom cobalt blues, and are therefore considered to provide a reliable indicator of the alum source. As is observed from TABLE 1, the Nimrud blues are elevated in the same suite of elements, and a similar cobalt alum source is therefore likely. However, the positive correlation between manganese and cobalt in 2nd-millennium Egyptian cobalt coloured glasses found by Kaczmarczyk and Hedges (1983) does not appear to occur in the 1st-millennium Nimrud cobalt glasses.

A further similarity between the New Kingdom and the Nimrud cobalt blues is the low potash contents of both groups. Shortland and Tite (2000) argued for the Egyptian glasses that this low potash indicates that the soda in the blue glasses was derived from natron, as plant ash generally imparts a potash concentration well in excess of 1.5%. They considered the high magnesium content of the glasses to be the result of the presence of magnesium in cobalt alum. This view was challenged, however, by Rehren (2001) who prefers a plant ash source for the soda in the New Kingdom glasses. Tite and Shortland (2003) later modified their position, suggesting that Egyptian cobalt blue glass contained both natron and plant ash. In the case of the Nimrud glasses, it seems probable that the soda is derived largely from natron, as their lime contents are generally much lower than those expected in glasses where the alkali is added in the form of plant ash. Of course, this still leaves open the question of the soda source in the New Kingdom cobalt blues, as these glasses contain high lime.

The cobalt alum imparts high magnesium to the glass, so a low magnesium natron-based glass was preferred in order to avoid resultant devitrification. This also resulted in a low lime glass, but its stability was not compromised due to the relatively high level of aluminium imparted by the cobalt alum. The low aluminium, low calcium natron glasses of Nesikhons on the other hand, are very unstable (Schlick-Nolte and Werthmann 2003).

DISCUSSION

The use of cobalt alum as a colorant in Iron Age Nimrud was not expected. Cobalt alum began to be used as an intentional colorant for dark blue glasses and faience in Egypt from the mid 2nd millennium BCE. However, the investigation of Egyptian faience glazes by Kaczmarczyk and Hedges (1983) indicated that no cobalt was used in Egypt after the New Kingdom, from the 11th to the 7th centuries BCE, during the unsettled Third Intermediate Period. Cobalt was again used as a colorant in Egypt from the beginning of the Late Period, in the mid 7th century, but cobalt-coloured glasses at this time do not exhibit the elevated levels of manganese, nickel or zinc observed in cobalt glasses of the earlier period. Kaczmarczyk (1986) inferred that this indicates a cobalt source outside Egypt.

While most Mesopotamian blue glasses appear to be coloured with copper from the 3rd to 1st millennium, a mere handful of cobalt-coloured glasses, faience and glazes have been reported from Eridu, Nippur and Ugarit (Garner 1956; Neumann 1927). These were found to be coloured with a non-Egyptian, non-alum cobalt source (Kaczmarczyk 1986, 374). Kaczmarczyk concluded that while the Great Western Oases were the most likely source of cobalt alum to the 2nd-millennium Egyptian craftsmen, the cobalt source for Mesopotamian glasses of all periods, and Egyptian glasses and glazes of the 1st millennium BCE, was Iran. This picture, however, was clearly an over-simplification.

The Nimrud cobalt-coloured glasses are therefore found in the middle of a period of over 400 years when cobalt is not reported as a colorant in Egyptian glass, and furthermore in a region not generally associated with the production of cobalt blue glass. Were it not for these chronological and geographical gaps, it would be logical to assume that the cobalt alum in the Nimrud glass represented a continuation of the use of the Egyptian source from the Bronze Age, but such a proposal clearly needs careful consideration.

There is little evidence for the production of the cobalt blue glass in Mesopotamia itself. However, it should be noted that the use of red alum (note that cobalt-bearing alum is pink in colour) as an additive in the manufacture of 'lapis lazuli' coloured glass is mentioned in the famous cuneiform glassmaking texts from Ashurbanipal's (668–627 BCE) library at Nineveh (Oppenheim *et al.* 1970, 41). This suggests that the use of alum as a colorant was known to Mesopotamian glass makers.

The Nimrud cobalt blue glass plaques seem most likely to have originated from Syro-Palestine, and were probably not made by local expatriate craftsmen imported by Ashurnasirpal II. There are similarities in base and colorant composition of the cobalt blue glasses from Nimrud to those analysed from early 1st millennium BCE France by Gratuze and Picon (in press) who attributed them to a Syro-Palestinian origin. If the glass arrived from the west, there is the possibility that Egyptian cobalt alum was used by Levantine glassmakers, or by glassmakers in Egypt itself, although the failure to detect alum-derived cobalt in Egyptian faience glazes of this period (Kaczmarczyk and Hedges 1983) renders the latter possibility unlikely.

Circumstantial evidence for an Egyptian source of cobalt lies in the apparently precocious use of natron as an alkali

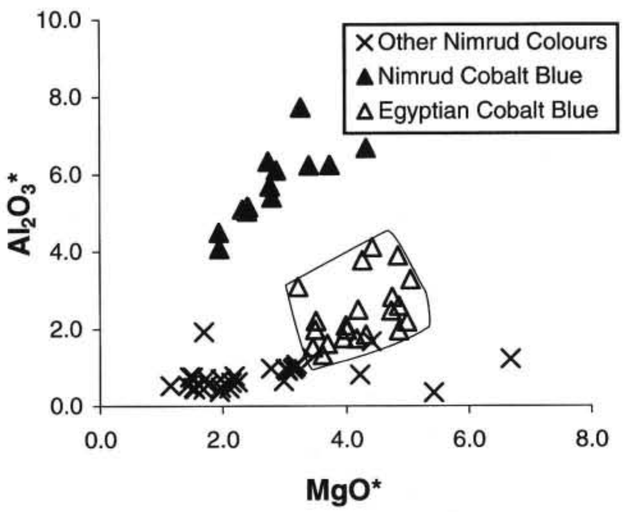

FIG. 3 Scatter-plot of magnesia *versus* alumina for Nimrud and Egyptian New Kingdom glasses

in these and other glasses from Nimrud. The work of Schlick-Nolte and Werthmann (2003) suggests that, as might be expected, Egypt was already exploiting its own natron sources at this time for non-cobalt blue glass. Thus it is very possible that the natron used in the Nimrud glasses was of Egyptian origin. If so, then it is also possible that the glassmakers obtained Egyptian cobalt.

The compositions of New Kingdom and Nimrud opaque dark blues are compared in FIG. 3 as a plot of alumina *versus* magnesia. There is a clear positive correlation between these components in the Nimrud glasses, which are displaced from the Egyptian cobalt blues, with much higher alumina. The $MgO:Al_2O_3$ ratio is around 0.5 in Nimrud glass but three to four times higher in the Egyptian glasses. These differences in composition may indicate a different alum source, either inside or outside Egypt, or possibly a continuity in the use of the Bronze Age alum source, with a change in the technology of separation of the cobalt pigment from the alum. There are suggestions of continuity between the Bronze Age and Iron Age approaches, for example in the low potash contents of the two groups of glasses.

At present there appear to be no published parallels for the Nimrud cobalt blue compositions, from Mesopotamia, Egypt or the Levant, so our ability to investigate this problem is restricted. It is unfortunate that the evidence for glassmaking in the 11th–7th centuries BCE is so limited, but this is not surprising on the basis of the results of the analysis of glass from Nimrud and the tomb of Nesikhons (Schlick-Nolte and Werthmann 2003). As might be expected, the earliest glassmakers using natron did not have good control of their raw materials. They were not aware of the importance of lime as a stabilizer and commonly used sands or pebbles low in lime as a source of silica. Natron contains essentially no lime. A consequence of the low lime in the Egyptian 10th-century glasses is that they are very unstable and appear to have been preserved only due to the extremely dry conditions in the tomb. Similarly, the Nimrud cobalt blue glasses are low in lime, but their resistance to weathering was enhanced by the additions of alumina and magnesia in the cobalt colorant. Robert Brill's analyses (1999, 48) show that opaque yellow glasses from Nimrud are also very low in lime, and opaque red glasses are moderately low; these colours are likely to have been preserved due to the presence of divalent lead and copper added to colour them. Thus it is very likely that a substantial number of glasses from this period, which were not coloured with large amounts of stabilizing compounds, or preserved in the extreme dry conditions such as those encountered in the tomb of Nesikhons, have simply weathered away, and that much of the evidence for Late Bronze Age to Early Iron Age use of natron-based glass has been lost completely.

Conclusions

Cobalt blue glasses from Nimrud were coloured using a pigment derived from cobaltiferous alum, similar to that used in New Kingdom Egypt. These glasses also share the characteristic that both are low in potash. Coupled with exceptionally low lime content, this characteristic indicates that the alkali in the Nimrud glasses was added mainly in the form of natron, with minor or no plant ash, although the relative amounts of natron and plant ash in the New Kingdom glasses remain uncertain. Other glasses from Nimrud are also low in potash and magnesia and appear to be natron-based. These technological characteristics hint both at continuity, in the form of the use of cobalt alum, and change, with a shift from plant ash to natron as the prime glass flux, during the LBA–IA transition. However, further work is needed to understand the intricacies of the glassmaking technology at this time. It is hoped that trace element analyses, now in progress, will help to answer these questions.

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RECONSIDERING THE IRON AGE GLASS INLAYS FOUND IN ASSOCIATION WITH CARVED IVORIES

Maud Spaer

In the early centuries of the 1st millennium BCE, carved ivories were among the foremost architectural ornaments in western Asiatic palaces. A number of different styles (or schools) of carving are known, among them the North-Syrian, the Phoenician, the Assyrian, and the so-called Intermediate or South-Syrian (Mallowan 1966, 471–598; 1978; Mallowan and Herrmann 1974; Barnett 1975; 1982; Winter 1976; 1981; Herrmann 1992, 22–39). Many of the ivories exhibit great artistic and aesthetic sense along with outstanding workmanship. This is especially true of the Phoenician-style examples – the ones most frequently highlighted by colourful inlays, mostly of glass. Furnishings with ivory inlays were sometimes also ornamented with glass inlays placed directly onto the furniture. This paper will consider various aspects of the glass inlays, with an emphasis on the 'rosette plaques' found at Arslan Tash.

Carved ivories have been discovered at Iron Age sites from Persia to Etruria and beyond, but the majority of glass inlays excavated in association with them were found at Nimrud in Assyria (northern Iraq; e.g. Mallowan 1978; Barnett 1975), Arslan Tash in northern Syria (Thureau-Dangin *et al.* 1931, 89–141), and Samaria in central Palestine (Crowfoot and Crowfoot 1938). The evidence from the Phoenician homeland thus still awaits discovery. Nimrud, incomparably larger than the other two sites, has been a particularly rich source both of carved ivories of different styles and of glass – not only inlays – in the Iron Age (von Saldern 1966), and glass continues to turn up at this site (Curtis *et al.* 1993, 15–16; Oates and Oates 2001, 240).

The glass inlays are of two main types: monochrome and bichrome. The monochrome vary considerably in shape (even including cylindrical pieces), size and colour. Red opaque glass occurs more frequently than it did in the 2nd millennium BCE. This probably has to do with the fact that just at this time the red colour appears for the first time to have been made with large inclusions of lead oxide (see, for example, Brill and Cahill 1988, especially 19–21). The addition of lead improved the colour formation of the copper in red glass, but the manufacturing process remained complicated and attests to the skills of the glassmakers (for example, Welham *et al.* 2000). The red opaque glasses:

> were definitely made in Mesopotamia (as opposed to Egypt). The lead in those glasses is of an isotopic type … found so far only in Mesopotamian and Iranian glasses, glazes, and metallic artefacts … from some as yet unidentified mining region somewhere in that greater area. That particular mining region appears to have supplied lead to glassmakers for some 2400 years … from 1500 BC to the ninth–tenth century' (R.H. Brill, pers. comm.; see also Brill *et al.* 1993).

(It should be noted that there exists a considerable amount of chemical and other research on red glass, which cannot be detailed here.)

While faience was hardly used in association with ivory, much Egyptian Blue has been found. It was used as an inlay by itself and also placed in powdered form under blue glass and inlays of other materials, just as a haematite pigment was placed under red glass. The powdered pigments may have been attached 'by means of some binder (or adhesive) – perhaps something like gum arabic'. 'Chemical and x-ray diffraction analyses have confirmed our microscopic observations that these powders contained haematite (Fe_2O_3) and Egyptian Blue ($CuO.CaO.4SiO_2$)' (both quotations R.H. Brill, pers. comm.; see also Barnett 1975, 240; Herrmann 1986, 59). This was done 'to form neater edges where the glass did not quite join the ivory walls' (R.H. Brill pers. comm.). The Egyptian Blue could, of course, also have been used to enhance the colour of translucent blue glass, but the fact that backings were also employed under opaque stone and glass reinforces Brill's view. The opinion that the 'bedding' was needed when the inlays were thin and the 'cells' were deeply carved has also been expressed (Plenderleith in Mallowan 1966, 141). The backings, however, were also used in the case of shallow carvings and might also have helped to fasten the inlays to the ivory.

Most of the bichrome inlays are small, blue, roughly square plaques with a six-petalled white rosette motif. In addition there are rarer, larger or round such plaques (Curtis 1999, 61, figs 6–7), and pieces with white motifs other than rosettes (Crowfoot and Crowfoot 1938, frontispiece 2, pl. xxiv), as well as some remarkable painted plaques (Orchard and Brill 1978).

As for the common rosette plaques we distinguish two types. The first is relatively small, mostly 5–7mm. square. The rosette motif traverses the glass and the two sides are identical; the (medium) blue glass is coloured by copper and easily recognized as translucent. Most rosettes of this type were found at Arslan-Tash (Thureau-Dangin *et al.* 1931, pl. xviii nos 113–17). The second type is larger, around 9–12mm square, and the rosette motif is inlaid into one side only, leaving the second side plain; the glass is coloured by cobalt (without copper) and it is of a darker blue colour than the first type, and less readily apparent as translucent. Most (though far from all) rosette plaques of this type were found at Nimrud (Curtis 1999, 59–61, figs 1–7, 67–9) as were most of the much smaller number of such plaques found at Samaria. 'The dark blue coloured glasses have unusually high alumina (Al_2O_3) levels', presumably 'associated with the source of the cobalt' (R.H. Brill, pers. comm.) and have withstood weathering better than glass of other colours.

Most Iron Age western Asiatic ivories fit a 9th to 7th-century BCE timeframe. The Phoenician and other ivories with glass inlays were in the past usually considered a frequent occurrence already in the second half of the 9th century, based on Samaria's connection to king Ahab and his Phoenician queen Jezebel (in spite of a lack of archaeological linkage: Tappy 2001, 491–5), and on inscriptions relating to other 9th-century rulers (eg Mallowan 1978, 36–7). Over the last decades, however, one discerns a clear trend to regard the glass-inlaid ivories as no earlier than the 8th century BCE (especially the second half), continuing into the 7th (Mallowan and Herrmann 1974, 19, 50–2; Winter 1976, 15–22; Mallowan 1978, 40–1; Barag 1985, 65–6, no. 40; Herrmann 2002, 141), though the possibility of some earlier beginnings is not disregarded.

The stylistic differences between groups of ivories have always been defined as regional. However, quite apart from the fact that one cannot be certain of a shared provenance for glass and ivory, a number of written sources have made it abundantly clear that ivories and ivory-inlaid furniture were widely traded, given as gifts and tribute, and taken as spoils of war; the booty may have also included the artisans themselves, who, of course, could have also migrated of their own volition (Mallowan and Herrmann 1974, 38–9; Oates and Oates 2001, 226–7). Although no glass workshop has been found, there is nonetheless sufficient evidence to conclude that glass was fashioned (and possibly also made) at Nimrud or close by (Mallowan 1966, 209–10). The evidence was summed up by Moorey (1994, 202–3). Glass is, however, likely to have been worked at several sites. The rosettes were almost certainly worked at more than one centre, considering their differences.

Most of the monochrome inlays – including the numerous ones not found *in situ* – would have been used as inlays in carved ivories (using both *champlevé* and *cloisonné* techniques). Both monochrome and bichrome inlays were also found inlaid into other kinds of objects, including some of glass. The relatively few rosettes used thus are quite small and arranged in bands or friezes (Barag 1993). More numerous rosette plaques of the Arslan Tash type with the pattern passing through the glass were set into wide, opaque red glass frames, weathered green; in some cases in turn mounted in bronze cases (FIG. 1). These pieces, were presumably nailed to wooden furniture, in turn adorned with ivory plaques. (This was apparently the case at Arslan Tash, where the ivories had only a few glass inlays or none at all: Thureau-Dangin *et al.* 1931, 90–1, 138.) The majority of the rosette plaques, including most (possibly all) of the common Nimrud type, lack frames and mounts and their uses are not known (for suggestions see Curtis 1999, 64–6).

Fifty-one rosette plaques from Arslan Tash, all of the type with the motif on both sides, are housed in the Bible Lands Museum, Jerusalem, and I was able to study these pieces. The collection has been partly published (Muscarella 1981, 285, no. 244, pl. xxii; Merhav 1981, no. 117; Bianchi 2002, 172, no. NE-24a). Additional museums with published holdings of rosette plaques from Arslan Tash include the Metropolitan Museum (Grose 1989, 76, fig. 40; our FIG. 1), the Karlsruhe Landesmuseum (Thimme 1973, no. 36; Stern and Schlick-Nolte 1994, 59, fig. 88), and the British Museum (Barag 1985, 72, no. 54). The Louvre and Aleppo museums presumably house additional pieces.

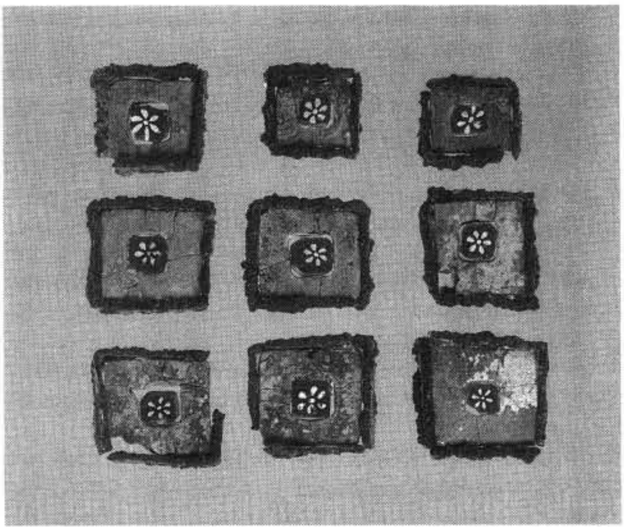

FIG. 1 Blue and white glass rosette plaques (cleaned) set in frames of opaque red glass (weathered green), mounted in bronze, found at Arslan-Tash; *c.* 19 x 19mm; The Metropolitan Museum of Art, Fletcher Fund, 1957 (57.80.18a-l)

The collection of the Bible Lands Museum includes twelve examples in a wide frame of red opaque glass, weathered green (COLOUR PLATE 9). None of these frames had been cleaned. The remainder of the rosette plaques in this collection lack frames; 18 are otherwise similar to the framed (COLOUR PLATE 10). Twenty-one pieces are strongly weathered into a dull brownish grey, not showing any blue colour and most have lost some of the white petals (COLOUR PLATE 11). Most Arslan Tash-type rosettes depicted so far had their weathered surface layer mechanically removed and show the original blue colour. I found that the cleaned pieces in the Jerusalem collection had been reduced in size by an average of about 1mm. It is therefore not surprising that the rosette plaques do not always fit the frames very well. Presumably, many plaques and frames were, furthermore, initially found separately (Barag 1985, 72, no. 54).

The probability (or certainty) that the plaques in which the rosette pattern traverses the glass were made by the mosaic technique has often been mentioned by glass historians (von Saldern 1966, 630; Barag 1985, 52, 71–2, nos 53–4; Grose 1989, 76, fig. 40; Stern in Stern and Schlick-Nolte 1994, 59; Bianchi 2002, 172, no. NE24a) and has been adopted by others (Moorey 1994, 200; Curtis 1999, 60). As for the plaques with inlaid recesses, opinions have differed. Von Saldern regards them as 'cut' (1966, 632–3) or as 'scooped out' (1970, 209) while Barag (1985, 71–2, no. 53) describes a hot-working technique.

My first examination of the Arslan Tash material housed in Jerusalem made me doubt that the mosaic technique had indeed been used (Spaer 2001, 273, n. 2). Many of the pieces had lost some of the white inlay, although the 'fusing-cum-drawing' technique of mosaic cane manufacture makes the loss of individual particles relatively rare, even among much weathered pieces. A perusal of published analyses of rosettes from Nimrud (including one piece described as the 'millefiori type') made it quite clear that the composition of the 'white fills' was in a category of its own; especially striking was the lack, or near lack, of silica (Brill 1999a, 46, nos 3229–30, 3249–52; 1999b, 47–9). I did wonder if two so disparate substances as the white and blue colours were sufficiently compatible to be combined by the mosaic technique.

I asked for and received detailed information from Dr Brill (pers.comm.).

> The white fill material in both the dark blue rosette inlays and the lighter blue 'mosaic' inlays is especially interesting. Our analyses of the blue glasses show them as typical for the time. As for the white colour, it is certain that it is produced by the presence of calcium antimonate ($Ca_2Sb_2O_7$ plus $CaSb_2O_6$). Our analyses and examinations suggest that a powdered white glass (or perhaps a separately prepared white calcium antimonate pigment) had been used for the white decorative fill. In at least some cases, the fill appears to have been lightly fired into place. Also, in my opinion, the so-called 'mosaic' pieces definitely were not manufactured by any sort of 'millefiori technique'.

Dr Brill's communication, as well as a further examination of the Bible Lands Museum rosette plaques, strengthened my view that the mosaic technique had not been used. At least one of the rosettes was found with a back side differing from the front (COLOUR PLATE 12). I also had the opportunity to study two dark blue glass rosette inlays from Samaria – of the type with the motif on one side only. One of these misses two petals as well as the central dot, but the rather shallow depressions of the missing petals can be clearly seen. I was surprised to find that the central depression was much deeper, the depth only slightly less than the thickness of this piece (*cf.* Curtis 1999, fig. 2 right). It seemed that the small round hole had been drilled to exact size.

Conclusions

Various views have been expressed regarding both the chronology and the provenance of carved ivories and their related glass inlays. Much of the 'evidence' is presumptive, and it is doubtful that a review of material published to date could lead to definite conclusions. As Moorey (1994, 202) put it: ' … many key questions about innovation and diffusion remain wide open'. Concerning the functions of the inlays we are partly informed, but the uses of many of the bichrome inlays remain unknown.

In contrast, it seems that one can be relatively certain about the major aspects of the manufacturing techniques employed in fashioning the glass ornaments. Both the monochrome and bichrome inlays were in most instances initially fashioned by moulding, most of them subsequently finished by abrasion, ensuring a better fit, for example, for the spaces in the ivories or the glass frames. Contrary to what has usually been suggested, the white rosette motif was added to the blue glass plaques, both versions, by cold-working techniques (though some hot-working is likely to have been employed subsequently for fusing purposes). This should not come as a surprise, as partly cold-worked glass is prominent in this period, well exemplified by the finds from Nimrud. One can deduce that the small dot-like centres were drilled with a bow-operated copper drill. Petal-shaped holes or recesses were presumably made by some other version of rotary abrasion; perhaps a small copper wheel attached to a bow-lathe. Subsequently, the empty spaces were filled with a white substance, apparently in powdered form.

The Arslan Tash-type rosette plaques with the rosette motif penetrating the glass were definitively not 'the forerunners of Greco-Roman mosaic glass' that they are sometimes said to be. This fact, however, in no way detracts from their appeal, nor should it diminish our esteem for the technical skill and inventiveness of their makers.

Acknowledgements

I received much information on composition and other matters related to vitreous materials from Dr Robert H. Brill of Corning, and I am most grateful for his generous help. Warm thanks are due as well to the late Dr Elie Borowski, founder and first director of the Bible Lands Museum, Jerusalem, and to Mrs Batya Borowski, the present director, and the museum's conservator Mrs Regula Muller Shacham, who enabled me to study the Arslan Tash glass inlays housed in the museum.

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PROTOHISTORIC VITREOUS MATERIALS OF ITALY: FROM EARLY FAIENCE TO FINAL BRONZE AGE GLASSES

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INTRODUCTION

Vitreous materials were known in the Near East and Egypt from the 4th millennium BC; faience became common during the 3rd millennium from the dynastic time (Aspinall *et al.* 1972, 27), whereas the mass-production of glass started in the 2nd millennium BC (Henderson 2000, 52). Investigations of Near Eastern samples have shown the presence of high magnesium glasses (HMG) from the 19th century BC at 'Ain 'Abata (Jordan) and Tel Dan (Israel); similar glass composition were found in materials from more recent sites, like Nuzi (Iraq), Ulu Burun (Turkey), Tell Al-Rimah (Iraq), as summarized by Henderson (Henderson 2000, 54–9). The early Egyptian glasses are of the HMG type and during the 15–14th centuries BC the Egyptian production includes copper blue and cobalt blue frits, glasses and faience (Tite and Shortland 2003). The earliest materials indicating the use of Na-rich minerals as the alkali source in low magnesium glasses (LMG) glass production are 13–12th centuries BC glasses from Pella (Jordan). Other early LMG glasses are from Tell Brak (Syria) and Crete. The picture of Bronze Age vitreous material production in the Aegean area is therefore rather complex. A separate class of glasses having mixed alkali chemical composition (LMHK, low magnesium high potassium) has been defined for most European materials dated to the late 2nd millennium BC (Henderson 2000, 54–9).

The Italian samples studied in the present work were selected according to their typology and age, for appropriate comparison with coeval samples from the Eastern Mediterranean area.

EXPERIMENTAL

Bronze Age vitreous materials are rare, especially the conical buttons and the Middle Bronze Age 3 (MBA-3) and Recent Bronze Age (RBA) glassy faiences. For most samples only microsampling (200–500μm^2) from the surface of the beads or from fractured areas is possible. Because of the scarcity of material and the severe alteration many samples were unusable. The slivers of vitreous materials were incorporated in epoxy resin and surface-polished for the analyses. The preliminary chemical analyses of the glass matrix, of the crystalline and metal inclusions, and of the weathered areas were carried out by energy dispersive spectrometry (EDS) coupled with a scanning electron microscopy (SEM). These data are shortly discussed but they are not reported. The mean chemical composition of the glass phase was performed by electron probe micro analysis (EPMA). The resulting compositions of the conical buttons, the glassy faience and the HMG brown glasses are reported in TABLE 1, together with their age and typology. The identification of the mineral phases present in the vitreous material as unreacted or newly formed crystals was performed by non-invasive X-ray powder diffraction (XRPD) analysis on the surface of the sample.

A quantitative characterisation and discrimination of the types of vitreous materials is obtained by the determination of a parameter (X_M) describing the relative amount of glass matrix with respect to the total area excluding porosity. X_M may be seen as the proportion of glass phase present in the material and it is estimated with the aid of computerized 2-D image analysis applied to SEM back-scattered images. The procedure has been discussed elsewhere in detail (Angelini *et al.* 2002, 585-6; Angelini *et al.* 2004).

EARLY BRONZE AGE FAIENCES

The vitreous material of the Italian Early Bronze Age (EBA; 2100–1700/1650 BC) are exclusively short truncated biconical and segmented faience beads. About 50 beads are known from Northern Italy, found in Lake Garda pile-dwelling and burial equipment from Liguria, and dated between the 'Lavagnone 2' period and the end of EBA. Beads with similar typology have been found across the Alps, from France to Slovakia. A possible origin of worked materials and/or production technology from central Europe has been postulated (Bellintani and Residori 2003, 484).

No Italian EBA faience sample has been analysed to date. Our previous investigation of one sample of pale blue faience from Riparo Gaban (Trentino) shows pervasive alteration of the glass matrix and no reliable composition could be obtained. The mineralogical composition shows mainly quartz grains and a small amount of feldspar. Copper oxides detected at the surface by diffraction probably indicate that Cu had been used as colouring agent.

MIDDLE BRONZE AGE 1–2 GLASSY FAIENCE

In the Middle Bronze Age 1–2 (MBA 1–2; 1700/1650–1450 BC) object and materials in North and South Italy are completely different. Conical buttons with plain

TABLE 1 LIST OF THE INVESTIGATED SAMPLES, AGE, LOCALITIES, TYPOLOGY AND AVERAGE EPMA CHEMICAL ANALYSES (WT%) OF THE GLASS PHASE

Sample	*Age*	*Locality*	*Typology*	*Materials*	Na_2O	*MgO*	Al_2O_3	SiO_2	P_2O_5	SO_3	*Cl*	K_2O	*CaO*	TiO_2	*MnO*	*FeO*	*CoO*	*NiO*	*CuO*	SnO_2	Sb_2O_3	*PbO*
MR2	MBA3-RBA	Montata (RE)	1/2 Flattened globular bead	HMBG	16.84	4.25	4.85	58.73	0.79	0.34	0.40	4.96	6.28	0.15	0.13	3.50	0.00	0.00	0.16	0.80	0.00	0.12
FELINA	MBA3-RBA	Felina (RE)	1/2 Barrel shaped bead with spirally wound line	HMBG	15.70	3.96	3.34	60.23	0.49	0.18	0.48	3.25	6.74	0.13	0.10	6.17	0.00	0.00	0.57	0.28	0.00	0.37
FZIGVR15	MBA3-RBA1	Franzine (VR)	Barrel shaped bead with spirally wound line	HMBG	16.78	4.11	1.78	59.57	0.44	0.87	0.44	3.77	5.59	0.00	0.00	7.07	0.00	0.00	0.15	0.00	0.00	0.00
FZIGVR63	MBA3-RBA1	Franzine (VR)	Fragments of Barrel shaped bead with spirally wound line	HMBG	14.03	4.75	2.30	58.81	na	na	0.27	3.37	7.19	0.10	0.12	8.01	na	na	0.14	na	na	na
FZIGVR10	MBA3-RBA1	Franzine (VR)	1/2 Barrel shaped bead with spirally wound line	HMBG	16.60	3.97	1.76	60.54	na	na	1.25	1.80	6.20	0.00	0.12	6.75	na	na	0.00	na	na	na
PV676	RBA 2	Poviglio (RE)	Barrel shaped bead with spirally wound line	HMBG	12.24	4.60	2.33	61.88	0.26	0.40	0.43	3.74	5.65	0.09	0.09	10.50	0.00	na	0.26	0.00	na	na
MVPAN12905	RBA-FBA	Monte Valestra (RE)	Annular bead with singular drawing	HMBG	14.53	4.33	3.47	56.56	na	na	0.32	3.73	7.74	0.16	0.00	6.96	na	na	0.00	na	na	na
DOSS BOT	MBA 1-2	Dos dell'Arca, Valcamonica (BS)	Conical button plain perforation	LMHK Glassy Faience	6.81	0.28	0.77	70.32	0.15	0.41	0.83	8.43	4.76	0.00	0.00	0.26	0.00	0.00	3.96	0.45	0.00	0.00
GVV1111	MBA 1-2	Grotta Vittorio Vecchi (LT)	Conical button V perforation	LMHK Glassy Faience	8.78	0.87	1.16	77.40	0.18	0.24	0.62	2.93	2.80	0.00	0.00	2.26	0.00	0.00	3.21	0.52	0.00	0.00
GVV1112	MBA 1-2	Grotta Vittorio Vecchi (LT)	Conical button V perforation	LMHK Glassy Faience	14.17	0.51	1.63	66.39	na	na	na	2.31	2.94	0.76	na	1.31	na	na	4.73	1.81	na	na
PV668 (strongly corroded)	MBA 2	Poviglio (RE)	Conical button plain perforation	LMHK Glassy Faience	0.76	0.28	4.44	50.72	na	na	na	0.38	2.14	0.05	na	0.71	na	na	na	na	na	na
Q105	MBA 1-2	Quingento (PR)	Conical button plain perforation	LMHK Glassy Faience	7.87	0.34	2.40	75.57	0.13	0.11	0.51	6.50	3.49	0.00	0.00	0.43	0.00	0.00	1.66	0.17	0.14	0.05
Q106	MBA 1-2	Quingento (PR)	Conical button plain perforation	LMHK Glassy Faience	4.96	0.68	3.15	73.93	0.13	0.26	0.63	9.99	3.22	0.08	0.00	0.49	0.00	0.07	1.98	0.08	0.53	0.00
VIC-F	MBA 2	Vicofertile (PR)	Conical button plain perforation	LMHK Glassy Faience	5.96	0.80	4.57	73.12	0.03	0.70	0.43	10.00	3.82	0.00	0.00	0.34	0.03	0.02	1.50	0.03	0.49	0.03
CC	MBA3-RBA	Case Cocconi (RE)	Fragment of melon bead	LMLKGF	8.96	0.32	2.10	80.55	0.00	0.38	0.50	1.06	1.87	0.00	0.00	0.87	0.00	0.00	3.06	0.15	0.00	0.00
PV960	RBA 1	Poviglio (RE)	Radially grooved bead	LMLKGF	8.60	0.71	0.67	75.48	0.08	0.34	0.39	1.87	2.22	0.09	0.02	3.17	0.84	0.09	2.70	0.01	0.75	2.15
MR1169171	MBA3-RBA	Montata (RE)	Radially grooved bead	LMLKGF	6.52	2.37	0.64	81.12	0.09	0.19	0.31	2.01	1.92	0.10	0.00	1.59	0.53	0.08	0.86	0.00	0.12	0.67
IBZ CG	MBA 3	Trinitapoli (FG)	Rhombohedral bead with wound line	LMLKGF	9.80	0.68	0.83	77.91	0.19	0.22	0.05	1.45	1.20	0.06	0.09	5.33	0.50	0.00	0.67	0.03	0.36	0.93
CIS CG	MBA 2-3	Cisternino (BR)	Rhombohedral bead with wound line	LMLKGF	7.42	0.74	0.73	78.67	0.08	0.16	0.07	0.66	1.78	0.09	0.03	2.36	0.43	0.14	1.57	0.00	0.45	1.79

perforations are the only object typology present in Northern Italy, especially in the north-western area (Mercurago pile-dwelling, Piemonte), in the central Po Valley ('terramare' facies), and sporadically in the Alpine region (Doss dell'Arca, Lombardia). In Central Italy conical buttons are similar, although they show a distinct 'V' perforation; in the same area 80 discoidal beads and a spacer-bead dated to the early MBA have been discovered in Prato di Frabulino (Lazio) (Bellintani and Residori 2003, 486).

The analyses carried out on five buttons from Northern Italy (samples: Doss Bott, Q105, Q106, Vic-F and PV 668) and two buttons from Central Italy (GVV1111 and GVV1112) indicate that the materials are very similar. They are all glassy faiences, defined as materials having an almost equal part of glass matrix and crystalline inclusions, and they have X_M values in the narrow range 0.41-0.54, except for the strongly corroded sample PV668 having $X_M = 0.37$. Glassy faience materials may be compared to *faience Variant E* in the classification of Lucas (Lucas 1934; Nicholson 1993, 14–15) and to the *frits* materials of Tite (1987, 21–3).

Crystalline inclusions are mainly quartz, and in a few samples a small amount of K-feldspar and calcite has been detected. In three samples (GVV 1112, PV668 and VIC-F) traces of cristobalite have been detected by XRPD. In the literature cristobalite is normally reported as the high temperature polymorph of silica, at T>1470°C, whereas tridymite is reported as being stabilized in presence of alkali in the range of 870–1470°C (Sosman 1965, 45–53). It is well known that alkali-free quartz converts directly to cristobalite at a rather low temperature (1050°C: Heaney 1994, 19, or even 835°C: Navrotsky 1994, 315), however recent studies have shown that cristobalite may also form in systems with a variable alkali content at rather low temperatures (Stevens *et al.* 1997). It is therefore not surprising to find traces of cristobalite in our glassy faience samples, in view of the complex behaviour of the silica diagram in the presence of impurities.

In the samples GVV1111 and Q105 few metallic inclusions of Cu and Sn were analysed by SEM-EDS.

The chemical compositions of the glass phases in the Northern Italian buttons are quite homogeneous, they are typical European LMHK glass with 0.3–0.9 MgO wt%, 5.0–8.8 Na_2O wt%, 6.5–10.0 K_2O wt% and 2.8–4.7 CaO wt %. This composition is directly comparable with the Final Bronze Age glasses from different Italian sites (Angelini *et al.* 2002, 587–92; Angelini *et al.* 2004; Brill 1992; Towle *et al.* 2001) and other European ones (Henderson 1988a; 1988b; 2000). The Central Italian buttons have a similar amount of divalent cations, but they show a distinctly higher amount of Na_2O (8.8–14 wt%), and a lower amount of K_2O (2.3–2.5 wt%) suggesting a different alkali source. The compositions are shown in FIGURES 1 and 2 and the mean chemical analyses in TABLE 1.

The fact that the conical buttons are an exclusively Italian object typology and have a LMHK composition are both strong evidence of local production. The slightly different composition and typology from North and Central Italy may reflect the existence of different production centres.

During the last part of the EBA and the beginning of MBA the first glass materials make their appearance in Eastern Sicily, Southern Italy, together with faience beads.

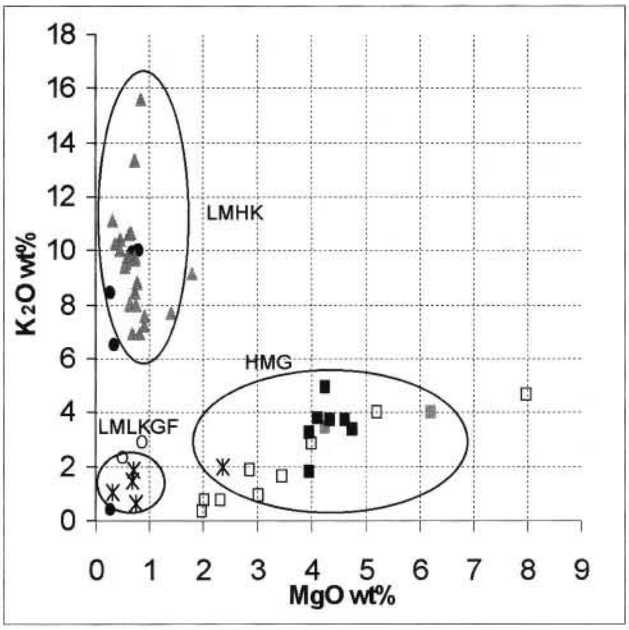

FIG. 1 Plot of K_2O *versus* Mg0

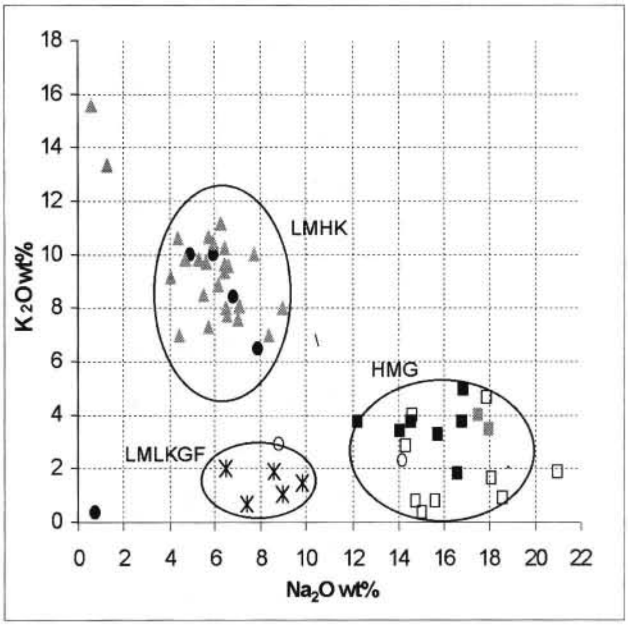

FIG. 2 Plot of K_2O *versus* Na_2O

Note: For both figures the symbols are respectively – filled circle = conical buttons from North Italy; void circle = conical buttons from Central Italy; pale gray square = HMG blue glass MBA 1–2; void square = HMG blue glass MBA 3– RBA; black square = HMG brown glass MBA 3–RBA; star = Glassy faience MBA3 – RBA; triangle = LMHK FBA.

Faience and glass beads are also found in Calabria, in the Flegero Islands (Campania), in Lipari and in Puglia during the MBA 1–2 and they may be related to the Mycenaean presence in the area (Angelini *et al.* 2003).

In a previous study five beads from Grotta Manaccora (Puglia) were analysed (Angelini *et al.* 2003). Only two samples showed the presence of residual glass (FIGS 1 and 2), with composition comparable to the previously analysed Italian HMG glasses of the RBA (Angelini *et al.* 2002) and to the typical Egyptian and Near East blue copper glass (Tite and Shortland 2003, 286, 303–4). There are no other available analyses of coeval Southern Italian glasses, so that the beads from Grotta Manaccora may have been imported from the Eastern Mediterranean or Egypt. The beads from Prato di Frabulino are actually glassy faiences with a chemical composition similar to the North Italian conical buttons (Santopadre and Verità 1995), and they may be further evidence of local production of LMHK materials.

MIDDLE BRONZE AGE 3 AND RECENT BRONZE AGE GLASS AND GLASSY FAIENCE

Middle Bronze Age 3 (MBA 3) and RBA (1450–1200 BC) are substantially coincident with the LH IIIA and B of the Aegean area. At this stage glass materials also occur in Sardinia. In Southern Italy necklaces in faience, glassy faience, glass, amber and quartz have been discovered in the settlement of Portella di Salina (Eolie Islands, Sicily) and in the burials of Madonna di Loreto di Trinitapoli (Puglia), Plemmyrion and Thapsos (Sicily) (Angelini *et al.* 2003). The objects show complex and new typologies directly comparable with the Mycenaean and Near Eastern materials. These typologies gradually replaced the known faience and glassy faience productions in Central and Northern Italy (Bellintani and Residori 2003, 488).

Ten glassy faience beads of this age were selected from Northern and Southern Italy; only five have an unaltered residual glass matrix (samples: CC, PV 690, MR1169171, IBZ CG and CIS-CG). Their typology, provenance and the mean chemical composition of the glass phase are set out in TABLE 1. These glassy faiences show a narrow range of proportion between the glass matrix and crystalline inclusions ($0.37<X_M<0.42$), with the glass phase being slightly less abundant than in the conical buttons. The quartz is always present, but the XRPD and SEM-EDS analyses show the presence in some samples (PV 690, MR1169171 and IBZ CG) of different metallic and Si-rich inclusions. The heterogeneity of the sample provenance and typology makes it impossible to discriminate different glassy faience material classes, however it is interesting to note that this group of materials consistently show low levels of K_2O (0.7–2.0 wt%), CaO (1.0–2.2 wt%), Mg (0.3–0.7 wt%), and high levels of Na_2O (6.5–9.8 wt%). Sample MR1169171 is exceptional in having MgO up to 2.4 wt%. The diagrams in FIGURES 1 and 2 show that these materials are clearly distinct from the well-known groups of LMHK, HMG and LMG glasses.

The chemical compositions of the glassy faiences of the Aegean beads of Platanos and Psaro analysed by Tite (Tite *at al.* this volume) and glassy faience wheel beads with two hubs from Poviglio (Reggio Emilia) analysed by Verità (Santopadre and Verità 2000) are the only comparable analyses found in the literature. The cited beads and the sample PV 960 show a similar amount of minor elements (Co, Sb and Pb), so that the Aegean origin of sample PV

960 is very likely. The glassy faience samples MR1169171, IBZ CG and CIS CG show significantly lower levels of Co, Sb and Pb, so that their Mycenaean origin is more doubtful. Sample CC is coloured only with copper and shows no trace of Co, Sb, or Pb.

In the MBAIII and RBA in Italy HMG glasses are exclusively present, there is no evidence of production of the LMHK glassy faience materials. The new analyses of globular and annular blue glasses beads from Gambolò (Lombardia), Trinitapoli (Puglia) and Montale (Reggio Emilia) show an HMG glass composition similar to the one previously found in samples from three different sites (Angelini *et al.* 2002, 583–91). All available chemical data of HMG blue glasses are plotted in FIGURES 1 and 2. The composition is comparable to that of the MBA 1–2 glasses from Southern Italy, and to that of the typical HMG copper blue Egyptian or Near East glasses (Tite and Shortland 2003, 286, 303–4). A trade link between the Aegean/Near East and Italy is more commonly accepted and it is entirely plausible for this kind of material.

A distinct group of HMG brown glass is here defined for the first time. The mean chemical compositions of six samples are reported in the first group in TABLE 1. These materials show amounts of Na_2O, K_2O, and MgO comparable to those of the HMG blue glasses, and a slightly higher amount of CaO. The distinction consists in the very high amount of FeO: 3.5–8.0wt%, (with respect to 0.2–0.6wt % in the blue HMG glasses) associated to a higher level of Al_2O_3: 1.8–4.8wt% (with respect to 0.3–1.5wt% in the blue HMG glasses). Diopside and augitic crystal inclusions are abundant. The SEM-EDS images show the ubiquitous presence of fine and coarse copper sulphide droplets, sometimes containing low amounts of Fe and other metals, possibly related to the use of small amount of metal slags as colorants.

Brown HMG glasses with comparable compositions are not know in Egypt and the Near East. The only similar glasses were found in more recent samples (1100–800 BC) from Hasanlu, Iran (Brill 1999, 44), but they show a high level of TiO_2 which is not present in our samples. The hypothesis of importation of HMG glasses and local reworking by colorant addition can not be excluded, although the rather different structure of the two glasses and the local abundance of the brown objects, together with the unusual chemical composition, in our view may be indicative of a local production imitating Aegean typologies.

FINAL BRONZE AGE GLASSES

In the Italian FBA (1200–1000/950 BC) there is an exclusive production of LMHK glasses, as elsewhere in Europe (Henderson 1988a; 1988b). The analyses carried out on materials from Monte Valestra and Bismantova (Reggio Emilia), and from Clanezzo (Lombardia) yield glass compositions comparable to the mixed alkali Frattesina glasses (Angelini *et al.* 2004; Brill 1992; Towle *et al.* 2001). No HMG production or trade seems to be present. The analyses of the LMHK glasses are reported in FIGURES 1 and 2.

CONCLUSIONS

The present investigation considerably increases the number of available analyses of BA vitreous materials in Italy. In the light of the present evidence, the evolution of glass technology during the entire Bronze Age is rather dynamic. Local production of typically European LMHK glassy faience during the MBAI–II appears to be coeval with the appearance of the first HMG glass materials in Southern Italy, probably produced in Egypt or the Near Eastern world.

It is not clear whether the observed absence of LMHK materials in Italy during the MBAIII and RBA indicates a change or a stop in glass production. Two new groups of materials are defined within the materials of this period: The 'high magnesium brown glasses' (HMBG) and the 'low magnesium low potassium glassy faiences' (LMLKGF). Indeed both groups may be envisaged as variants of existing classes, since the HMBG are closely related to the HMG of the Middle East, and the LMLKGF have close analogues within Egyptian faiences or glassy faiences. However they both carry distinct chemical signatures, the HMBG having consistently high amounts of Fe and Al with respect to Eastern HMG, and the LMLKGF having: 1) a very low level of CaO (0.6–2.0 wt%) in the glass phase with respect to the Egyptian glassy faiences and frits (CaO = 6.8–6.9 wt% and 11.3–12.3 wt%; Tite 1987, 22); 2) a lower Al_2O_3 level (0.6–2.1 wt%) with respect to Egyptian Co-containing faiences (5.8–6.3 wt%; Tite 2003, 286); and 3) lower K_2O and CuO levels (K_2O = 0.6–2.0, CuO = 0.7–3.1 wt%) with respect to Egyptian Cu-containing faiences (K_2O = 4.3, CuO =10.6 wt%; Tite 2003, 286).

If our interpretation is correct, then the HMBG materials are likely to be of local production or reworking, as they are unknown in the Eastern Mediterranean area, suggesting a change rather than a hiatus in Italian glass technology.

Similarly, the LMLKGF materials may well be related to newly analysed Aegean materials and may have a common origin. If this assumption is correct, the interpretation indicates both local production and trade from/through the Aegean during the MBAIII and RBA periods. In the FBA mixed alkali glasses are present in the entire peninsula, and the Frattesina workshop may have been a major production centre of glass materials.

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THE LATER FIRST MILLENNIUM BC

COLOURLESS GLASS VESSELS FROM THE MAUSSOLLEION AT HALIKARNASSOS

Despina Ignatiadou

The satrap of Caria Maussollos died in 353 BC and was buried, by his sister and queen Artemisia, in Halikarnassos (modern Bodrum, Turkey). His burial chamber stood in the heart of the monumental tomb that became famous as one of the Seven Wonders of the World. Artemisia died two years later and was buried in the antechamber of the same tomb. The Maussolleion was demolished in the 15th century, leaving behind a myth and, luckily, also some material finds.

Excavations at the site have revealed the foundation of the tomb and the bottom of the burial chamber. There, in a cutting associated with a tomb-robbers' mine, were found fragments of a few grave-goods; mainly gold, ivory, pottery and colourless glass. All evidence indicates that the finds belong to the rich inventory of the burial of Maussollos and not to that of Artemisia.

Eight colourless glass vessels have been identified from fragmentary material (FIG. 1). They are the first that can be securely dated to the first half of the 4th century BC, at the beginning of the colourless glass production of the classical period, and they provide secure ground for the comparison and dating of similar, unprovenanced vessels.

They were created within the cultural environment of the Achaemenid Empire but they must not be considered Persian. Many different cultural traditions contributed local popular shapes and decorative elements to form the Achaemenid International Style, which was common and widespread throughout the Empire. The Assyrian and Anatolian origins, and Ionian influence are evident in all the vessel shapes present in the Maussolleion.

A full report on the vessels is forthcoming in the excavation publication (Zahle 2004)

The shapes

Tall calyx-cups

Two vessels are tall calyx-cups decorated with long petals. The shape of the tall calyx-cup originates in Mesopotamia (the 15th–14th century BC Hurrian Nuzi, and, later, the 8th–7th century BC Assyrian Nimrud), but may have roots in 3rd millennium Egypt. In the Achaemenid period it is incorporated in the repertory of the Achaemenid International Style and starts being decorated with the popular motifs of white lotus leaves and ionic (or long) petals. The only other extant glass tall calyx-cup is the vessel known as the Corning Beaker.

Beakers

Four vessels are beakers decorated with horizontal grooves. They are either thin (1–2mm) or thick walled (3–4mm). The grooves start below the rim, leaving an upper undecorated band; their width varies from 3 to 6mm. The bottoms are not preserved. Beakers 1, 2 and 3 probably had ordinary flat bottoms. Beaker 4 is too small and too inward sloping for an ordinary beaker. It is perhaps the lower part of a small conical animal-head beaker terminating in a small bovine or ram's head, now lost. The only extant glass animal-head beaker is the Miho Museum vessel.

Most of the silver and glass beakers of the classical and early Hellenistic period were found in Anatolia, so the shape is probably associated with that region. Their decoration also points towards Western Anatolia; grooves were a favourite decorative element of the Phrygian and Lydian metalwork, before they became incorporated in the Achaemenid International Style. Two almost comparable glass vessels exist: a complete one from Derveni, Macedonia, and a fragmentary one from Gordion, Phrygia.

Animal-head situla

One grooved vessel has very thick walls and its diameter is large for a beaker. It preserves an undecorated area, but it is not evident whether that is from the rim or from the lower body; the latter being perhaps more possible. The vessel is probably a *situla*, either with a flat bottom or with an animal-head bottom. Fragments that curve irregularly were also found; they are of similar fabric and thickness. They are probably associated with this vessel, and can be identified as parts from the nose and mouth area of a ram's-head.

The fragments do not indicate the existence of a *rhyton* (a bent or a horn type vessel with a perforated bottom). They belong to a straight animal-head vessel; those are never perforated. They originate in Assyria, but were also produced in West Anatolian workshops, and are often

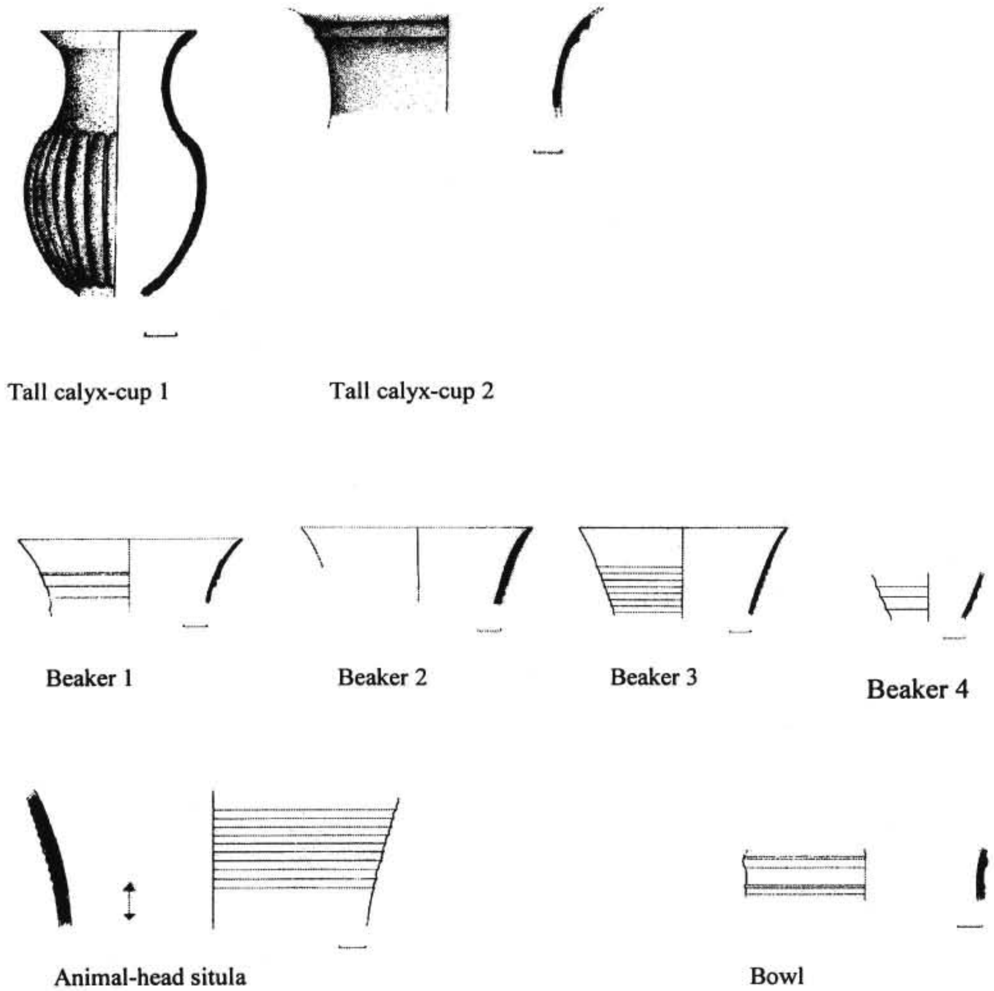

FIG. 1 Colourless glass vessels from the Maussolleion

terminating in a ram's or a lion's head. There is no other animal-head glass *situla* surviving. From the characteristics of the fragments, and by comparison to bronze and ceramic parallels, it appears that the animal represented is probably a ram.

Bowl

One vessel is probably a bowl. It is decorated with a rib and a groove, below the rim. Its rim lip and lower part are not preserved. There are no contemporary parallel finds to this vessel; similar but not totally comparable finds are the 8th–7th century BC cups from Nimrud. The relief decoration there is cut, unlike in the Maussolleion example which is moulded.

THE TECHNOLOGY

All the vessels were shaped and decorated by moulding. Their surface is smooth and all the details are sharp. There is no indication of cutting, except on the rim lips, which are slightly rough and were probably ground. It is not clear whether they were made by the indirect method (the lost-wax technique), or the direct one (stationary or rotary pressing). The existence on the same vessel of a moulded relief part (the animal head) together with grooves indicates the use of a wax model for the whole vessel, as it is impossible to cut negative grooves on the interior of a mould. The bowl has internal vertical striations that are impossible to explain, especially in the absence of the rim.

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THE PRIMARY PRODUCTION OF GLASS AT HELLENISTIC RHODES

THILO REHREN, LINDSAY SPENCER AND PAVLOS TRIANTAFYLLIDIS

INTRODUCTION

Hellenistic Rhodes has long been acknowledged as a major manufacturing centre for consumer goods, such as those transported in Rhodian amphorae (Whitbread 1995), as well as luxury goods, including glass bowls and jewellery. This is based primarily on surviving artefacts, found throughout the eastern Mediterranean and Middle East and attributed to Rhodian production centres based on stylistic grounds (eg Triantafyllidis 2000). Impressive workshop evidence from the modern city of Rhodes attests to the making of large-scale bronze statuary during the Hellenistic period (Zimmer 1990).

The archaeological evidence for the working of glass is almost exclusively based on the material excavated in 1966–67 at the Kakoula Property by Gladys Davidson-Weinberg and Olga Kakavogianni of the 22nd Ephorate of Prehistoric and Classical Antiquities. This material comprises predominantly finished beads, and bead and vessel manufacturing debris, as well as thousands of centimetre-sized pieces of fresh cullet (i.e. fragments of newly-coloured glass rather than recycled vessel fragments) in a range of colours, from high-quality clear and gold glass, to red, yellow, purple and various blues. A specific corpus of this material includes ceramic trays covered with intensely coloured glass residue, thought to be trays in which glass was liquefied for working (Weinberg 1983). The cullet also comprises considerable quantities of uncoloured transparent 'aqua' glass as well as raw glass of the same colour but that appears opaque from inclusions and porosity. The particular nature of this opaque or waste raw glass stimulated the scientific investigation of a range of samples, thought to be representative of the raw and aqua glass present.

The archaeological context of this material is in the Hellenistic period (second quarter of the 2nd century BC: Weinberg 1983; Triantafyllidis forthcoming); however, it is clearly in a secondary position and no evidence for a furnace structure was found with the production remains.

The main aim of the investigation was to test the hypothesis that this waste raw glass may represent evidence for the actual making of raw glass, as opposed to the much more common working of glass, and to discuss whether this took place at Rhodes or elsewhere.

THE MATERIAL

This study focuses on the suspected waste raw glass fragments as possible indicators of the making of glass from its raw materials, as well as the chemical relationship between these raw glass fragments, the aqua glass and the coloured glass cullet worked on site. Two groups of samples were analysed: waste raw and aqua glass, and some pieces of coloured glass.

Waste raw and aqua glass are extremes of a continuous group of variable appearance, from opaque off-white ('waste raw glass') to translucent to fully transparent fragments ('aqua glass') with but a few inclusions and air bubbles. The colour is typically pale green to watery blue resulting from minor iron oxide levels and varying redox conditions in the melt; the term 'aqua' was chosen to reflect this range. Many of the fragments, particularly the more opaque ones, are heavily weathered, resulting in the formation of an outer zone of off-white colour, often several millimetres deep.

The shape of the aqua glass fragments includes a similar range as that presented by the coloured glass cullet (see below). The raw glass in particular includes larger pieces, some of which have one smooth surface, apparently fragments of cakes or slabs. The most significant of these latter pieces are two flat slabs, of about 150x200mm and 100x150mm in area, respectively, and 20–30mm thick (FIG. 1). Other pieces are up to 60mm thick. They are smooth on one side only, while the opposite side is rather rough and irregular. Larger pieces show a polygonal fracture pattern typical of shrinking glazes or drying mud. No edge is identifiable on any of the pieces, indicating that they are probably fragments of even larger cakes.

The coloured glass cullet comes in a range of colours, from the predominant dark blue to light blue, purple, opaque white, yellow, green, aqua and decoloured clear glass. The typical size of the fragments is from 1–10cms^2 with irregular morphologies. A quick inspection of the material yielded no evidence for any original surfaces; all pieces appeared broken on all sides. They appear generally of a reasonable to very good quality, with few stones and seeds present. We assume that this cullet represents freshly produced new glass rather than recycled material.

METHODOLOGY

The sampling concentrated on the waste raw and aqua glasses, trying to include very 'dirty', inclusion-rich samples as well as relatively clean transparent ones, and a few coloured pieces of cullet; the main study of the coloured and worked glass is being undertaken by Dr Helen Mangou from the National Museum in Athens.

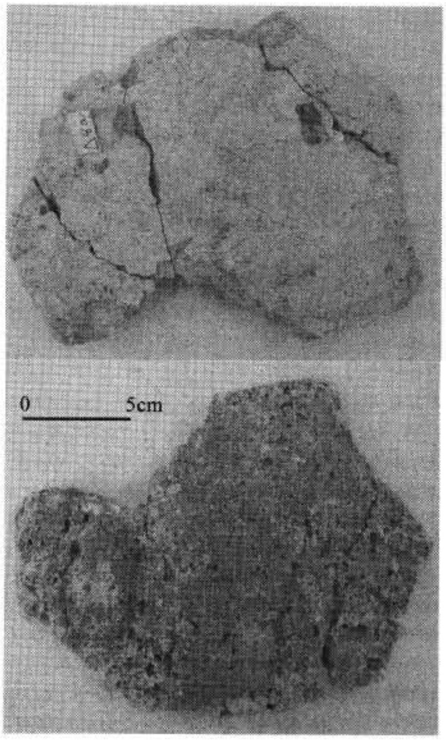

FIG. 1 Raw glass cake from Rhodes, Kakoula property. Top: upper side, bottom: lower side. The cake is 190mm long and *c*. 20mm thick

All samples were cut on site with a portable circular saw using a thin diamond-coated blade. The offcuts were mounted in cold-setting resin and then ground and polished following established metallographic procedures. The mounts were initially studied by optical and electron microscopy to establish the nature and distribution of any crystalline phases present. Particular emphasis was placed on their morphology, as a guide to distinguish between residual phases of the original batch material, and newly formed crystals grown from the cooling glass melt. Chemical analyses of all glasses were then done using a JEOL electron microprobe analyser (JXA 8600 Superprobe) at the Wolfson Archaeological Sciences Laboratories at the Institute of Archaeology UCL. The analyses were done at full screen scans at 800x magnification, equivalent to areas of about 50 by 80 micrometers, to avoid sodium loss during analysis (see Shugar and Rehren 2002 for details). Areas free of any visible crystals or major porosity were selected in an effort to establish the composition of the pure glass phase rather than the bulk composition of glass plus crystal phases. Inevitably, some crystal phases or air bubbles may have been present just below the surface of the polished samples, therefore not visible in the electron image but still within the analysed volume; individual analyses with unusually low totals or extreme values for either silica or lime were excluded prior to averaging. The calibration of the superprobe was based on pure elements and simple compounds; oxygen was not measured but calculated based on stoichiometry. All data are reported as averages of about eight to twelve individual area analyses per sample, expressed in weight percent element oxides, except for chlorine. In the tables, the oxides are normalized to 100 wt% to facilitate comparison between samples; however, the original measured totals are given as well to indicate data quality. The accuracy of the calibration and validity of the ZAF correction procedures were tested by four repeat analyses of Corning A and B glass standards (TABLE 1).

RESULTS

The microscopic study of the waste raw glass demonstrated that the overwhelming majority of the crystalline material in the samples is quartz, with smaller amounts of a 1:1 silica-lime phase ('wollastonite'), and a few crystals of an as yet unidentified magnesia-rich phase, which is badly corroded and hence did not provide satisfactory analytical results.

TABLE 1 PUBLISHED VALUES FOR CORNING A AND B GLASS STANDARDS (CORNA AND CORNB), AND AVERAGES OF FOUR ELECTRON MICROPROBE ANALYSES OF THESE GLASSES DONE DURING THE ANALYSIS OF THE RHODES GLASSES (IOA A AND IOA B). BELOW THIS ARE THE ANALYSES OF FIVE DIFFERENT RAW GLASS SAMPLES AND THREE COLOURED PIECES OF CULLET (BLUE, PURPLE AND BLUE, RESPECTIVELY). EACH ANALYSIS IS THE AVERAGE OF SEVERAL AREA MEASUREMENTS AS DETAILED IN THE TEXT

Sample	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	CaO	MgO	MnO	Sb_2O_3	PbO	CuO	CoO	Total
CornA	67.1	1.00	1.09	14.30	2.87	5.03	2.66	1.00	1.75	0.12	1.17	0.17	100.0
IoA A	*67.2*	*0.97*	*1.00*	*14.72*	*2.82*	*5.05*	*2.68*	*0.98*	*1.49*	*0.07*	*1.12*	*0.15*	*98.7*
CornB	62.6	4.36	0.34	17.00	1.00	8.56	1.03	0.25	0.46	0.61	2.66	0.05	100.0
IoA B	*61.8*	*4.43*	*0.32*	*17.35*	*1.02*	*8.70*	*1.01*	*0.25*	*0.33*	*0.40*	*2.44*	*0.04*	*99.0*
Raw glass													
875	72.5	1.98	0.43	13.1	0.77	8.9	0.64	0.35	Bdl	0.20	Bdl	Bdl	96.4
876	72.2	2.01	0.45	13.2	0.70	9.2	0.65	Bdl	Bdl	0.34	Bdl	Bdl	99.4
881	72.1	2.51	0.46	12.0	0.70	10.3	0.79	Bdl	Bdl	Bdl	Bdl	Bdl	95.5
886	73.0	2.12	0.56	12.2	1.18	9.0	0.72	Bdl	Bdl	Bdl	Bdl	Bdl	95.9
891	72.3	2.42	0.35	11.7	0.65	10.8	0.65	Bdl	Bdl	Bdl	Bdl	Bdl	95.9
Average	*72.4*	*2.21*	*0.45*	*12.5*	*0.80*	*9.6*	*0.69*	*Bdl*	*Bdl*	*0.11*	*Bdl*	*Bdl*	
Coloured glass													
882	71.4	2.47	1.18	15.5	0.46	7.0	0.48	0.25	Bdl	Bdl	0.20	0.09	100.1
890	69.9	2.38	0.44	14.6	0.63	9.0	0.65	1.64	Bdl	Bdl	Bdl	Bdl	96.8
889	70.2	2.40	2.51	15.0	0.46	6.7	0.51	0.42	Bdl	Bdl	0.62	0.31	97.7

The quartz is present as well-rounded grains with evidence of chemical corrosion, such as rounded cavities and blending into the surrounding glass melt. Frequently, a carpet of tiny needles of silica crystals surround major quartz grains ('hedgehog pattern'). The latter phenomenon is particularly prevalent in areas with dense clusters of quartz grains, and is interpreted as indicating the saturation of the surrounding melt in silica and subsequent precipitation of SiO_2 (probably as cristobalite or tridymite) during cooling.

Wollastonite, in contrast, occurs more widely distributed and inevitably with sharp and well-developed crystal faces, indicating that it formed from the melt during cooling. Wollastonite is a typical intermediate phase in glass-forming reactions, and its presence in significant quantities indicates insufficient time and/or temperature during the glassmaking process to form a fully molten glass.

A few porous grains of chromium oxide were found in some samples, and interpreted as former chromite grains whose initial iron oxide content has been leached out.

The five analysed raw glasses all have a low-magnesia soda-lime-silica composition (TABLE 1). Neither typical colorants, such as cobalt or copper oxide, nor decolorants such as manganese or antimony oxide were found in any sample, with the exception of 875 which contains 0.35wt% MnO. The measured totals, of around 96 to 99wt%, are slightly lower than those obtained for the Corning A and B glasses; this is probably due to micro-porosity in the raw glass.

This composition is typical for soda–lime–silica glasses made from quartz and mineral natron; in particular the low levels of magnesia and potash are diagnostic. However, the levels of silica and lime are unusually high for Hellenistic and Roman SLS glass, and those of soda surprisingly low. The combination of surplus quartz, with further growth from the surrounding melt, and the high silica levels in the glass indicate that these samples were melted with insufficient flux present. Plotting the reduced base glass compositions (Rehren 2000) into the soda–lime–silica diagram (Shahid and Glasser 1971) places them onto the 1200°C isotherm on the slope towards the silica corner of the system (FIG. 2a). This indicates melt temperatures some 200 to 300°C higher than those obtained for other Hellenistic glasses (Spencer 2002; comparative data from Vergina, Olympia, Tel Anafa and Morgantina, all from Brill 1999). It is also consistent with the hedgehog pattern frequently observed in these samples, and the principles of the partial melting model as developed by Rehren (2000).

A few samples of coloured glass were also analysed by electron probe micro analysis. These show, within the overall low-magnesia soda-lime-silica formula expected of Hellenistic glasses, a wider range of compositions and colorants/decolorants than the raw glasses (TABLE 1), with, on average, slightly higher soda levels and somewhat lower silica and lime. However, when plotted into the soda-lime-silica diagram, they still fall onto the silica-rich slope of the system (FIG. 2b), with melting temperatures of around 1100°C.

Based on the limited data available so far, the transparent blue glass seems to be coloured by a combination of cobalt and copper oxide. The purple glass is coloured by manganese, and the opaque yellow and green glasses are

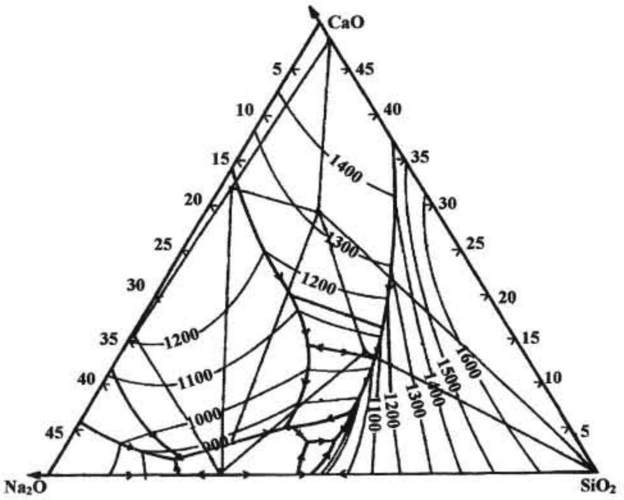

FIG. 2a Plot of raw glass analyses from the Kakoula Property. Data reduction according to Rehren (2000). Note the scatter along the 1200°C isotherm towards the silica corner of the system

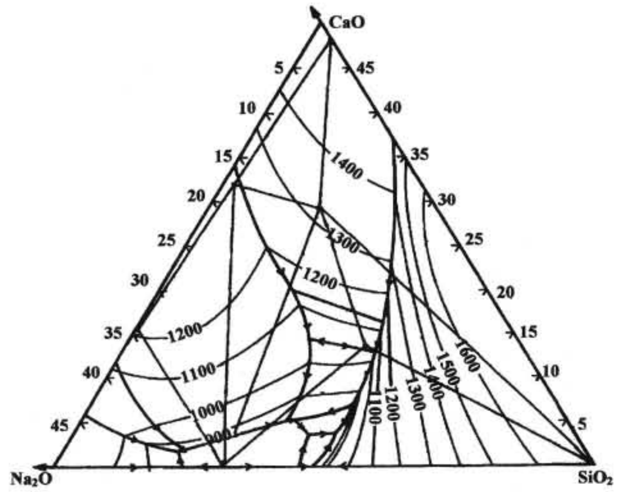

Fig 2b Plot of coloured glass analyses from the Kakoula Property. Data reduction according to Rehren (2000). The theoretical melting temperatures of these glasses are about 100°C lower than those of the raw glasses

coloured by lead antimonate and lead antimonate plus copper oxide, respectively, with somewhat elevated levels of iron oxide, but otherwise unchanged levels of minor oxides, and no detectable tin, zinc or arsenic oxide.

INTERPRETATION

The raw or aqua glass contains almost no discernible additives such as colorants or decolorants, indicating that it is indeed freshly made glass rather than recycled cullet. Many pieces contain areas rich in relict quartz, rendering the glass opaque and unworkable. These fragments are of a shape different from most other samples, exhibiting a smooth top surface and a distinct fracture pattern. It is argued that these samples represent raw glass melted from quartz sand mixed with insufficient natron, resulting in a soda-deficient glass melt containing quantities of residual quartz and newly grown wollastonite. This material is very similar in texture and composition to experimentally produced samples of partly melted glass batches (Shugar and Rehren 2002), and is interpreted as waste material from raw glassmaking. The scarcity of such material in the archaeological record is most likely due to either its deceptive nature when weathered, appearing almost like ordinary rocks, or to the efficient recycling in antiquity of this material. Recent ethnographic work on raw glassmaking in India indicates that only about half of the total glass produced in a given smelt is used straight away, the balance being intermediate or waste material of a kind apparently similar to the raw glass found at Rhodes. In India, this incompletely fused material is not discarded, but kept for remelting with the next batch of glassmaking (Sode and Kock 2001). The presence of some quantities of such material among the glassworking debris at the Kakoula Property at Rhodes therefore points to the local production of raw glass. Unfortunately, no furnace structures or fragments of raw glass with adhering furnace wall fragments have been found, severely limiting our ability to discuss the nature of these furnaces.

The composition of the coloured glass from the same complex differs from the raw glass in so far as it is less soda deficient and contains suitable amounts of colorants and decolorants. However, it is still much more similar to the Kakoula raw glass than to most of the published Hellenistic glass compositions used for comparison. Significantly, the coloured glasses from the Kakoula property plot on the silica-rich slope in the soda-lime-silica system, as opposed to the low-temperature region between the two eutectic troughs (see Rehren 2000 for a more detailed discussion of these eutectic troughs, and their significance for glass melt formation), which is occupied by the glasses from Tel Anafa, Olympia and Vergina (Spencer 2002). Only some of the Morgantina glasses plot also on the silica-rich slope of the system, at the 1000°C isotherm, relatively close to the Rhodes glass.

The apparent differences in melting temperatures indicated by the position of the glass compositions in the SLS diagram are not to be taken to represent true differences in the operating temperatures employed when making or working these glasses. The likely furnace temperature can only be taken from the diagram in the case of coexisting crystal phases under partial melting conditions (Rehren 2000; Shugar and Rehren 2002); thus, only the raw glass samples are suitable for this. The temperature indicated by their reduced composition, of around 1200°C, has in reality to be lowered by probably some 100°C to account for the effect of minor oxides which were included in the major oxide concentrations when processing the data. The temperatures obtained for crystal-free glasses, in contrast, are lowest estimates; while they too need to be corrected down to account for the minor oxides, the very fact that these samples have no or almost no coexisting crystal phases indicates that the actual furnace temperatures were likely to have been higher, due to the overheating necessary to obtain good-quality glass (Cable 1998). In effect, we may assume operating temperatures for the Rhodian glass furnaces of around 1100°C, consistent with estimated glassworking temperatures in antiquity elsewhere (Turner 1954).

Discussion

In the absence of any related furnace structures it is impossible to state with confidence that the raw glass debris was indeed produced locally. It could have been imported to Rhodes together with the glass cullet, as a poor-quality minority among otherwise good glass for the local object production. At present, however, this seems unlikely, particularly as the raw glass pieces are often significantly larger than the cullet fragments and would therefore not likely go unnoticed in a shipment of ready-made cullet. The occurrence of chromite grains in the waste raw glass may also indicate a local origin, as the Rhodian sands are known to contain this mineral, which is much rarer in sands from the Levantine coast (Whitbread 1995; Ian Freestone, pers. comm.). A further indication for the presence at Rhodes of at least some parts of the full *chaine operatoire* of glassmaking and working is the close compositional relationship between the raw/aqua glass and at least some of the coloured or decoloured glass from the same site, indicating that the raw or aqua glass was refined and coloured locally. To further test this hypothesis, however, one would have to study more of the glassworking remains; if the aqua glass composition is absent from the corpus of worked glass, then one has to assume that it was indeed only a semi-finished material used to produce either decoloured or coloured glass cullet for object production.

It is hoped that continuing work, including trace element and strontium isotope analyses, will eventually provide clearer evidence for the provenance of the raw materials. At present, the archaeological evidence seems to support the hypothesis of a local Rhodian glassmaking tradition, initially brought forward by Harden (1965) on purely stylistic grounds. It is hoped that the description of the waste raw glass will in the long term assist the identification of similar material from other glassmaking sites, both in the Late Bronze Age and the Hellenistic and Roman periods.

Acknowledgements

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LATE HELLENISTIC GLASS FROM SOME MILITARY AND CIVILIAN SITES IN THE LEVANT: JEBEL KHALID, PELLA AND JERUSALEM

MARGARET O'HEA

The open, sagged bowl forms of late Hellenistic glassware within the Levant have a restricted range of fabrics and forms which have been categorized by Grose (1979, 54, 56, chart; 1989, 193, fig. 110) into conical, parabolic, hemispherical and shallow hemispherical forms. These could be decorated by internal horizontal grooves, externally cut with petal decoration, vertically grooved, or, in the 1st century BC, have external vertical ribbing. Their broad uniformity across the eastern Mediterranean provides little typological basis for establishing product horizons, centres of supply or indeed regional fashions. However, a preliminary comparison of relative frequencies of fabrics and some forms of late Hellenistic glassware from three very different types of urban sites was undertaken by the author to explore the possibility of identifying differences in these assemblages which might be used to infer either different types of urban markets or else micro-regional centres of production, just as military and civilian, urban and rural consumers and their tastes have been explored through Roman pottery studies in the past quarter-century, or more recently, by studies of ribbed glass bowls in west or east (*cf.* Lightfoot 1993, 89–95). This experiment has yielded some unexpected results, differentiating the military settlement at Jebel Khalid from the primarily non-military sites of Jerusalem and Pella. The application of such a comparison deserves some methodological discussion here, since the preliminary results indicate that a study of fabric frequencies, rather than form distribution, might yield a more potentially useful set of variants than the more common use of regional forms by which different types of urban markets can be isolated in the Hellenistic period.

THE SITES (FIG. 1)

The three sites whose glass forms the basis of this initial and tentative exercise are the Seleucid military foundation of Jebel Khalid on the upper Euphrates, excavated since 1987 by a joint University of Melbourne/Australian National University team under the current direction of G. Clarke; the Hasmonean and Herodian royal city of Jerusalem as retrieved through the scattered trenches of Dame Kathleen Kenyon for the British School at Jerusalem from 1960–1967; and the small Decapolis city of Pella in the north Jordan Valley, excavated since 1979 by the University of Sydney under the direction of J.B. Hennessy, A.W. McNicoll, S.J. Bourke, P. Watson and A. Walmsley.

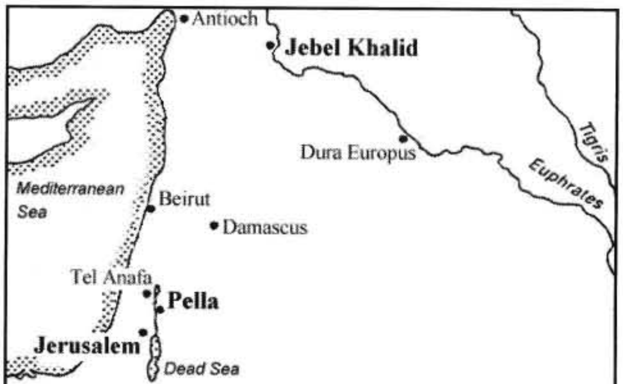

FIG. 1 Map of the Levant, showing Jebel Khalid, Pella and Jerusalem

The walled settlement of Jebel Khalid, whose ancient name has not yet been identified, reaches some 30ha in area. Located north of Dura-Europos, it appears to have been a Seleucid military foundation *ex nihilo*, with an acropolis containing a palatial commandant's residence, surrounded by a gridded town which surely by its extent must have included indigenous north Syrians. The town's official buildings were deliberately dismantled at some point in the second quarter of the 1st century BC – probably by *c.* 70 BC – and apart from a small and discrete use of the site in the Julio-Claudian or Flavian period, was not again occupied until the 4th century AD (Clarke *et al.* 2002, ix, 295–7). The Hellenistic artefacts from this site were, therefore, either upcasts, retrieved from domestic rubbish deposits, or *in situ* detritus from abandoned buildings. None of the Hellenistic glass was retrieved from the solitary temple identified in the lower city.

Kenyon's excavations at Jerusalem sampled the city both within its Herodian walls (Area L) and outside them to the south; no Hellenistic/Herodian primary occupational contexts were found, but up to 8m depth in places of secondary, pre-Flavian deposits were excavated outside the city in the Kidron valley. There was in addition some scrappy but stratified earlier Iron Age occupation, material relating to Roman occupation after the thorough sack of the city in AD 70, and stratified Byzantine and Islamic buildings. Kenyon originally envisaged the extra-mural Hellenistic/Herodian deposits as deliberate Roman dumping of material from destroyed houses cleared from the citadel after the Roman sack (1974, 132) and thus mostly dating to the early Roman period but with earlier upcasts. More recently, a gradual accretion of urban refuse from the Hasmonean period until the city's destruction has been proposed (Reich and Shukron 2003, 13–14), although in practice there is no difference in assemblage throughout the contexts in the extra-mural Hellenistic/Herodian deposits. In either case, the proposed overall date range for this copious material is the same. These deposits were again encountered by Israeli archaeologists (Ariel *et al.* 1990), and raise a challenge as to how such material can be put to interpretive use. None of the Hellenistic glassware from Kenyon's excavations as yet can be associated by context, function or decoration specifically with the Herodian palace or its military garrison, nor with the Herodian temple; and so it can only be assumed that this is representative of the detritus from the domestic, secular assemblage of a largely Jewish population in the last centuries BC and the early 1st century AD.

Pella, occupied since at least the 5th millennium BC, was one of the Decapolis cities which shared a tradition in antiquity that it had been (re)founded as a Greek settlement in the early Hellenistic period. By the Roman period, Pella clearly had a mixed population of Jews, Greeks and Aramaic speakers, although there is no differentiation in the material culture retrieved from the houses of Pella. Pella's Hellenistic glassware comes from a third process of site formation – apart from the usual upcasts and slope-wash, there are scattered across the tell and its neighbouring acropolis (Tell Husn) a number of mud-brick town-houses on rubble foundations which were destroyed by fire, their walls collapsing in and sealing material. This destruction has been attributed to the Hasmonean king Alexander Jannaeus *c.* 82 BC (Josephus, *Jewish Antiquities*, 13.392–7; Tidmarsh in Edwards *et al.* 1990, 73–4).

It is clear from this preliminary overview of these three sites that their assemblages were formed under different conditions, and, for Jerusalem, has a firm *terminus ante quem* about 150 years later. However, two elements of these assemblages can, I believe, be usefully compared with each other – firstly, the relative frequency of conical bowls to other forms within the open bowl series, and secondly, the relative proportions of what shall, for convenience sake, be termed 'fabrics' as defined by visible colour.

In the first case, there is no reason to doubt the universally held view that conical bowls were among the earliest forms of open sagged drinking bowls, beginning in the 2nd century BC (Grose 1979, 57–8) and tapering off in production in the 1st century BC, although there is no certain date by which they ceased to have been produced. The later material in the sagged bowl assemblage from Kenyon's Jerusalem excavations should therefore not strongly affect the comparative statistics of conical bowls.

At Jebel Khalid, much of the glass came from surface or topsoil, with accompanying hydration and abrasion at a level beyond that found at any other site studied by the author. However, the robust thick rim and easily identified straight angle of conical bowls goes a long way to offset the different processes by which glassware survived at all three sites. Survivability or fragmentation is thus not a major problem affecting identification of the conical form of sagged bowls, although fragmentation at Jebel Khalid did affect the identification of other, more convex-walled forms of deep bowls (FIG. 2, far right). Overall, however, Hellenistic sagged glass bowls tend to be more easily identifiable as such, and have a form more easily extrapolated from a rim than many later, blown glass forms.

Minimum number estimates (henceforth MNE) in this paper were made for sagged glass bowls by identifying rim profiles (angle and section) in conjunction with fabric and a wide range of internal groove patterns.

CONICAL BOWLS (FIG. 2)

An MNE of at least 178 Hellenistic glass vessels has been retrieved between 1987 and 2000 from Jebel Khalid. Of these, 93% were sagged bowls which must have functioned as drinking cups, the remaining 7% representing core-formed unguent-containers (they formed an even smaller percentage (1%) by weight). This is typical enough of a secular as opposed to a religious urban site; at Pella, core-formed vessels were 5% of all Hellenistic/early Roman vessel glass (total MNE 167), a proportion similar to that published from Delos (Nenna 1993, 11–12).

At Jebel Khalid, conical bowls formed just under 15% of all sagged bowls – ovoid, parabolic and deep and shallow hemispherical forms – at a site at which ribbed bowls have not yet appeared. Given that conical bowls are early in the series, it could be argued that this low proportion reflects a possibility that conical bowls were decreasing in numbers at the time of abandonment, perhaps by the 70s BC. However, it is important to realize that the deliberate dismantling of this site, down to the removal of timber frames and roof-tiles, as well as the very small fragmentary nature of the surviving glassware, both indicate that there is not a disproportionate survival of the last phase of occupation. It is therefore not necessary to assume that 15% represents the proportion of conical bowls *c.* 70 BC, however tempting that explanation might be.

What is striking is that the proportions of conical to hemispherical or shallow bowls at other sites seems to have been typically much higher. At Beirut, a much smaller sample (46 MNE) of unribbed sagged bowls from a longer period extending into the early Roman series, nevertheless yielded a much higher proportion of conical bowls – 37% (17 out 46 in Jennings 2000, 43). As with the Jebel Khalid sample, these bowls survived as upcasts and urban detritus, rather than in any sealed, truly 'occupational' contexts.

Very close to this is the proportion of 36% of conical bowls at the civilian settlement of Pella in the north Jordan Valley. This is as a percentage of all sagged, unribbed bowls (MNE 159), including upcasts, which of course includes glassware extending into the early Roman period. But conical bowls, as an early form, should form a lower percentage in assemblages that extend into the Roman period, not a higher one than that found at Jebel Khalid, which has an earlier end-point. Even if restricted to the three houses on the main tell at Pella which collapsed onto their datable contents when burnt down as a result of Alexander Jannaeus' attacks on the city in 83/82 BC, the percentage of conical to other forms is 30%. Although most of the glassware from these houses was not retrieved intact, and the MNE includes material from the upper, unsealed strata of the same mud-brick collapse, the absence of

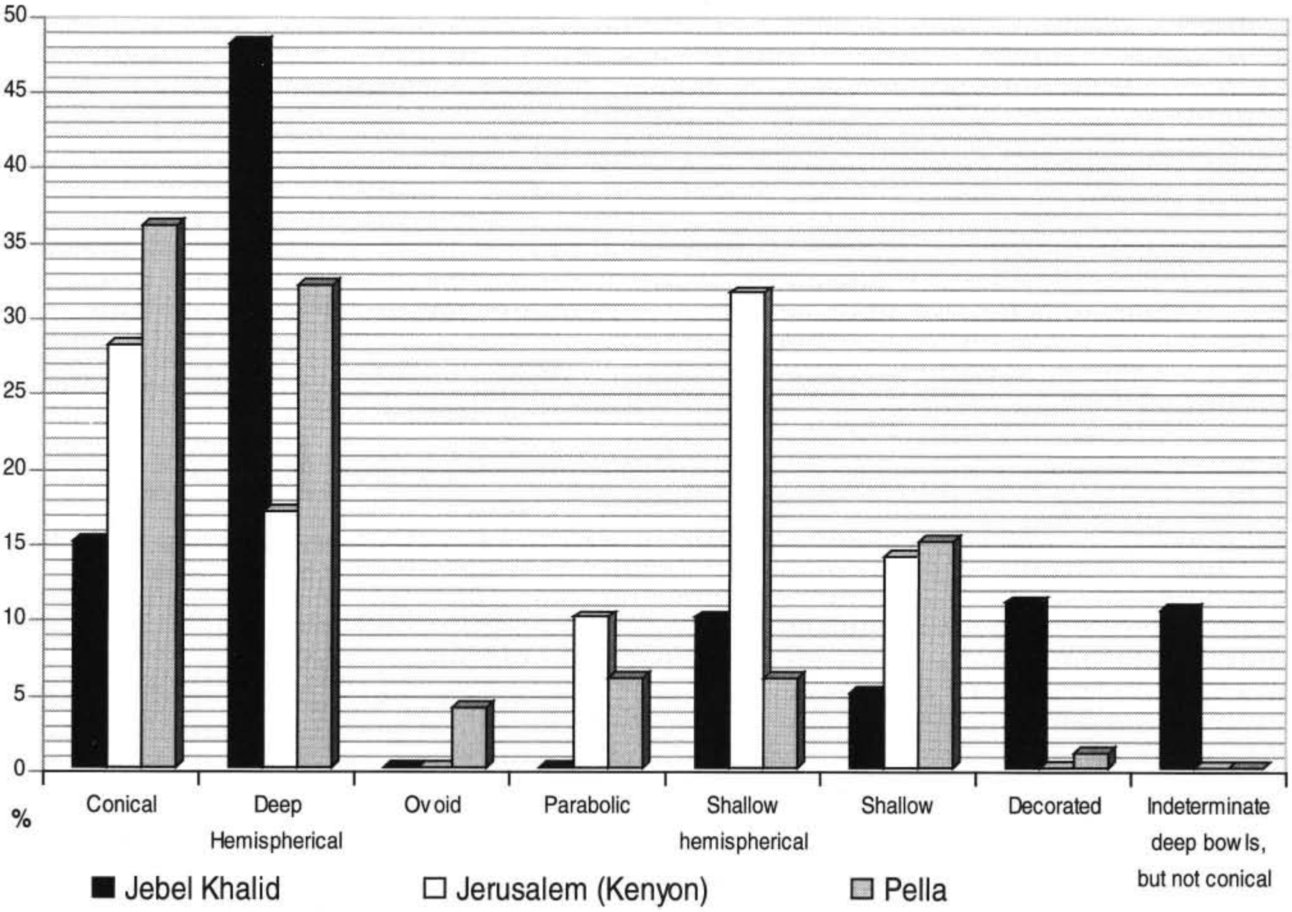

FIG. 2 Relative percentages of MNE of broad categories of forms of Late Hellenistic–Early Roman sagged and unribbed bowls at Jebel Khalid, Kenyon's excavations at Jerusalem and Pella in Jordan

architectural reconstruction above these houses until the very late Roman period at the earliest renders it unlikely that this sample is contaminated with sagged bowls postdating the Hellenistic destruction of the old town on the main tell at Pella.

At Jerusalem, Kenyon's excavations yielded a statistically viable MNE of 110 unribbed sagged bowls, all redeposited through uncertain processes in areas L and A by AD 70, and again extending to include the unribbed early Roman bowls. Again, conical bowls still measure a much higher proportion than at the Seleucid fortress-town in north Syria – 28% of the total unribbed sagged bowls.

At Jebel Khalid, deep hemispherical rather than conical bowls seem to have been preferred overall down to the main abandonment *c.* 70 BC. A chronological seriation cannot be identified here because of the nature of the deposits, as outlined above. The consistently high proportion of conical bowls at Pella, whether calculated from a corpus ending before the abandonment of Jebel Khalid, or from a longer sequence extending beyond the 70s BC, does not seem to support an argument that the higher relative proportions at Beirut, Jerusalem and Pella resulted from a continued large-scale production of conical bowls well into the 1st century BC. An alternative but equally hypothetical explanation would be that Jebel Khalid is anomalous purely for reasons of supply and demand – either the market in this Greek fortress-town with surrounding mixed settlement did not demand conical bowls, or its glass suppliers did not normally manufacture them. Given the Hellenism and/or mixed ethnicity of the consumers of all the sites so far mentioned here in the Hellenistic period, it would be pointless to make *a priori* assumptions about underlying cultural preferences at work.

Indeed, the presence of imported glass cups at Jebel Khalid suggests a Hellenized élite who had access to mosaic cane glassware not available to the well-to-do town-house occupants of Pella, or indeed of Hellenistic Jerusalem. Fluted and petal-decorated incised bowls and mosaic cane cast bowls all appeared within the acropolis and in the domestic *insulae* of the lower city at Jebel Khalid (FIG. 2, far right), although only the acropolis has yielded examples of all of the above in the one structure (and two of the three petal-decorated bowls) in what was presumably the principal residence. At Pella, mosaic cane cast bowls are completely absent from the Hellenistic or early Roman material, as are fluted bowls, but at least two petal-decorated bowls were retrieved from different areas of the town. Seleucid military élite contacts with the Mediterranean world may have played a part in the importation of mosaic cane bowls at Jebel Khalid, although it is difficult to extrapolate from a single site – the mosaic cane bowls published from Dura-Europos are more likely to be Roman than Hellenistic (Clairmont 1963, 10–12, nos 20–3, pl. 18). Yet clearly even the well-to-do at Pella – on

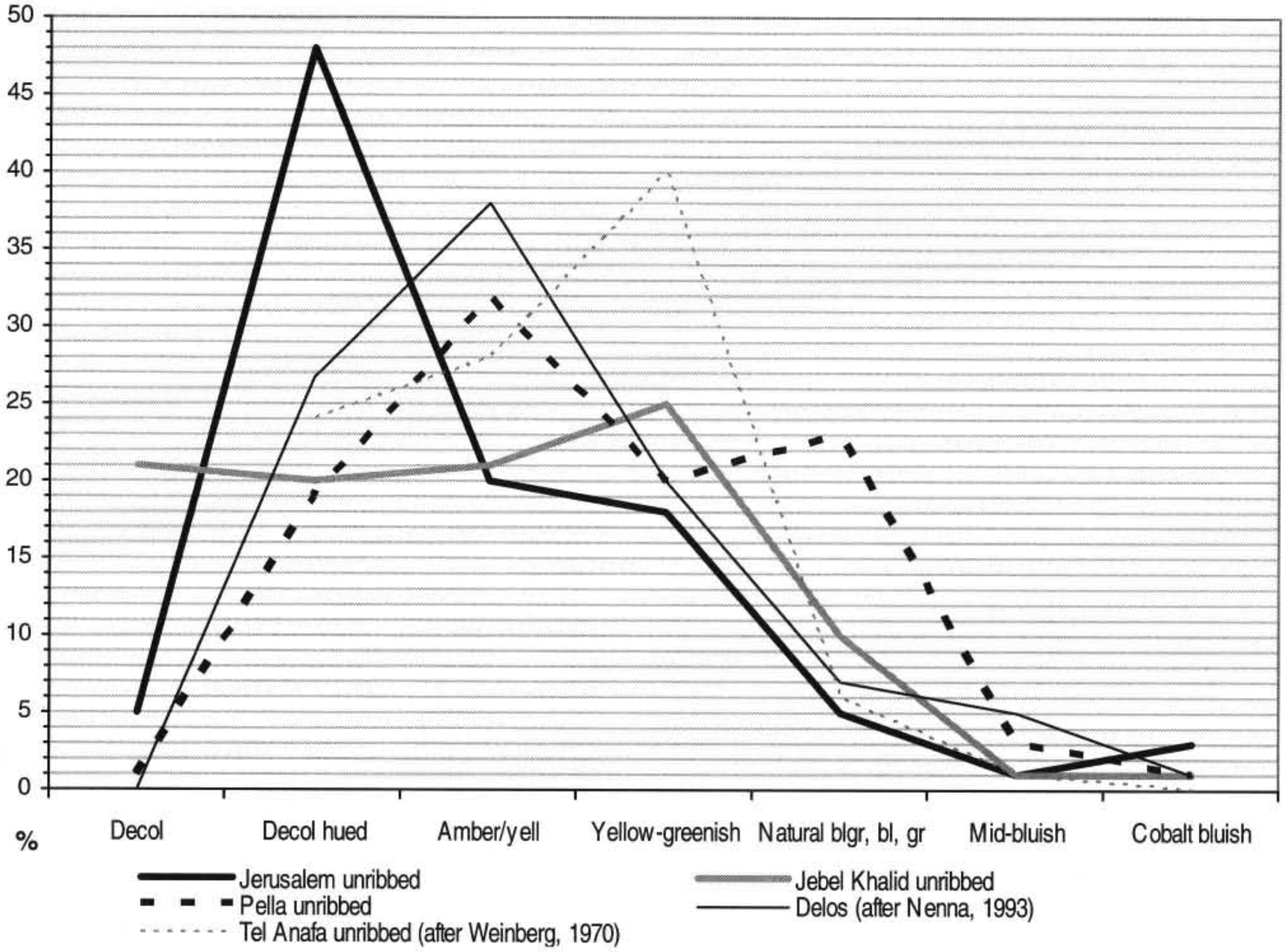

FIG. 3 Relative percentages using MNEs of major fabric hue categories for Late Hellenistic–Early Roman sagged glass bowls. NB: Success of decolourisation at Delos not differentiated in 1993 publication: 25% are decolourized, with at least 1.7% overtinted with manganese

a major junction of trade routes north–south and west to the Mediterranean coast – either did not choose or had no access to this imported form of drinking vessel. It is also curiously rare at the Nabataean capital, where only an early Roman fragment has yet been published (Keller 1997, 245). Jerusalem to date has yielded only one Roman/Herodian Drag. 27 mosaic cane bowl (Ariel *et al.* 1990, 155–6, GL. 23, fig. 29).

REGIONAL FABRICS (FIG. 3)

A second area for comparison is that of fabrics used for sagged bowls. Without discounting the importance of chemical analysis of glass fabrics in identifying possible regional patterns, visual categorisation of glass fabric, including grittiness and bubbliness as well as colour and clarity, can also yield potentially useful information. Neither grit nor much bubbliness is visible in the sagged bowls of Jebel Khalid, Pella, or Jerusalem; but a simple examination of broad colour categories has highlighted some interesting points.

At the fort on the Euphrates, 41% of all bowls were decolourized. From Kenyon's Jerusalem trenches, 50% of all the sagged bowls of an MNE 142 (110 unribbed, 32 ribbed) were decolourized, and even excluding the ribbed bowls as intrinsically later than any of the Jebel Khalid glass, decolourized bowls still formed 48% of unribbed sagged bowls at Jerusalem. This radically contrasts with Ariel's published sample from the eastern slopes of ancient Jerusalem, where only 17% of sagged bowls were decolourized, and just over half amber yellowish (Ariel *et al.* 1990, 151, table 14). The vagaries of different human eyes determining different fabric hues here can safely be discounted, because Ariel's pattern at Jerusalem approximates that identified by the author at Pella. Here, the largest colour group within the entire ribbed and unribbed sagged bowl series was amber yellowish (32%). If restricted to contexts destroyed by Alexander Jannaeus, amber yellowish and lime olive, greenish fabrics each formed 28% of the whole, and decolourized bowls formed less than 20% of the total. This low decolourized percentage is half the proportion of contemporary Jebel Khalid and less than half of that from Kenyon's excavations at Jerusalem. Delos (25% from a very large assemblage, in Nenna 1993, 14) and Tel Anafa (24% from Weinberg 1970, 19) repeat this pattern closely.

But there is another more significant oddity regarding glass fabrics at Jebel Khalid, and its roots seem to be in the 'successful' techniques of the glass-suppliers for that town. Whereas only 5% of Kenyon's Jerusalem's decolourized bowls were *truly* decolourized (no refractive index, no tinge), about 20% of Jebel Khalid's bowls were entirely successful in removing all tints from the metallic compounds in the silica – that is to say, about half the time, the decolourized bowls at Jebel Khalid were completely such. This is a much higher rate than found either in Jerusalem or Pella, where most 'decolourized' glass either had too much manganese, making it sometimes swirled pinkish, or with not enough, leaving a faintly lime greenish (or rarely, very faintly blue greenish or greenish) tinge.

The relatively shallow stratigraphy and abandonment of the site of Jebel Khalid may partly explain the relatively high proportion of hydrated glassware that also suffered abrasion when compared with glassware of similar age from the more deeply stratified material from Pella or Jerusalem. Yet there is less evidence for solarized glass – turned reddish from UV light – at Jebel Khalid than elsewhere.

It is possible that amber and lime/olive greenish fabrics were deliberate choices of Late Hellenistic glassmakers, in imitation of bronze vessels, even though the hues themselves were not artificially added to the batch (Grose 1979, 57 n. 7). At Jebel Khalid, just over 25% were either an acidic lime or a darker olive greenish, which is close to the proportion at Pella (28%) and a bit higher than among Jerusalem's unribbed bowls (23%). In other words, the bronze-like hues were in roughly similar proportions at all these sites – but at Jebel Khalid, the other 'natural' colours were all in much lower proportions: amber (at 19%), blue-greenish, bluish, and greenish – the decolourized glass making up the difference. Given the regional tradition of truly or nearly truly decolourized glass in earlier, Neo-Assyrian glassware and later, Sassanid glassware, this is surely not an accident. It also suggests local suppliers for Jebel Khalid whose abilities to produce well decolourized glass were not wholly dependent on particular silica sources unavailable elsewhere in the Levant; this is demonstrable simply by the fact that all the natural blue greenish, pale greenish and bluish fabrics found everywhere else in the Roman Levant also appeared at Hellenistic Jebel Khalid, merely in lower proportions (together, 11%). As some of those batches were used to produce decolourized glass, their original proportions would have been higher still. At pre-82 BC Pella, blue-greenish, greenish and bluish glass were also present, at twice the level of the Seleucid fortified town (altogether, 23%). What really differed between these two sites was what seemed to sell best – imitation crystal at Jebel Khalid, imitation bronze elsewhere.

Current evidence, then seems to suggest that the glassware for the fortress of Jebel Khalid was mostly locally/regionally supplied, although at the same time, the presence of Late Hellenistic *millefiori* and spiral mosaic cane bowls also shows an atypical fondness for imported fine glassware which was not the taste elsewhere in the Levant, away from coastal sites. Whilst it is possible that the preference for deep hemispherical rather than conical bowls at Jebel Khalid might be a Greek Seleucid rather than a North Syrian taste – we have seen that it certainly is not a Levantine one – a detailed comparison with the ceramic assemblages of Megarian bowls on Levantine sites needs to be undertaken before any such generalisation could safely be hypothesized. The emergence of patterns of glass fabrics and forms as a way to understand supply and demand in the Levant can only be furthered by more publications of Hellenistic sites, including the glassware; and in particular, we can only in the end determine if Jebel Khalid's patterns were products of Greek military demand upon North Syrian suppliers if more Seleucid fortresses are fully examined and published.

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A PRELIMINARY SURVEY OF THE LATE HELLENISTIC GLASS FROM MARESHA (MARISA), ISRAEL

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The Syro-Palestinian northern shore is considered to be a major place of production for Late Hellenistic glass. This assumption is based on historical sources and the archaeological finds from Tel Anafa (Weinberg 1970; Grose 1979; 1981). In recent years several excavations have been carried out at sites in Israel with excavation layers dated to the Late Hellenistic period. Among these sites are Maresha, Yavneh-Yam, Jaffa/Yaffo, Mount Gerizim, Dor, Akko and others. Some of the sites contain destruction layers well connected with the conquests of the Hashmonean rulers during the late 2nd and early 1st century BCE.

In the following I will focus mainly on vessel glass from the site of Maresha/Hellenistic Marisa. This yielded a large variety of glass finds from well-dated contexts. This is a preliminary study of the glass finds from Maresha. The complete report will be published by the Israel Antiquities Authority within the series of excavation reports.

Maresha is situated in the southern foothills of Judah (Judea), 40km south-west of Jerusalem. It was a major settlement from the Iron Age, and is mentioned in the Bible as one of the cities of the kingdom of Judah (Joshua 15, 44). During the Persian period it was part of the region of Edom, and in the Hellenistic period it became the capital city of Western Edomea mentioned in the Zenon Papyri (*PCZ* 1, 59006, 59015, 58537). It was a multicultural city with diverse ethnic groups, situated on the border of Edomea and Judea, on a trade route from Arabia to the Mediterranean coast.

John Hyrcanus I destroyed Maresha (*Josephus* Ant. XIII, 257; War I, 63) in the late 2nd century BCE. After its destruction, the site was nearly deserted and its urban character completely altered by the time of the Roman conquest of Palestine in 63 BCE (Kloner 2003, 1–6).

Maresha was partly excavated in the late 19th century by Bliss (Bliss and Macalister 1902, 52–8). The excavation concentrated on the upper Tell and subterranean complexes in the eastern side. A few years later four *loculi* tombs were documented and studied by Peters and Thiersch (1905); two of them were adorned with wall paintings.

During the late 1980s and 1990 the site was extensively excavated by Amos Kloner on behalf of the Israel Antiquities Authority. The site contains levels from the Iron Age to the Byzantine period, but the most prosperous period in the site's existence was definitely the Hellenistic period. The excavations show the site was divided into an upper and lower settlement. The upper settlement contains Iron Age and Hellenistic remains. The Hellenistic level was fortified with walls and inserted towers. The site plan was in a grid form, in order to delimit *insulae* for various functions. The lower settlement was extensively excavated in the renewed excavations. The excavations show it was partly fortified, with upper buildings and numerous subterranean complexes carved in the local soft limestone. The subterranean complexes were used as olive presses, *columbaria* (for dove breeding), water cisterns and other various functions (Kloner 2003, 9–30).

The destruction of the lower settlement is well documented according to the epigraphical, numismatic and stamped amphorae handle finds. Several dated inscriptions and epitaphs were discovered in the tombs at the site. The latest dated funerary inscription was from a burial cave south-west of the Tell, dated to the year 200 of the Seleucid era, corresponding to the year 112/111 BCE (Kloner 1993, 953; 2003, 5–6). In addition, a coin hoard was discovered in a destroyed building in Area 53 of the lower settlement. The latest coin found in it is dated to the year 201 of the Seleucid era, corresponding to the year 113/112 BCE (Barkay 1994). It may also be noted that only four coins of the 1000 found in the lower settlement are dated later than 112 BCE. This evidence, together with additional evidence of a destruction during the second half of the 2nd century BCE in many parts of the excavation of the lower settlement, date the destruction there to the year 112/111 BCE (Kloner 1993, 953; 2003, 5–6). However, another date – 108/107 BCE – has recently been suggested on the basis of an *agoronomos* type lead weight and stamped Rhodian amphora handles found at the site (Finkielsztejn 1998). This destruction, whether dated to the year 112/11 or to the year 108/107 BCE, was probably caused by the conquests of John Hyrcanus I, as attested in Josephus (Barag 1994, 4–5).

THE GLASS VESSELS

The glass vessels presented here were found during the Israel Antiquities Authority excavations, in layers of fill in the upper settlement and, mostly, the subterranean complexes of the lower settlement. The subterranean complexes were not resettled after the destruction and the glass vessels found in them can be securely dated at the latest to the year 112/111 BCE. It should be noted that no Hellenistic glass vessels were documented in the publications of the earlier excavations at the site. Around 200 glass fragments were found at Maresha, prototypes are presented below according to their production techniques.

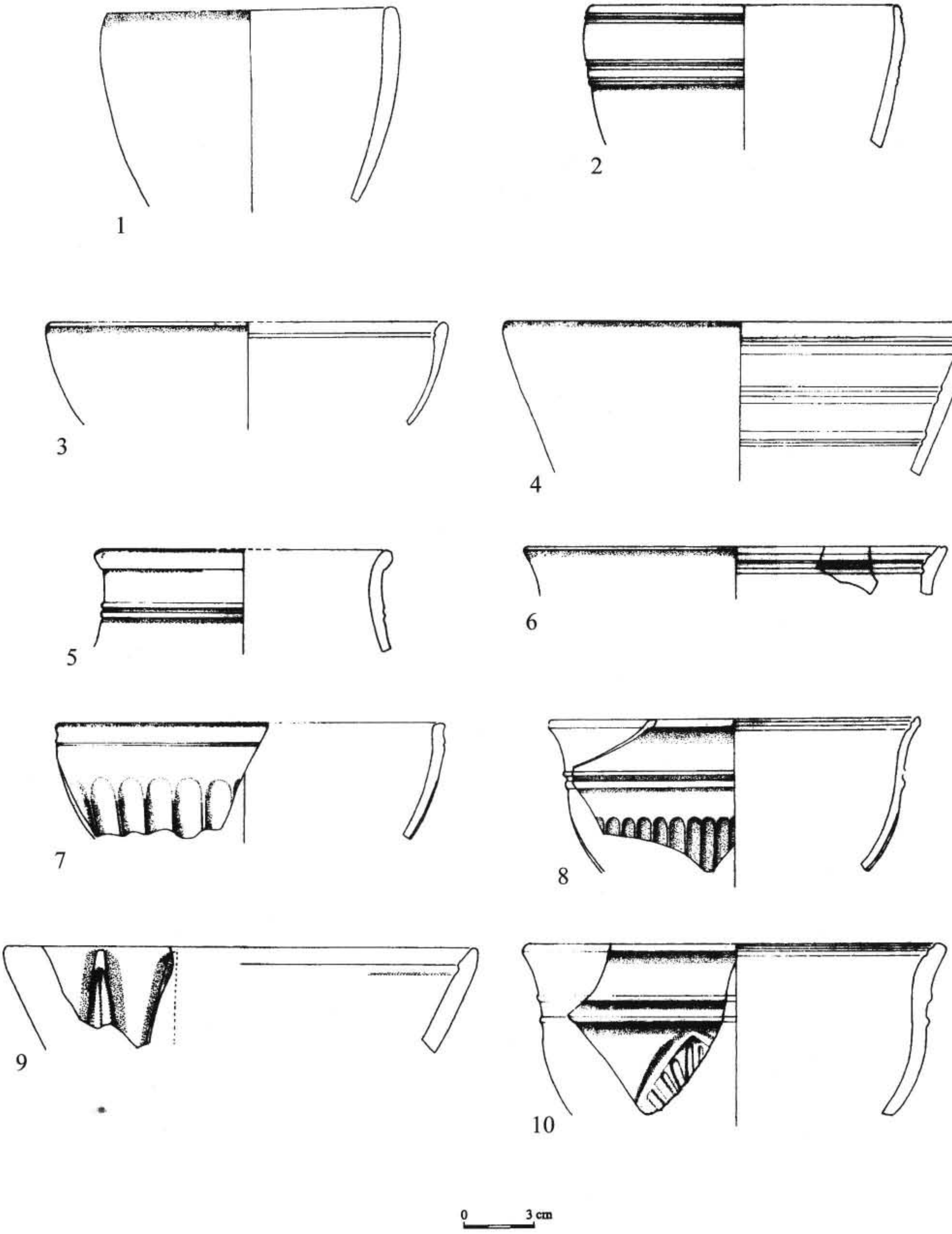

FIG. 1 Cast monochrome bowls

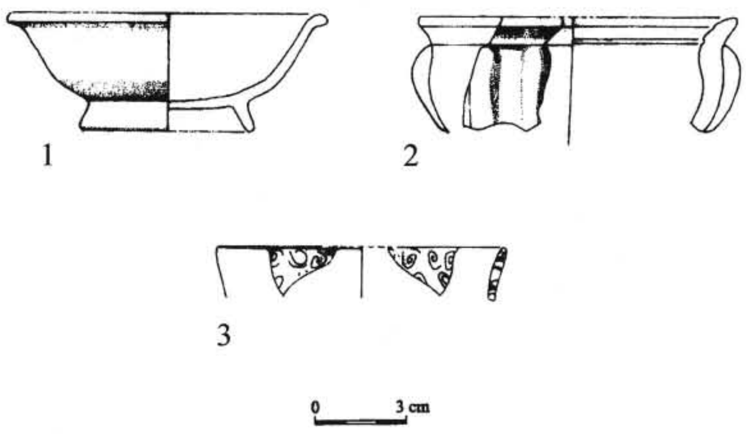

FIG. 2 Bowl with base-ring, cast ribbed bowl, and mosaic bowl

Core-formed vessels

Ten core-formed fragments of the Mediterranean Core-formed Group III vessels were found at Maresha. This group is dated from the 3rd (Harden 1981, 53–4, 122–37) or the mid 2nd (Grose 1989, 122) to the 1st century BCE (see also McClellan 1984, 127–64). The best preserved fragment belongs to an *alabastron* (Jackson-Tal 2004, fig. 2). An *amphoriskos* fragment could be identified among several small unidentified wall fragments. Late Hellenistic vessels of the Mediterranean Core-formed Group III have been discovered in small quantities in excavations in Israel. Complete profiles are rare. The best preserved vessels are *amphoriskoi* found in burial complexes, at Jericho (Hachlili and Killebrew 1999, 134, fig. III.71.1), Tell Qasile (Kaplan 1958, 97, photo and illustration; Jackson-Tal 2004, fig. 4) and Geva (Tell Abu Shuseh; Jackson-Tal 2004, fig. 5). Small fragments attributed to *alabastra*, *amphoriskoi*, *oinochoai*, and *unguentaria* were also found in Israel. Most of the vessels are made of trailed blue, brown or green glass, some with colourless or translucent coloured handles and bases. They were found in contexts ranging from the 3rd to the 1st century BCE (Jackson-Tal 2004, 15–16).

Sagged/cast bowls

Sagged monochrome bowls, ovoid, conical or hemispherical, are the predominant glass vessels of the Late Hellenistic period (Grose 1989, 193–4). Many different types of sagged bowls were found at Maresha, including plain ones with no particular ornamentation (FIG. 1.1). Bowls with horizontal grooves (FIG. 1.2–5), horizontal ridges polished in a bead pattern (FIG. 1.6), flutes (FIG. 1.7–8) and vegetal design (FIG. 1.9–10) were also found. Two bowls with a base-ring were found, one almost complete with a flaring rounded rim (FIG. 2.1). A single example of a ribbed bowl, probably of an early type (with thick crude spaced ribs) was also found (FIG. 2.2). The finds at Maresha reflect the general typological trend throughout the country. The most common type are the grooved bowls, while all other types are significantly less frequent (TABLE 1). The majority of bowls are colourless and greenish with fewer examples in yellowish-green, bluish green and yellowish brown (TABLE 1). The bowls were found in contexts ranging from the 3rd to the 1st century BCE, but the majority in 2nd to 1st century BCE contexts (Jackson-Tal 2004, 22–4). Most of the bowls found at Maresha were classified in Grose's Syro-Palestinian typology (Grose 1979), but the beaded and vegetal-decorated bowls are a new addition for the state of glass research in Israel. These types are nevertheless well known from Delos and other sites (Nenna 1999, 94–7, figs 29–30, nos C241–C256; 89–90, pl. 26, nos C210–C215).

Mosaic vessels

Small numbers of Late Hellenistic polychrome mosaic bowls and inlays have been found in Israel, but they are well known during the Late Hellenistic period (Grose 1989, 189–93). Only four small fragments of polychrome mosaic vessels were found at Maresha – two hemispherical bowl fragments (FIG. 2.3) and two wall fragments of bowls or inlays. They are made of green, colourless, blue, and greenish glass and are ornamented with yellowish spirals, sometimes with a brown centre. When the contexts are clear they occur in the 3rd and 2nd century BCE (Jackson-Tal 2004, 24–5).

TABLE 1 DIVISION BY COLOUR AND TYPE OF MONOCHROME CAST VESSELS (RIMS ONLY)

Type	**Colourless**	**Greenish**	**Yellow-green**	**Blue-green**	**Bluish**	**Yellow-brown**	**Purple**	**Total (no./%)**
Grooved	98	45	26	1	2	12	3	188 (90%)
Fluted	4	1	1	1	–	–	–	7 (3%)
Vegetal	1	1	–	–	–	–	–	2 (1%)
Ring-Base	2	–	–	–	–	–	–	2 (1%)
Ribbed	1	–	–	–	–	–	–	1 (>1%)
Total (no./%)	106 (50%)	47 (22%)	27 (12%)	2 (1%)	2 (1%)	12 (6%)	3 (1%)	199

Gold-glass vessels

A tiny fragment of blue and colourless glass, with a gold-leaf design sandwiched between the layers, was a stray find at Maresha, and will be published by Yael Israeli. A complete blue and colourless bowl, decorated with geometric and vegetal gold designs, was purchased in Jerusalem at the beginning of the 20th century. It was published as part of the Rothschild collection (Wuilleumier 1930, 29–30, pls 11–12). This bowl appeared in the antiquities market immediately after the discovery of Tomb I of the eastern necropolis at Maresha, which led Dan Barag to suggest it may have originated in this very tomb (D. Barag pers. comm; see also Barag 1973, 46–7). He bases this on the following account by Peters:

> 'It was early in June, 1902, when we heard in Jerusalem that there was much illicit excavating for antiquities in the neighborhood of Beit Jibrin, and especially that in a tomb at that place some notable 'finds' had recently been made, for which dealers had paid £50 on the spot' (Peters and Thirsche 1905, 1).

Summary

The glass finds from Maresha are an important contribution to Late Hellenistic glass research in Israel. The variety of the finds and especially their *ad quem* dating to the year 112/111 BCE makes them an excellent chronological tool. The glass vessels are mostly connected to the occupational level of the dated destruction layer. However, ethnographical studies show that equally fragmented vessels, such as cooking pots, are mostly preserved for no more than a few years (Tani and Longacre 1999, 305–7). If we apply such observations to our finds, while taking into consideration their probable less frequent use and gentler handling, we can conclude that the sagged bowls at Maresha were used for no more than one generation, namely from the mid 2nd century BCE. The variety and quantity of types can only be compared in Israel to the numerous finds from Tel Anafa (Weinberg 1970). However the two sites are very different in character. While Maresha is an urban settlement, the remains at Tel Anafa of the Late Hellenistic period are of a single large building, probably a palace according to its size, lavish decoration and luxury finds (Herbert 1994, 14–19). The building is dated *c*. 125–80 BCE according to the numismatic and stamped amphora handle evidence (*ibid*, 14). This date partially corresponds to the destruction date of the lower settlement at Maresha.

In the absence of archaeological evidence for the existence of a glass industry at Maresha, it is reasonable to assume that the glass vessels were brought to the site through commerce, rather than being produced there. However, the quality, type variety, homogeneity and quantity of the sagged glass bowls from Maresha, and data from other sites in Israel – especially those at Tel Anafa – support the assumption that there was a glass manufacturing centre on the northern coast of Palestine in the Late Hellenistic period. Presumably, despite the abundance of finds in Israel, there were manufacturing centres in several parts of the Eastern Mediterranean basin at the time, but one of the centres, if not the most important one, was probably on the Phoenician coast. This centre may have been producing Mediterranean Core-formed Group III vessels as well, as indicated by the use of translucent handles and bases. However the smaller numbers of core-formed vessels, polychrome glass vessels (mosaic and gold-glass) indicate they were probably imported from outside the country, perhaps from Rhodes and Alexandria.

During the Late Hellenistic period, a drastic change in the method of manufacturing glass vessels occurred: a shift to simpler, quicker methods using former moulds and a simple style of ornamentation that consisted mainly of horizontal grooves. Quite likely, the change was prompted not only by a simplification of the work process but also by the discovery of a way of making the raw material cheaper (Barag 1985, 59–60). The result was a dramatic increase in the affordability of glass vessels, which had previously been a luxury available only to the higher classes. The fairly uniform distribution of glass vessels in the various excavation areas in the lower settlement at Maresha reinforces this argument, since it is difficult to assume that all parts of the lower settlement served equal socio-economic classes.

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WHAT DID JERUSALEM'S FIRST-CENTURY BCE GLASS WORKSHOP PRODUCE?

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The assemblage of glass fragments discussed here was uncovered in the Old City of Jerusalem, in the centre of the Jewish Quarter, which in the Early Roman period was a well-to-do neighbourhood called the 'Upper City' (Avigad 1983, 186–92). The excavations, which took place in the early 1970s, were directed by Professor Nahman Avigad on behalf of the Institute of Archaeology of the Hebrew University of Jerusalem.

The assemblage was found in a disused ritual bath (*miqvah*) that was intentionally filled with refuse. The bath was sealed by a road built during the reign of King Herod (37–4 BCE), or shortly thereafter. The pottery and the many coins found in the debris date the filling of the ritual bath to the first half or middle of the 1st century BCE.

Several hundred glass fragments were found concentrated in a layer of the fill, which consisted mainly of organic matter. Professor Avigad assumed that the glass assemblage was manufacturing waste from a nearby workshop, that had been dumped into the ritual bath after it had gone out of use. Indeed, careful sorting of the material showed remarkable homogeneity of all the finds, which seem to originate from a single location.

The finds can be grouped as follows: mould-made bowls, applicators or stirring rods, tiny blown bottles, inlays, whorls and gaming pieces, and flat glass sheets. Much of the material consists of manufacturing waste, the exact character of which is hard to ascertain. This assemblage from Jerusalem attests to the existence of a Hellenistic workshop. This is a significant addition to the few such known ones (Weinberg 1971; Nenna 1999, 159–68). The fragments provide evidence for three glassworking techniques – casting, blowing and tooling – all presumably in one workshop. Some of the products such as the cast bowls are quite common; others are very rare or even unique. The most important feature of the assemblage is the evidence it provides for the blowing of glass vessels from glass tubes, found here for the first time. This evidence may explain how glassblowing was discovered – the wondrous technique that made glass one of the most common materials.

SAGGED (SLUMPED) BOWLS

The group of bowls includes 120–30 items, mostly conical bowls and hemispheric ones with grooves inside, and a few more elaborate types. All are well known from the repertoire of sagged bowls in Hellenistic sites throughout the Eastern Mediterranean (Grose 1989, 193–4). However, in contrast to other large assemblages, in Jerusalem there were only a few fragments of fluted bowls and of bowls decorated with cut leaves. Only one tiny fragment of a ribbed bowl was found. Many base fragments survived, almost all showing remains of superficially abraded circles on the outside, most of them with tiny circles in the centre. Apparently, the majority of the bowls had such marks which may have resulted from the pressure of the stand on which the bowl was held while being polished or engraved. It is hard to single out manufacturing waste of the bowls: some fragments are deformed, but this could be due to damage caused by excessive heat, after the object had been finished.

Most of the bowls are colourless, sometimes with a yellow or greenish-bluish tinge, several are greenish of various hues, and a few are of the strong yellow-brown (amber) colour. Comparisons with the groups of Hellenistic cast bowls found in the Eastern Mediterranean as at Delos (Nenna 1999, 66–7) and Anafa (Weinberg 1970, 19–21) are limited because of the small number of fragments from the Jerusalem workshop. Still the relation between the types – the number of conical bowls exceeding that of the hemispherical ones – is the same in these three sites, whereas the proportions of the colours is different. In Anafa and Delos strongly coloured bowls dominate, while in the Jerusalem workshop the colourless are the absolute majority. The group of bowls found in the Souks of Beirut comprises more hemispherical than conical bowls (Jennings 2000, 45).

APPLICATORS OR STIRRING RODS

Two types of objects belong to this group: a) smooth rods with both ends rounded (FIG. 1); b) twisted rods with one edge rounded and the other pointed (FIG. 2). Of the first type, a few were found complete – their length varies from 95 to 145mm; one is purple, and all the others are colourless. The total length of the many fragments of smooth rods, 40mm long and more, is about 30m. Published examples of this type of rods are rare (Ariel 1990, 159, fig. 31.GL60; Spaer 2001, 264 no. 236, pl. 49).

No twisted rod was found complete. There were many fragments with rounded ends and a few with pointed ones. Their length when complete was probably similar to that of the smooth rods. The fragments preserved are up to 90mm long. The total length of the twisted rods fragments may be more than 5m. Most of the twisted fragments are

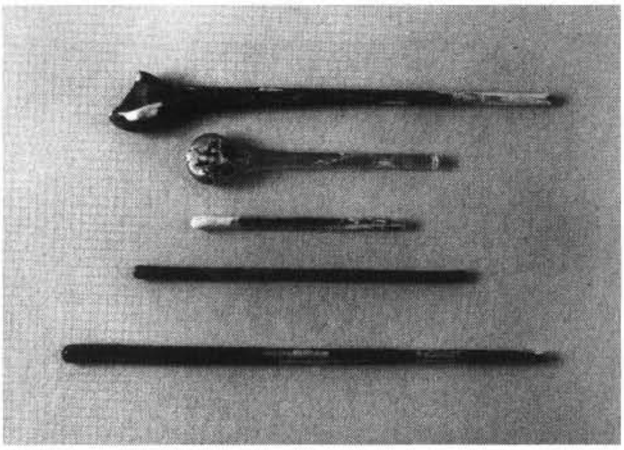

FIG. 1 Smooth rods and manufacturing waste

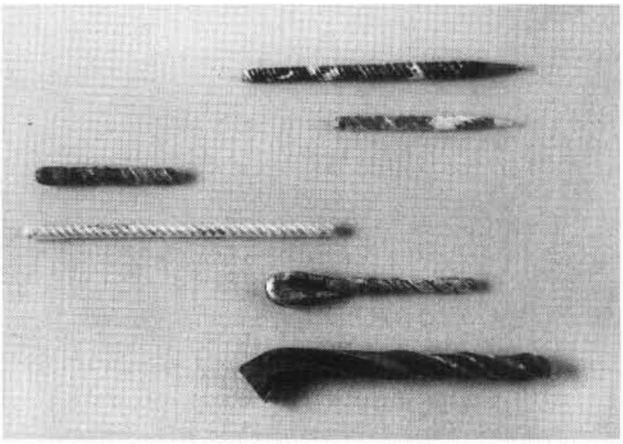

FIG. 2 Fragments of twisted rods and manufacturing waste

colourless, but there is also one purple, one brown, one yellow, and two blue ones, and several of two colours, with a white thread wound around the colourless rod. The remains of production stages are easy to identify – ends of rods with the impressions of the tongs by which they were held, pulled and twisted. The twisted rods seem to be of an earlier type than the known Roman ones, with one end formed like a flattened disc and the other decorated with an attached bird or a tiny jar, or shaped like a ring (Spaer 2001, 262, pl. 49.631–2).

BLOWN BOTTLES (FIG. 3)

The most important and unique finds in the Jerusalem workshop were the remains of glassblowing that suggested that glass was blown directly from glass tubes – most likely an early stage of glassblowing (proto-blowing) before the use of a metal blow-pipe. A preliminary description of the remains of tube blowing in the workshop was published a few years ago (Israeli 1991). Strips of glass were folded to form glass tubes; these were then drawn, having a squeezed shape at their ends and becoming rounder further from the edges. After trimming of its ends, the tube was pressed closed on one end, and inflated to the shape of a small bulb which formed the oval body of the bottle. Part of the tube above the bulb formed the neck of the bottle, and the

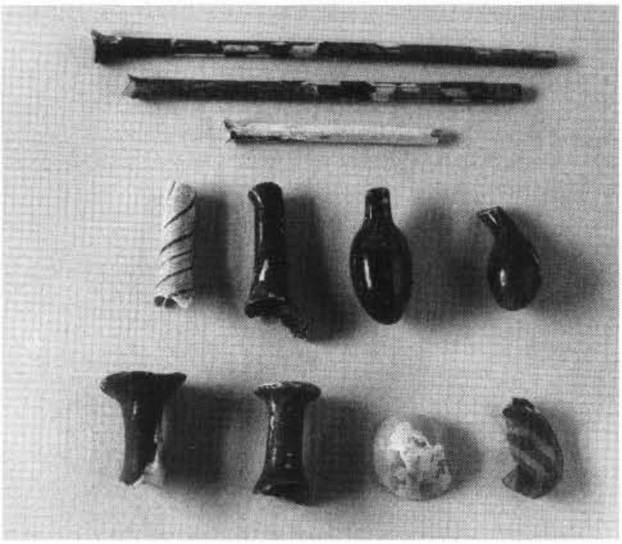

FIG. 3 Remains of blown bottles and discarded material of tube-blowing

rim was shaped and out-turned at the top of the neck. Wasters from all the production stages were found in the assemblage, leaving no doubt that they were locally produced. One bottle, of yellowish glass with wound white thread, was found entire but collapsed (FIG. 4). Altogether ten necks with finished rims were found, these being the last parts to be shaped in the formation sequence of the vessel; they may be considered parts of finished bottles. The colours are hard to define because of the heavy weathering, but it seems that about half of the bottles had wound threads in contrasting colours.

Fragments of tubes, the raw material for the blowing process in the Jerusalem workshop, were found in various sizes and in considerable number. Many are very thin, probably the end parts of the drawing operation. They seem

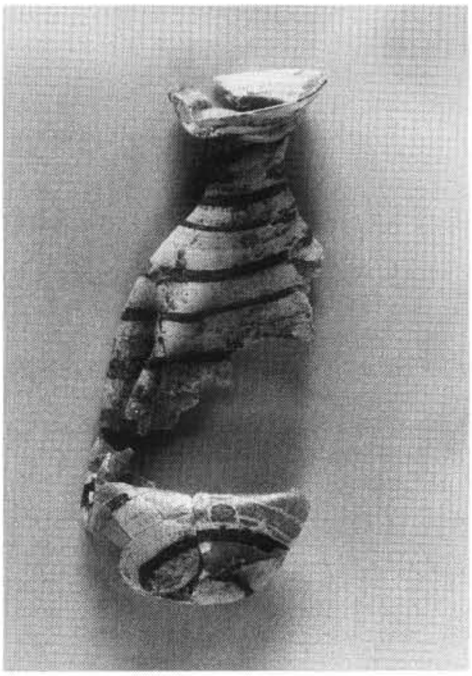

FIG. 4 A finished bottle that sagged after production

to have been made mostly from colourless glass and naturally coloured glass, but the blue and the yellow brown seem to be more in evidence among the tubes than in the other groups. Conceivably all the tubes from the workshop were prepared for the production of blown bottles. To the best of my knowledge, no other occurrence of glass tube-blowing is known from that period (Whitehouse 1997, 142, no. 236; Crowfoot 1957, 420).

WHORLS, BEADS, INLAYS AND GAME-PIECES (FIG. 5)

This group consists of several artefacts, all made by tooling or moulding. Their functions are not always clear; similar ones have been found in excavations, and a few unprovenanced ones exist in collections. Very few examples of each were found, including: ten colourless and greenish whorls – 15 to 40mm in diameter (Nenna 1999, 135–6, pl. 55.E115–E121); seven small flat beads of indeterminate colour, some probably white 10 to 27mm in diameter (Nenna 1999, 135, pl. 55.E110–E114); six flat inlay pieces – triangular, rhomboid, and round plaques are of opaque white and light blue glass in addition to transparent or translucent colourless glass (Weinberg 1971, pl. 80c; Nenna 1999, 154, pl. 55.E271; Christie's 1999, lot 243). In this context we may consider the possibility of using fragments of twisted rods as inlays, like the wall pavement from Rome in the Corning Museum Collection (Goldstein 1979, 263–4, no. 791, pl. 35). Other inlays for jewellery or game-pieces are round to oval, convex in section. These simple objects are very common and have been found in hundreds in excavations, but only eight were found in the Jerusalem workshop. Most are colourless, one is greenish, and one yellow (e.g. Crowfoot 1957, 392, fig. 92.86–7; Weinberg 1971, pl. 80b; Ariel 1990, 157, fig. 31.GL37–GL40; Spaer 2001, 233, pl. 41:548). Seven conical pieces, 15–10mm high and 8–13mm in diameter, some with a vertical hole, could also be parts of jewellery or game pieces. Three puzzling objects – 40mm high thick rectangles with a rounded top and a large hole – may be weights of some sort. One is bluish-green and two are yellow.

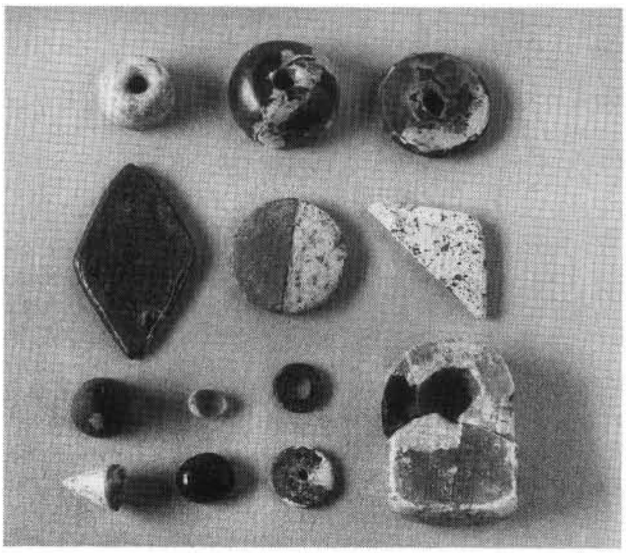

FIG. 5 Whorls, inlays, beads(?), etc

Identifiable wasters(?) of this group are a few inlays fused together, and perhaps some of the flat and composite strips.

FLAT SHEETS (FIG. 6, right)

Few colourless flat fragments were found, the largest 100mm long. Some have straight edges and rounded corners, which may indicate that the complete panes were rectangular. Could they have been used as window panes? Or they may have been used as inlays. Gladys Weinberg in her article on the Rhodes bead workshop suggested that the flat fragments were intended to be sagged to make bowls (Weinberg 1971, 147–8).

PRODUCTION WASTE AND RAW MATERIAL (FIG. 6)

Only a few fragments look like splinters from chunks of raw glass. More seem to be wasters from the manipulation of the glass during manufacture – drops, small lumps drippings, etc.

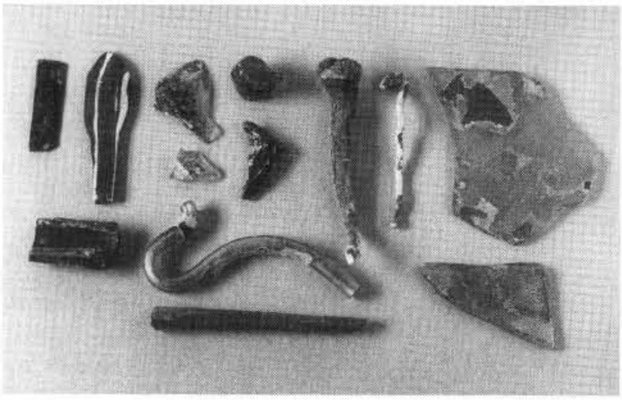

FIG. 6 Flat plaques, splinters of raw glass, and wasters

THE COLOURS OF THE GLASS (COLOUR PLATE 13)

The glass from the Jerusalem workshop is heavily corroded and covered with a thick weathering crust; the thickness of the glass, therefore, could not be measured. Sometimes the glass itself is no more, and the weathered layer is all that has kept the shape of the artefact. Because of the weathering it is hard to determine the colours, but it seems that most of the usual colours common in glass of the Hellenistic period are represented in the lot. As mentioned above, most of the glass is colourless, sometimes with greenish, bluish or yellowish tinges. Light hues of yellow, green and blue exist as well. The strong colours are yellow brown (amber), blue, and purple. All these are transparent or translucent. A few opaque red, white and light blue glass pieces are also extant, but in small quantities.

To date, some 40 samples have been analysed by energy dispersive X-ray analysis in the scanning electron microscope (SEM–EDXA), all of them proved to be of the typical soda-lime-silica type (preliminary unpublished report). According to Dr Ian Freestone, the *yellow brown* is due to a complex of iron and sulphur (ferro-sulphide chromophore), which is formed in the glassmaking furnace under highly reduced conditions and is a natural colour of the glass. This may explain the frequent occurrence of yellow-brown glass in Late Hellenistic bowls. The *colourless* glass was obtained by adding manganese oxide to the batch. The *purple* glass was obtained by the manganese in oxidized conditions, either intentionally or by chance. The *blue* was obtained by adding cobalt. According to Dr Freestone, these colours form fairly tight groupings and probably correspond to single batches of glass or campaigns of melting.

Some of the major elements divide the material into two groups, differing in their lime and alumina content. The two groups also differ in chlorine content. This implies that they were made from different sands and alkali and under different conditions – either the glass was created by two separate firings of the furnace, with raw materials brought from different sources, or it came from different workshops of raw glass production. Comparison of alumina content in colourless bowls with other colourless artefacts shows that different batches were used for making them. In the yellow-brown group, on the other hand, the bowl (only one was analyzed) and the other products seem to have been made from the same batch.

To sum up, in Ian Freestone's words:

> In general, the workshop waste and working pieces are of the same composition as the objects. The different colours are not widely separated, but occur in the same general groupings, which seem to indicate that the transparent colours were made in this workshop by adding manganese and/or cobalt' (I. Freestone pers. comm.)

The tight groupings of the colours also show that only a limited number of glass batches were used in the workshop, suggesting a short period of production.

In conclusion, at this stage it seems that the products mentioned were locally manufactured in the Jerusalem workshop. Future research may provide fuller understanding of the remains, and offer more insights into the character of secondary glass workshops in the late Hellenistic period.

Acknowledgements

I am grateful to Hillel Geva, who is responsible for the publication of the excavation results, for letting me work on the finds. The research is still in its early stage, and the conclusions presented here should be considered preliminary. The final report will be published in the series *Jewish Quarter Excavations in the Old City of Jerusalem conducted by Nahman Avigad, 1969–1982*, issued by the Israel Exploration Society and the Institute of Archaeology, Hebrew University of Jerusalem. (The first and second volumes appeared in 2000 and 2003.)

The processing of the finds was done in collaboration with Natalya Katsnelson, Associate Curator in charge of the ancient glass collection in the Israel Museum, Jerusalem. The photographs were prepared by Peter Lanyi, FIG. 4 was taken by Mariana Salzberger.

Dr Ian Freestone, then Deputy Keeper of the Department of Conservation and Science in the British Museum, kindly agreed to conduct the scientific analyses and interpretation of the material.

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THE IMPERIAL ROMAN WORLD – GLASS MANUFACTURE AND COMPOSITIONS

ATELIERS PRIMAIRES DU WADI NATRUN: NOUVELLES DÉCOUVERTES

MARIE-DOMINIQUE NENNA, MAURICE PICON, VALÉRIE THIRION-MERLE ET MICHÈLE VICHY

Depuis 1996, nous avons mené des prospections en Égypte à la recherche d'ateliers primaires de verriers (Nenna *et al.* 1997; Nenna *et al.* 2000). Ces recherches se sont concentrées sur la Maréotide, voisine d'Alexandrie, et sur le Wadi Natrun (FIG. 1). Dans la région, située à l'ouest d'Alexandrie, des vestiges d'ateliers primaires ont été identifiés dans les ports lacustres de Taposiris Magna et de Maréa-Philoxénité (Nenna *et al.* 2000, 102–4). Dans les deux cas, les briques qui constituaient le sol du four portent encore les traces de concassage de la dalle de verre et on peut supposer, au vu de la quantité de briques et de vestiges de four épars sur le site ou bien remployés dans des fondations de bâtiments, qu'il s'agissait de fours appartenant au même modèle technologique que celui mis en évidence à Bet Eli'ezer par Y. Gorin-Rosen (2000). L'activité de ces ateliers primaires semble devoir être située à l'époque romaine tardive, la station de pèlerinage de Maréa-Philoxénité est occupée entre le V^{e} et le début du VIII^{e} siècle apr. J.-C.; à Taposiris, les déchets de fours sont reliés à la phase d'utilisation romaine tardive du port.

À l'Est d'Alexandrie, le site de Barnughi, l'ancienne Nitrie, situé au Sud de Damanhour sur un canal qui menait dans l'Antiquité de Naucratis à Alexandrie par le lac Mariout a retenu notre attention (De Cosson 1936). La présence d'un lac où le natron était recueilli aussi bien dans l'Antiquité qu'à l'époque médiévale (Décobert 2003) et peut encore l'être aujourd'hui, pouvait constituer une clé possible de l'implantation d'ateliers de verriers. De surcroît, l'équipe américaine qui y avait prospecté à la fin des années 1970 avait relevé la présence de 'glass slags' et de creusets, mais aussi de 'metal slags', et en avait déduit la présence d'un quartier artisanal (Coulson et Leonard 1979, 163, fig. 19 et 21). Le site est aujourd'hui malheureusement encore plus dévasté qu'il y a une vingtaine d'années et nous n'avons reconnu aucun vestige de ce type dans l'ensemble des zones prospectées, aujourd'hui mises en culture ; en outre, le lac est devenu le dépotoir de la ville de Damanhour.

L'EMPLACEMENT DES ATELIERS DU WADI NATRUN

Trois sites d'ateliers primaires ont été reconnus dans le

FIG. 1 Carte des sites mentionnés dans le texte

Wadi Natrun, cette dépression située entre le Caire et Alexandrie, qui comprend une série de lacs exploités depuis la plus haute Antiquité pour le sel et le natron (Shortland sous presse).

Le site de Zakik était déjà connu par les Savants de la *Description de l'Égypte et a été visité par l'égyptologue ang*lais Wilkinson en 1823 (Nenna *et al.* 2000, 100–2). Les résultats de la prospection géophysique que nous y avons menée en septembre 2002 ont été négatifs: de fait, aucune structure témoignant de magnétisme rémanent n'a pu être reconnue en raison de l'occupation de ce site au début du XIX^{e} siècle par un village d'ouvriers du natron et donc de la destruction des couches de surface de l'atelier. La prospection céramologique systématique qui sera menée à l'automne 2004 devrait néanmoins permettre de mieux dater les différentes phases d'activité de ce site. Notons déjà que les céramiques les plus anciennes recueillies sur le site datent du IV^{e} av. J.-C.

L'atelier de Bir Hooker (FIG. 2), découvert en avril 2002, se trouve à 2,5 km au sud du village de Wadi Natrun (Thirion-Merle *et al.* 2003). Il est installé au pied d'une butte témoin, à peu de distance de la route conduisant aux monastères. La récente exploitation en carrière du sable de la butte témoin, a très fortement endommagé l'atelier au point qu'il est impossible de se rendre compte de son

FIG. 2 Vue de l'atelier de Bir Hooker

extension initiale. En outre, la plupart des structures semblent avoir été profondément bouleversées. On trouve, épars, des parois et des fonds de 'bassins' recouverts d'une couche de verre, des matériaux céramiques plus ou moins fondus, des fragments de verre brut, etc. Une première prospection céramologique a indiqué que les céramiques recueillies sur le site sont datées entre le IIIe siècle av. J.-C. et la fin du IIe siècle apr. J.-C. Une prospection géophysique sera menée en janvier 2004 sur ce site.

La prospection géophysique effectuée sur le site de Beni Salama en 2000 et 2002 a fourni des résultats intéressants (Nenna *et al.* 2000, 99–100; Nenna 2001, 34). Cinq structures à fort magnétisme rémanent y ont été identifiées. Une première campagne de fouilles a été menée à l'automne 2003, à l'emplacement de l'anomalie magnétique la plus significative. La fouille en extension sur plus de 250m^2 nous a permis de mettre au jour la dernière phase d'activité de ce site qui se situe dans les trois premiers siècles de notre ère. Un ensemble de structures chauffées en relation avec la production de verre brut a été mis en évidence ainsi que les sols, constitués de couches de natron, de sulfate de sodium et de sel liées à cette activité. La fouille s'est révélée assez difficile, il a fallu d'un côté mener des nettoyages très délicats sur les briques des fours, très mal conservées en surface; de l'autre la couche de natron qui recouvre l'ensemble du terrain a en quelque sorte fossilisé les assises inférieures des fours et est extrêmement difficile à briser avec les seules forces humaines. En un point ouvert par des pillards, il nous a été possible de constater que cette couche de natron avait scellé et extrêmement bien protégé les couches antérieures, témoin en est un mur en briques crues fort bien conservé sur au moins cinq assises. La prospection céramologique, menée sur le site d'habitat voisin a permis de reconnaître les différents phases d'occupation du site du Moyen Empire jusqu'au début du VIIe siècle apr. J.-C.

Ces trois sites se trouvent à l'extrémité des pistes qui reliaient le Wadi Natrun à Térénouthis, principal entrepôt et site de réexpédition du natron sur le Nil. La piste méridionale menait à Beni Salama, tandis que la piste la plus au nord conduisait à Zakik. L'atelier de Bir Hooker était sur la troisième de ces pistes, entre les deux précédentes. Des indices d'un atelier antique avaient déjà été repérés sur cette piste médiane, juste avant la traversée des lacs, en venant de Térénouthis. Mais les destructions provoquées par l'implantation au XIXe siècle de l'usine de la Salt and Soda Company ne permettaient pas d'être affirmatif (Nenna e*t al.*, 2000, 102). La proximité d'une butte témoin, de nature sableuse, semble une caractéristique commune à ces trois ateliers, tout comme la proximité des lacs. Aucun vestige d'atelier secondaire n'a été repéré sur ces sites, malgré ce que nous avons écrit (Nenna *et al.* 2000, 102), de fait les fils et les coulures de verre que nous y avions repérés doivent être mises en relation avec la fabrication primaire du verre. La datation de ces trois ateliers doit être affinée par de nouvelles prospections céramologiques et par la fouille, mais il semble d'ores et déjà certain qu'ils ont fonctionné entre le Ier et le IIIe siècle apr. J.-C.

LES TECHNIQUES DES ATELIERS DU WADI NATRUN

L'observation des éléments de fours, visibles en prospection notamment sur le site de Bir Hooker, ou recueillis en fouille sur le site de Beni Salama, bien qu'ils soient très fragmentaires et déplacés, permet d'affirmer que la technique de fabrication du verre brut n'est pas celle des ateliers de Maréotide, elle-même très proche de celle que les ateliers palestiniens d'époque tardive nous ont fait connaître. Il n'y a en effet aucun indice permettant de supposer l'existence de dalles de verre épaisses, élaborées et refroidies dans le bassin du four, sans coulée, puis débitées en blocs de verre brut. On observe au contraire des traces évidentes de coulées du verre, absentes en Maréotide, mais repérées dans le matériel de certaines épaves comme celle des Sanguinaires A datée du IIIe siècle av. J.-C. (Foy et Nenna 2001, 102, fig. p. 24). La surface de la couche de verre (FIG. 3) qui subsiste dans le fond des 'bassins' est lisse et ne présente aucune des traces d'arrachement, systématiquement présentes en Maréotide. En coupe, la masse de verre présente plusieurs couches qui pourraient correspondre à l'emploi successif des bassins. Ces 'bassins-creusets' ne sont pas construits en briques comme en Maréotide, mais modelés en argile, et, semble-t-il, de bien plus petite taille. En examinant attentivement cette couche lisse de verre, on aperçoit quelquefois des lignes d'écoulement qui pourrait correspondre au vidage de la partie supérieure du 'bassin', par un trou de coulée ouvert dans la paroi verticale, à peu de centimètres au-dessus du fond du 'bassin'. Les gouttes et traînées de verre attachées à cette paroi verticale, au-dessus de la couche lisse du fond, témoigneraient, elles aussi, de cette opération de vidage du 'bassin' par un trou de coulée.

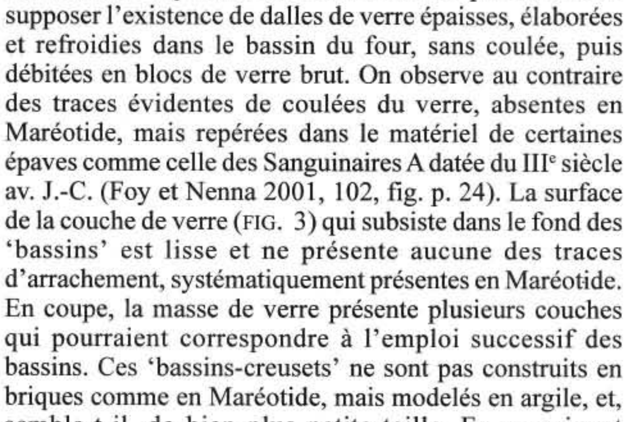

FIG. 3 Bir Hooker: fond de 'bassin' vue de la face supérieure, de la face latérale et de la face inférieure

La forme exacte de ces bassins est inconnue; aucun vestige n'a pu en être identifié dans nos travaux de prospection ou de fouille. La reconstitution de la technique proposée par Saleh *et al.* (1972, 145–8) à partir d'éléments de 'bassin', recueillis sur le site de Beni Salama est irrecevable. En effet, les deux étapes de frittage et de fusion ne semblent pas pouvoir être reconnues à partir des vestiges épars sur le site et les auteurs ont en fait suivi là l'interprétation commune aussi bien des Anciens que des Modernes dans les années 1960 (Picon 2001, 23). Les petits bassins–creusets analysés ne contiennent probablement que la matière vitreuse laissée au rebut et n'étaient donc certainement pas destinés au transport. Enfin, les analyses effectuées sur la matière vitreuse ne peuvent être prises en compte pour permettre de définir les compositions de verre fabriquées au Wadi Natrun, car les pollutions dues au contact entre le matériel céramique et le mélange vitreux sont trop importantes. Nous avons de fait analysé trois fonds de bassin recueillis à Bir Hooker, en effectuant des prélèvements par strate pour deux d'entre eux. Les compositions s'éloignent fortement de celles des verres bruts, par des taux plus élevés de calcium, d'aluminium, de fer, de titane, de potassium et de magnésium et inversement par des teneurs très faibles en sodium. On remarque en outre que, plus on se rapproche du matériel céramique, plus ces caractéristiques s'accentuent.

Ces bassins devaient être chauffés par le haut, par réverbération de la chaleur. Si l'on peut imaginer selon le modèle métallurgique le percement de la paroi du bassin pour faire couler le verre, dans quoi était-il coulé et un concassage s'effectuait-il par la suite? Comment les bassins étaient-ils placés à l'intérieur du four et quelle forme avait ce four? Autant de questions qui restent irrésolues pour l'instant.

Les compositions du Wadi Natrun

À la suite de la découverte de l'atelier de Bir Hooker, de nouvelles analyses ont été faites sur le matériel des ateliers de Beni Salama et de Zakik; elles ont permis d'améliorer notablement la classification des verres du Wadi Natrun, ainsi que la caractérisation des sables employés dans les ateliers. Les analyses de 54 exemplaires ont été retenues pour la classification: 23 de Beni Salama, 10 de Bir Hooker et 21 de Zakik. La classification des 54 exemplaires a été faite par analyse de grappes, en affinité moyenne non pondérée, sur variables centrées réduites relatives aux 8 constituants suivants: sodium Na, Potassium K, Magnésium Mg, Calcium Ca, Aluminium Al, Fer Fe, Silicium Si, Titane Ti. Ainsi a-t-on privilégié, dans la classification, les constituants qui ont, pour les sables, une signification géochimique, et a-t-on évité de faire intervenir des constituants comme le manganèse, Mn, l'antimoine, Sb, ou le plomb, Pb, qui ont souvent une signification technique évidente. On a néanmoins conservé le sodium, Na, dont les fluctuations sont faibles.

Le résultat de la classification est représenté par le dendrogramme de la FIG. 4. On y a distingué 6 groupes de composition, de wna jusqu'à wnf, et quelques exemplaires isolés. Les compositions moyennes et les écarts-types des 6 groupes sont reportés sur le TABLEAU 1; pour le groupe wnd, seule figure la moyenne, l'effectif étant par trop restreint. On note tout d'abord que l'importance relative de chacun des groupes, dans l'échantillonnage analysé, n'a certainement pas grand chose à voir avec son importance effective dans la production du Wadi Natrun. Les groupes résultent en effet d'une double sélection, celle des échantillons visibles à la surface des dépotoirs, et celle des exemplaires retenus pour l'analyse: on a de fait cherché à rééquilibrer l'effectif des groupes de composition, afin d'en faciliter la classification.

Sur les compositions des groupes, on fera quelques remarques. Il faut signaler d'abord que les pourcentages d'oxyde de manganèse, MnO, et ceux d'antimoine, Sb, du groupe wna pourraient et devraient être calculés différemment. En effet, les échantillons de ce groupe, en provenance de Zakik, sont décolorés par le manganèse, alors que ceux de Bir Hooker le sont par l'antimoine. Si l'on avait séparé les exemplaires du groupe wna selon leur origine, on aurait obtenu des taux de manganèse MnO et des taux d'antimoine Sb respectivement égaux à 1.15% et 18ppm pour Zakik, contre 0.00% et 6518ppm pour Bir Hooker. On remarque d'autre part que l'on trouve des verres recueillis sur les trois sites d'ateliers dans un même groupe. Il ne faut pas y voir nécessairement des transports de sables, mais, plus vraisemblablement, la présence, à proximité des ateliers, de niveaux sableux possédant des

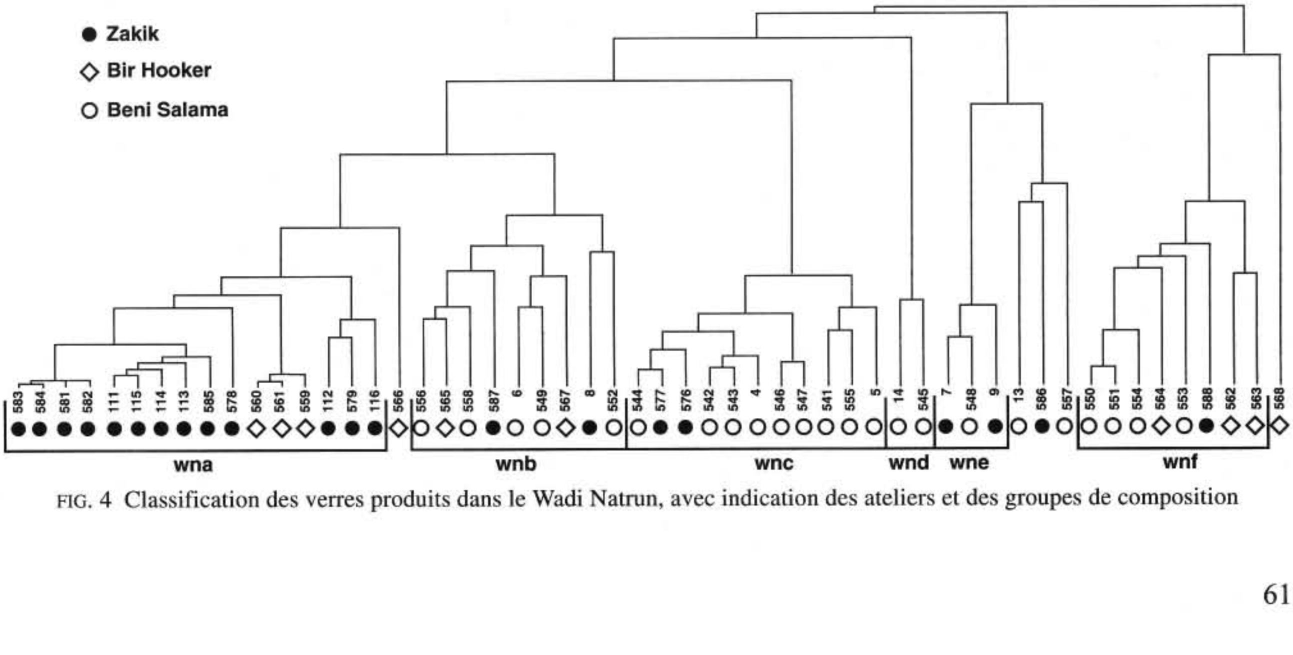

FIG. 4 Classification des verres produits dans le Wadi Natrun, avec indication des ateliers et des groupes de composition

Tableau 1 Moyennes, écarts-types et effectifs des 6 groupes de composition actuellement répertoriés au Wadi Natrun

		CaO	Fe_2O_3	TiO_2	K_2O	SiO_2	Al_2O_3	MgO	P_2O_5	Zr	Na_2O	MnO	Pb	Sb
		%	%	%	%	%	%	%	%	ppm	%	%	ppm	ppm
wna	**m**	1.87	0.88	0.24	0.47	66.16	2.33	0.71	0.05	150	24.56	0.941	37	1236
n = 16	**ó**	0.48	0.03	0.01	0.09	2.53	0.08	0.11	0.04	16	0.90	0.460	83	2540
wnb	**m**	3.94	1.12	0.29	0.29	67.19	2.63	1.30	0.02	198	22.33	0.008	4	2
n =9	**ó**	0.50	0.09	0.02	0.13	2.16	0.12	0.10	0.03	31	0.98	0.015	1	4
wnc	**m**	5.53	0.37	0.08	0.35	67.61	1.76	0.45	0.00	57	23.30	0.000	19	7660
n = 11	**ó**	0.62	0.06	0.02	0.06	0.86	0.09	0.07	0.01	11	0.98	0.000	16	3839
wnd	**m**	1.64	0.69	0.23	0.93	69.79	2.79	0.65	0.06	126	21.77	0.000	4872	14095
n = 2														
wne	**m**	1.94	1.75	0.38	0.38	68.49	3.56	0.87	0.04	185	20.97	0.007	1	0
n = 3	**ó**	0.21	0.09	0.01	0.04	1.19	0.13	0.04	0.01	3	0.07	0.009	2	0
wnf	**m**	4.72	1.55	0.34	0.25	64.33	3.22	1.74	0.03	240	23.78	0.032	4	1
n = 8	**ó**	0.56	0.11	0.02	0.08	1.26	0.17	0.31	0.04	41	1.06	0.021	2	2

caractéristiques semblables, de fait il n'y a jamais qu'une vingtaine de km entre Beni Salama et Zakik.

Seul le groupe wnc pourrait faire exception, la composition de son sable étant très différente de celles des sables des autres groupes, notamment pour le fer, le titane, l'aluminium, le magnésium et le zirconium. Il semble former un groupe minoritaire par rapport aux autres sables. Ce groupe décoloré à l'antimoine a une première allure qui ferait songer au groupe 4 de verres incolores (Foy *et al.* 2000a; 2000b), mais il s'en sépare par les pourcentages de sodium, de l'ordre de 23.3%, tandis que la moyenne générale du groupe 4 est de 18.8%. Si l'on enlève le sodium, la composition est la même sur les autres éléments. Rien dans les sables analysés jusque ici dans le Wadi Natrun ne correspond à la composition du sable employé dans la fabrication de ce verre. L'origine de ce groupe wnc n'est importante que dans la mesure où elle croise l'origine de groupe 4 des verres incolores. Si l'on suppose que le groupe 4 est un groupe proche-oriental, sa présence dans le Wadi Natrun ne se justifie que si l'on suppose l'existence d'un atelier-relai près de l'embouchure du Nil où arriverait ce type de sable de Syro-Palestine. L'autre hypothèse est que le sable du groupe 4 soit égyptien et que l'atelier-relai dont nous venons de parler soit l'atelier principal du groupe 4; on n'aurait dans ce cas dans le Wadi Natrun qu'une tentative limitée de fabrication de ce verre à l'antimoine. L'Égypte, au contraire de la Syro-Palestine, utilise beaucoup l'antimoine comme décolorant, comme le montrent par exemple les verres de Maréotide. Au niveau des produits finis, la présence de verre incolore est importante, tout au long de l'Empire, même sur des sites reculés du Fayoum ou des oasis du désert libyque; enfin on ne saurait oublier le *vitrum alexandrinum* de l'édit de Dioclétien qui dénote bien sûr une qualité du verre, mais doit aussi témoigner d'une provenance au moins à l'origine.

Il n'est pas encore possible aujourd'hui d'évoquer la répartition de ces différents groupes sur les sites de consommation, en Égypte et hors d'Égypte, ni leur importance relative dans l'ensemble de la production verrière égyptienne. Ce sont des recherches qui n'en sont qu'à leurs débuts. Des analyses sont en cours sur le matériel de Coptos et sur des pièces conservées au Musée du Louvre. Elles ont révélé par exemple que le groupe des flacons à khôl (IIe–IIIe siècle apr. J.-C.) ainsi que d'autres contenants comme des unguentaria (IIe–IIIe siècle apr. J.-C.) étaient réalisés avec un fondant végétal. Un autre programme est en cours sur les verres mosaïqués en collaboration avec Bernard Gratuze. Il vise à partir d'échantillons datés entre le IIIe siècle av. J.-C. et le IVe siècle apr. J.-C., à suivre dans le temps l'évolution ou les permanences des différentes couleurs de verre employées.

En conclusion, soulignons une nouvelle fois la variété des compositions de verres fabriqués en Égypte:pour l'époque antique, au moins six compositions dans le Wadi Natrun, auxquelles il convient d'ajouter les verres de Maréotide, les verres aux cendres de plantes des tubes de khôl, ainsi que probablement le groupe HIMT et peut-être un groupe des verres décolorés à l'antimoine.

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NITRUM CHALESTRICUM: THE NATRON OF MACEDONIA

Despina Ignatiadou, Elissavet Dotsika, Athanassios Kouras and Yannis Maniatis

During the last century, raw materials and their sources have become major issues for the study of glassmaking. Research on natron has focused on the Egyptian source of Wadi Natrun (De Cosson 1936; Coulson and Leonard 1979; Henderson 1985, 273–6), and other sources have been forgotten.

Yet, natron was also being formed in Greece, in Macedonia. It was produced in a lake near the city of Chalastra. It was exploited on such a scale that the city became rich and famous because of it; in turn, the product was associated with the city to the point that it was called *nitrum chalestricum*, or simply *chalestricum* (in Greek: *chalestraion nitron* or simply *chalestraion*).

Its main and earliest use was obviously that of a detergent. As such, it is mentioned for the first time by Plato in the 5th century BC, in his *Republic* (Appendix: Testimonium 1). Education, he says, must be like an indelible dye that cannot be washed out by detergents. It must not be affected by pleasure, which is stronger than the most powerful *chalestraion*. Trying to explain, one of his commentators added that '*Chalastra* is a city in Macedonia and a lake where the Chalastraion nitron is formed or dissolved over a period of nine days' (Appendix: Testimonium 2). Other authors mention *Chalastra* as 'a city or lake in Macedonia where nitron was being burned, the Chalastraion nitron named after it' (Appendix: Testimonium 3), or natron as 'Chalastraion nitron, named after Chalastra, the lake in Macedonia' (Appendix: Testimonium 4).

In his *Natural History*, Pliny the Elder supplies the most extensive report on the Chalastraion nitron. This passage remains rather unknown to researchers of ancient glass as it is not part of Book 36 (chapters lxv-lxvi), where glassmaking is described, but is included in Book 31 (Appendix: Testimonium 5) on medicine.

The passage begins with a list of sources of natron outside Macedonia.

> A little is formed in Media in valleys that are white through draught; they call it *halmyrax* [salty]. It is also found in Thrace near Philippi, but in less quantities and contaminated with earth; it is called *agrium* [wild] (Skordara *et al.* 2001).

Aphronitrum (foam of nitron) is collected in caves in Lydia while springs of alkaline water exist in Chalcis.

The text continues:

> At Clitae in Macedonia is found in abundance the best, called soda of Chalestra, white and pure like salt. There is an alkaline lake there with a little spring of fresh water rising up in the centre. Soda forms in it about the rising of the Dog Star for nine days, ceases for nine days, comes to the top again and then ceases. This shows that it is the character of the soil that produces soda, since it has been discovered that, when it ceases, neither sunshine is of any help at all nor yet rain. Another wonderful thing about the lake is that although the spring is always bubbling up it neither gets larger nor overflows. But if, on those days on which soda forms, there has been rain, it makes the soda more salty, while north winds on those days, by stirring up the mud too vigorously, make it inferior. This soda is natural but in Egypt it is made artificially, in much greater abundance but of inferior quality, for it is dark and stony. It is made almost in the same manner as salt, except that they pour seawater into the salt-beds but the Nile into the soda-beds. The latter as the Nile rises become dry; as it falls they are moist with liquid soda for 40 days on end and not as in Macedonia during fixed periods. If rain also has fallen, they add less river water, and gather at once the soda that has begun to solidify, lest it should melt back into the soda-bed.

We must, however, note that Pliny refers to natron sources near Naucratis and Memphis; it is uncertain whether the second one coincides with that of Wadi Natrun. We must also take into consideration the views of Alfred Lucas, who researched into the Egyptian natron and also analysed it in the middle of the last century. He concluded that Pliny was actually wrong and misleading in describing this way of obtaining natron from soda beds (Lucas and Harris 1962, 263–7, 493–4).

Pliny continues to cite the uses of natron that are very interesting and varied:

In purple dyeing:

> Of soda the best is the finest, and therefore froth of soda is superior, but for some purposes the impure is good, for example colouring purple cloths and all kinds of dyeing.

In glassmaking as is described in Book 36:

> Soda is of great use in the making of glass, as will be described in its proper place (Knoll *et al.* 1979; Ignatiadou 2002)

In embalming:

> For the bodies too that they wish to embalm this is the soda they use (Lucas and Harris 1962, 278–303; Brill 1999, vol. 1, 211, nos 655–8, vol.2, 480).

The Macedonian natron is used in bread making, while the Egyptian one is used for vegetables:

> They use Chalestran soda for bread instead of salt, Egyptian

soda for radishes; it makes them more tender; but meats white and inferior and vegetables greener.

The most impressive uses of natron are, however in medicine. It is widely used, in various preparations with oil or vinegar, to cure skin diseases such as psoriasis and leprous sores; it alleviates other skin problems, like pimples, blisters, ulcers, dog and snake bites and the attack of lice. With alum it is used as a deodorant. With pepper and wine it is used as a mouthwash for toothache, with leek as toothpaste, with vinegar it dissolves earwax. Boiled with wine it improves scars of the eyes, with resin wine and honey it improves vision. It is administered by mouth against dropsy, jaundice, fungi poisoning, coughing; also injected, inhaled, or used in a soda-bath.

The exact position of the ancient city of Chalastra is today unknown. Various sites have been suggested, like the modern town of Nea Anchialos, or the mound between the villages of Aghios Athanassios and Gefyra (Tiverios 1991/1992, 219–21). Locating the city is of extreme importance, but the issue remains open. It has, however, been suggested that it is fairly secure to identify the lake of Chalastra with the modern lake of Pikrolimni, 20km north-west of Thessaloniki. Two other cities seem to be associated with Chalastra. Morrylos was the city that took over the exploitation of soda in the Roman Period (Hatzopoulos and Loukopoulou 1989, 87–92). Votive inscriptions with the name of Morrylos have been unearthed near the modern village of Ano Apostoloi. The city was famous for a sanctuary of Asclepius, and statues of the god and his children have been found. The healing treatment, the therapy, was perhaps based on the application of the healing mud of the nearby lake. The other city is Clitai, mentioned by Pliny as being closest to the lake. It has not yet been excavated, but it can be identified either with the table-mound of Xylokeratea to the north of the lake, or with that of Xerochori to its south (Savvopoulou 1998, 93–7, 105).

Although the identification of the lake is generally accepted, this is the first attempt of scientific research on the Macedonian natron.

We started the on-site research with a visit to the lake in the summer of 2002. August was chosen as the time when the Dog Star rises, as is mentioned by Pliny.

When approaching the region, one is impressed by the landscape. The infertile ground is covered with a low and weak cultivation of wheat. There are almost no trees. One recalls the saying of Pliny that soda 'produces nothing and nourishes nothing, whereas in salt pits grow plants and in the sea so many animals and so much sea weed'.

In geological maps Pikrolimni appears as a proper lake, but it is filled with water only after periods of intense rainfall (COLOUR PLATE 14). Then the water begins to evaporate and usually in the summer it dries out. What we saw during that first visit was an almost dry basin. In places it was so dry that one could walk on it, in others there was thick mud a few centimetres deep. There were also mud basins of approximately 1 or 2m^2, and up to half a metre deep; those were full with watery mud. On that mud yellowish water accumulated, and on the surface of the water the natron of Chalastra formed thin white crusts (COLOUR PLATE 15). Natron also formed on footsteps on the mud, as they were drying (COLOUR PLATE 16), and even on our skin and clothes as the drops of water dried.

There are many visitors to the lake, as the water and the mud are still considered to be healing, as they were in antiquity. A spa centre is built on the shore and most of the visitors use the facilities for mud and water baths. Those who want to feel closer to nature prefer following the outdoor therapy. This consists of a bath in the mud basins, or application of mud literally all over the body, followed by sunbathing to help the mud dry out.

We collected samples of sediment, water and brine from the mud basins. We sampled the fresh water of the region. Additionally we sampled water from a local borehole *c.* 250m deep. This water is naturally sparkling, with a metallic aftertaste and a slight organic smell. It is distributed for free as tap water. It is very popular with the visitors, who drink it on the spot, but also fill bottles to take away. We, of course, also collected metallic salt ('natron') from the mud basins (COLOUR PLATE 17). George Angelakis, the owner of the spa centre, offered for analysis natron he had collected during the previous years. According to his testimony, the formation of natron varies according to rainfall. After a dry winter the natron is formed in large quantities; then the surface of the lake is covered with a white crust. Even a few decades ago, people from nearby villages used to collect large amounts of natron to sell, either as an additive to livestock food, or for use in bread making. Travellers of the 19th century supply relevant information. Already before 1812, the Turk Hadschi Chalfa testified that the inhabitants of the area are active in the trade of the 'white salt' (Appendix: Testimonium 6). Sixty years later, the Greek historian and archaeologist Margaritis Dimitsas cites this reference in his treatises on the archaeology and the ancient geography of Macedonia (Dimitsas 1874, v. 2, 248–50; Dimitsas 1896, v. 1, 404). Macedonia was under Turkish occupation until 1912, so until that time the lake was known as lake Yacilar, which is the Turkish name of the nearby village of Xylokeratea, or as Aci Göl, literally meaning Bitter Lake. The modern Greek name, Pikrolimni, also means Bitter Lake. One needs to just taste the natron to realize that the name is totally justified.

The chemical and mineralogical analysis of a sample of mature clay showed that its water-soluble components are (in g/kg): Na^+ (56.4), K^+(0.32), Ca^{2+}(0.09), Mg^{2+} (0.09), Cl^- (60.3), SO_4^{2-} (26.9), CO_3^{2-} (4.1), HCO_3^- (4.1), F^- (0.32).

The chemical analysis of silicate minerals showed: Na_2O (2.4%), K_2O (2.5%), MgO (1.6%), CaO (0.3%), Al_2O_3 (16.5%), Fe_2O_3 (4.3%), and SiO_2 (36.5%).

Components soluble in HCl are (% w/w): $CaCO_3$ (8.9%), $MgCO_3$ (3.2%) and Fe_2O_3 (1.9%).

Mineralogical analysis showed the presence of montmorillonite, mica, kaolinite, feldspars, quartz, and calcite.

Trace elements in the clay (in mg/kg) are: As (140), B (650), Br (210), Ba (930), Sd (2), U (6), Cr (92), Zn (79), Co (18), Cs (4).

PH, temperature and conductivity of the water were measured *in situ*. The isotopic contents of ^{18}O and ^{2}H were measured in the laboratory. Quantitative analysis was carried out for Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, Br^-, F^-, SO_4^{2-}, CO_3^{2-} HCO_3^-, NO_3^- (TABLE 1).

According to the results, two types of waters are distinguished:

TABLE 1 ANALYSIS OF THE WATER AND BRINES

Samples	**Local fresh water**	**Borehole**	**Borehole fresh water**	**Borehole fresh water**	**Brine**	**Brine**
Date	8/2002	8/2002	8/2002	1/2003	8/2002	1/2003
PH	7.1	6.3	6.1	6.55	9.85	9.6
Cond. μS/m	–	12700	3200	4200	>20000	23000
t⁰C	–	21	22.5	–	27.4	–
Total alkalinity mgCaCO$_3$/L	280	2650	2550	2775	62000	1975
Na$^+$	29	365	355	335	118299	5678
K$^+$	1.2	7.8	7.5	7.1	401	19.6
Ca^{2+}	42	154	304	159	346	353
Mg^{2+}	47	393	282	405	66	18
Cl$^-$	27.7	113	131	107	147000	6031
Br$^-$	0.1	0,61	0.65	0.34	660	23.2
F$^-$	0.1	0.1	0,5	n.d	n.d	6.3
SO$_4^{2-}$	11.2	22	29.3	23.63	31870	1747
CO$_3^{2-}$	24	0	0	0	37200	840
HCO$_3^-$	317	3233	3111	3386	0	854
NO$_3^-$	5.8	5.7	n.d	10.8	n.d	n.d
Sum of anions meq/L	7.11	56.74	55.33	59.2	5861.07	249.12
Sum of cations meq/L	7.24	56.1	54,01	56	5174.08	266.6
Error %	0.9	-0.6	-1.2	-2.8	-6.2	3.4
d^{18} O‰ *vs* SMOW	–	–	–	–	5.64	–
d^{2}H ‰ *vs* SMOW	–	–	–	–	-4.9	–

Waters of the Mg-(Na-Ca)-HCO$_3$ – these include the water from the boreholes and the local tap water.

Brines of the Na-Cl-(CO$_3$-SO$_4$) type – these result from the mixing and the condensation of the waters which are accumulated in the basin of the lake, and come not only from sources that feed the lake, e.g. waters from boreholes, but also from rain water. The waters of these sources are mainly of meteoric origin and circulate deeply, mixed probably with salt water of deeper and probably of warmer horizons. This is in agreement with the hydrothermal field, which exists in the area. Hydrochemical data show that the brines of summer clearly correspond to waters which have undergone extensive evaporation – they are residual mother solutions before the precipitation of halite. During winter, dilution of brines and dissolution of depositing minerals by meteoric water are observed. On the other hand, evaporating conditions are created in the lake during summer.

These brines, in a laboratory experiment, gave the following sequence of salts upon evaporation:

Burkeite (Na_2CO_3*2 Na_2SO_4)
Trona (Na_2CO_3*$NaHCO_3$*$2H_2O$)
Halite (NaCl)

This sequence is similar for lakes that are known to produce deposition of natron mineral today:

A. Natron Lake, Tanzania: Calcite ($CaCO_3$), Trona, (Na_2CO_3*$NaHCO_3$*$2H_2O$), Thermonatrite (Na_2CO_3*H_2O), Halite (NaCl)

B. Magadi Lake, Kenya: Trona (Na_2CO_3*$NaHCO_3$*$2H_2O$), Natron (Na_2CO_3*$10H_2O$), Nahcolite ($NaHCO_3$), Thermonatrite (Na_2CO_3*H_2O)

C. Deep Springs Lake, California: Calcite-Mg [Ca(Mg)CO_3], Dolomite ($MgCO_3$), Nahcolite ($NaHCO_3$), Trona (Na_2CO_3*$NaHCO_3$*$2H_2O$), Thenardite (Na_2SO_4), Burkeite (Na_2CO_3*2 Na_2SO_4), Halite (NaCl)

After the first results, it was decided to make repeated samplings of the water all year round. The water sample of January is a dilute version of the August sample, as, after intense rainfall, the dry basin of Pikrolimni was a lake again. It was approximately 1m deep throughout the winter, so more water samples were taken in February, March, May, and August. Our hope of seeing the dry basin and the formation of natron again this summer was not fulfilled. Pikrolimni remained a shallow lake throughout the summer and now we hope for next year.

Other lakes producing brines do not exist in central Macedonia. Additionally, geological data indicate it is impossible that such a lake existed in the past and is today dried out. All results show it is hydrochemically possible for Pikrolimni to have been the source of the *nitrum chalestricum*.

APPENDIX – TESTIMONIA

Testimonium 1. Plato, *Respublica* 430a (ed. I. Burnet 1963). *'και μη αυτών εκπλύναι την βαφήν τα ρύμματα ταύτα, δεινά όντα εκκλύζειν, ή τε ηδονή, παντός χαλεστραίου δεινοτέρα ούσα τούτο δραν και κονίας, λύπη τε και φόβος και επιθυμία, παντός άλλου ρύμματος'*

Testimonium 2. Scolia in Platonem, 159 (ed. Ruhnken). *'πόλις της Μακεδονίας, και λίμνη, ένθα το Χαλαστραίον νίτρον γιγνόμενον δια εννεατηρίδος πήγνυται, ομοίως δε και λύεται'*

Testimonium 3. Etymologicum Magnum, Χαλάστρη. *'πόλις ή λίμνη τις εν Μακεδονία όθεν έκαιον το νίτρον, εξ ης το Χαλαστραίον νίτρον κέκληται'*

Testimonium 4. Stephanus Byzantius, Χαλάστρα. *'Χαλαστραίον νίτρον, από Χαλάστρας της εν Μακεδονία λίμνης'*

Testimonium 5. Pliny, *Naturalis Historiae* 31, 46 (ed. W.H.S. Jones, Loeb 1963). Chapter on soda, esp. 106–9:

'Optimum copiosumque in Clitis Macedoniae, quod vocant Chalestricum, candidum purumque, proximum sali. Lacus est nitrosus exiliente e medio dulci fonticulo. Ibi fit nitrum circa canis ortum novenis diebus totidemque cessat ac rursus innatat et deinde cessat. Quo apparet soli naturam esse quae gignat, quoniam compertum est nee soles proficere quicquam, cum cesset, nee imbres. Mirum et illud, scatebra fonticuli semper emicante lacum neque augeri neque effluere, his autem diebus quibus gignitur si fuere imbres, salsius nitrum faciunt, aquilones deterius, quia validius commovent linum. Et hoc quidem nascitur, in Aegypto autem conficitur multo abundantius, sed deterius. Nam fuscum lapidosumque est. Fit paene eodem modo quo sal, nisi quod salinis mare infundunt, Nilum autem nitrariis. Hae cedente Nilo siccantur, decedente madent suco nitri XL diebus continuis, non ut in Macedonia statis. si etiam imbres adfuerunt, minus ex flumine addunt, statimque ut densaricoeptum est, rapitur, ne resolvatur in nitrariis'

Testimonium 6. Hadschi Chalfa's impressions were published in German in 1812, and cited in Dimitsas 1874, 249, n. 2: 'Hadschi Chalfa Rumel. et. Bosn, p. 81.'Der See Jaidchiler eine Tagreise nordwestlich von Salonich, drei Miglien im Umfange. Das Wasser ist bitter und es leben keine Fische darin ... weisses Salz an, womit die Bewohner Handel treiben"

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This paper is dedicated to Professor Michael Tite

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EXISTE-IL UN ATELIER DE VERRIERS GALLO-ROMAINS A LA FIN DU I^{ER} SIECLE, A REIMS (MARNE)?

HUBERT CABART

LE SITE, CIRCONSTANCES DE LA DÉCOUVERTE

Le Chantier de la rue de l'Équerre est localisé dans le quart sud-ouest de la ville antique. Cette zone est occupée durant toute la période du Haut Empire par des artisans des arts du feu. Sur le site même, les traces de fabrication de céramiques sont nombreuses et bien conservées.

Les fouilles, de 2002, ont mis au jour une couche homogène de rejets qui couvrait une surface de plus de 20m^2, et qui contenait plus de 8000 tessons de céramiques sigillées (dont la majorité est décorée), des tessons de céramiques plombifères, des fragments de lampes à huile, des fragments de figurines en terre blanche de l'Allier et plus d'un kilogramme de tessons de verre de différentes couleurs (bleu, jaune, bleuté, vert-jaune, ambre).

Si on compare cette masse aux quantités retrouvées sur d'autres sites, la découverte de Reims n'est pas très importante: à Avenches, le verre brut a un poids de 1351.6g et il y a plus de 6kg de déchets (Amrein 2001, 18); à Lyon, les fosses contenaient plus de 10kg de verre (Motte et Martin 2003, 311); à Saintes, le verre brut et les tessons pèsent 33kg (Hochuli-Gysel in Foy et Sennequier 1991, 58*)*.

LES INDICES D'UN ATELIER (FIG. 1)

L'étude de ces tessons conduit à envisager la présence d'un atelier de verrerie dans la métropole des Rèmes. En effet, même si les travaux n'ont pas permis la découverte de four, de creuset ou d'outil de verrier, les indices, qui permettent de penser que cette activité existe certainement au voisinage immédiat, sont les suivants :

Il y a tout d'abord le 'verre brut' formé de morceaux de petite taille de forme irrégulière obtenue en brisant des morceaux de plus grandes dimensions. C'est une matière d'excellente qualité, transparente, sans bulle ni filandre. On ne constate pas d'empreinte de creuset ni de trace d'outil. Six fragments de verre brut ont été analysés. Les résultats montrent l'apparition probable à Reims des premiers éléments du groupe 4 et la présence d'une série particulière du groupe 3 apparemment décolorée au manganèse et à l'antimoine (Picon et Vichy 2003).

Le deuxième indice est la présence de gouttes informes. La surface n'est pas lisse et brillante mais terne et rugueuse. La goutte, encore chaude et visqueuse, en tombant sur un sol en terre battue, a fixé extérieurement de petits morceaux de céramique.

Comme à Avenches, plusieurs baguettes cannelées sont trouvées sur le site. Ces fragments peuvent avoir été utilisés dans le processus de fabrication d'anses ou pour former des filets (Amrein 2001, 39).

Le quatrième indice est la présence de meules qui proviennent de la canne du souffleur (Fontaine 2002/2003, 10). Entre deux fabrications, ce verre est détaché par un choc thermique ou mécanique. Les fragments, qui en découlent, portent parfois l'empreinte de la canne sur leur face interne et permettent dans certains cas de mesurer le diamètre de l'outil. Ces humbles fragments sont donc la preuve de l'utilisation d'une canne à souffler le verre et donc d'une fabrication au voisinage immédiat.

Enfin, sur deux morceaux de baguettes, on remarque l'empreinte d'une pince métallique à mâchoire triangulaire

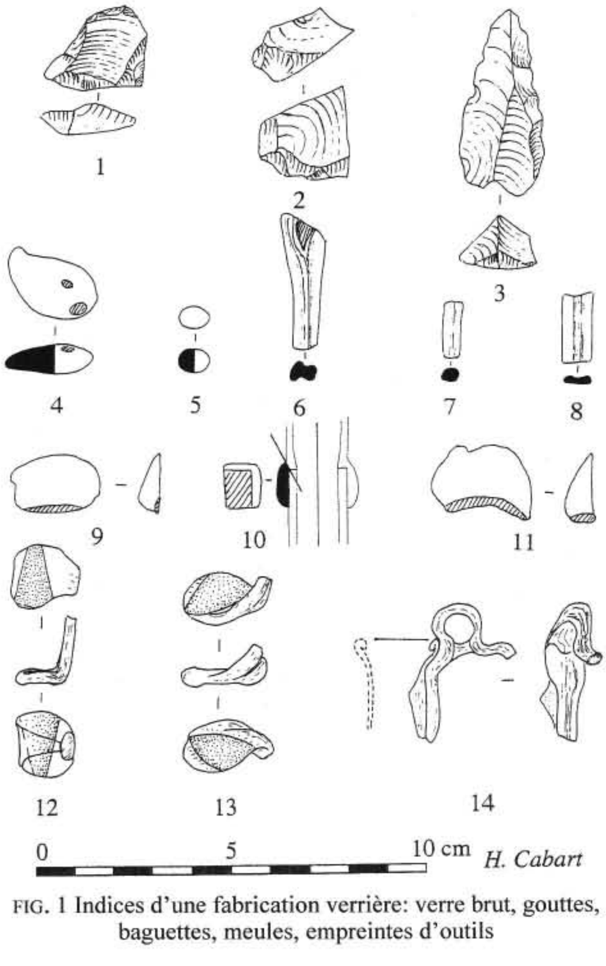

FIG. 1 Indices d'une fabrication verrière: verre brut, gouttes, baguettes, meules, empreintes d'outils

d'un centimètre de longueur. Cet outil permettait au verrier de manipuler le verre encore chaud et malléable puisqu'il a pu laisser son empreinte.

Les ratés de fabrication sont rarement retrouvés car le verre est recyclé. L'objet est une petite bouteille à anse Isings 56 ou une amphorisque en verre verdâtre. Ce récipient mal venu a été rejeté dans les rebuts. Ce fragment démontre la fabrication de bouteilles ansées à proximité.

Morceaux de récipients reconnus sur le site (fig. 2)

Ces fragments peuvent être classés en deux catégories : les objets de fabrication locale et les vases importés. La Figure 2 donne des dessins d'objets complets, mais il faut savoir qu'aucun de ces vases n'est entier et que l'on ne dispose que de fragments. Les dessins ne sont donc que des schémas de reconstitution obtenus par comparaison avec des objets conservés dans les musées.

Balsamaires sphériques (Isings 10)

Les verres de fabrication locale sont essentiellement des balsamaires sphériques (Isings 10). Le comptage des cols permet de dénombrer environ 120 balsamaires pour plus de 700 morceaux. S'il existe une fabrication sur le site c'est certainement cette forme tout à fait simple. Tous les balsamaires sont brisés. On ne peut que donner une approximation du diamètre. La forme sphérique est confortée par l'existence d'un fragment de fond avec décor en spirale et par les fonds recouverts de plomb fondu. Le col est cylindrique avec un léger rétrécissement à l'épaule qui est la partie la mieux conservée. Il n'y a pas de trace de pontil mais, à de nombreuses reprises, on remarque une légère déformation au niveau de la base du col. Il s'agit de la marque laissée par la pince du verrier pendant la manipulation de l'objet encore chaud et malléable. Les décors sont très variés: des filets de même couleur que la panse ou de couleur différente, des filandres de couleur donnant un aspect marbré, des bandes ou des points d'émail ou de peinture et les gouttes de plomb fondu qui donnent à la boule l'aspect brillant et métallique d'un miroir.

Il faut remarquer que les exemplaires entiers découverts dans les tombes (musée de Dijon, musées de Normandie) n'ont pratiquement jamais de goulot mais une toute petite ouverture. Madame Sennequier parle de 'sphère percée d'une ouverture minuscule' (Sennequier 1985, 201, no. 310). Doit-on en conclure que ces flacons, fabriqués avec un col comme on les trouve à Reims, sont, après leur remplissage, refermés à la flamme? L'utilisation du produit nécessiterait de briser le col en verre comme c'était l'usage pour les balsamaires en forme d'oiseau.

Le morceau d'anse mal formé (no. 14) démontre une fabrication de petites cruches Isings 56 sur le site. Ici on ne dispose pas du col entier et seul le départ d'une anse est conservé. La forme n'est pas franchement identifiée. Des cruches à anse identique sont trouvées à Zara en Croatie (Masseroli 1997, 151). Une bouteille à deux anses, datée deuxième moitié du Ier siècle a été mise au jour à Augst (Rütti 1991, 161, no. 3724) et une fabrication est démontrée à Avenches (Amrein 2001, 65).

Les verres importés

Les autres verres reconnus lors de l'étude ne sont attestés que par quelques fragments - voire un seul. Ils sont sans doute 'importés' d'autres ateliers.

Ce sont :

• un balsamaire en forme d'oiseau (Isings 11)

Trois fragments de verre soufflé en forme d'oiseau, avec une tête ronde et un bec fin tubulaire. Le long cou se termine par une panse ovoïde, sans aile et à queue pointue. Le verre est bleuté, très fin. Seules les extrémités de l'oiseau (tête et queue) sont identifiables.

Attestés d'Auguste aux Flaviens, ces flacons ont une grande diffusion sous le règne de Néron. Ils sont sans doute originaire d'Italie du Nord ou du Tessin (Facchini 1998, 131; Biaggio Simona 1991, 125).

• des autres balsamaires (Isings 8, 27 ou 28)

Ce sont des balsamaires soufflés librement. Ils sont attestés soit par le col, soit par le fond. Il existe plusieurs formes de fonds (arrondi, plat ou concave) et plusieurs sortes de lèvres (évasée, ourlée ou brute). Une légère contraction marque la limite entre le col et la panse. Ces récipients appartiennent à plusieurs types de profils différents. Sauf pour l'exemplaire complet Isings 68, il n'est pas possible de trier ces balsamaires entre les formes Isings 8, 27 ou 28. Ces types sont contemporains et abondent dès le Ier siècle. Isings remarque que les exemplaires colorés, d'abord très nombreux, sont progressivement remplacés par des verres bleutés dans le troisième quart du Ier siècle (Isings 1957, 23).

• des bouteilles sur base en anneau (Isings 52a et 52b)

La base est formée par un repli de la matière. Si la panse est côtelée, c'est la forme 52b.

• une cruche ou pot à anse (Isings 57)

Le col de ces objets porte, de chaque côté de l'anse, une décoration très particulière avec un filet travaillé à la pince. Ce même décor est souvent utilisé pour la base des anses des cruches (Isings 52b).

• des bouteilles carrées (Isings 50)

Un fragment de lèvre, un morceau d'épaule et quelques morceaux de paroi plate correspondent à des bouteilles carrées en verre mince bleuté. La présence de pots carrés Isings 62 n'est pas à exclure.

• des pots et bols

Ce sont des récipients à lèvre ourlée vers l'extérieur. Le diamètre d'ouverture fait penser à des pots globulaires ou carrés ou, pour les plus grands, à des bols. La hauteur est toujours inconnue. Le fond peut être moulé pour obtenir un anneau plus ou moins saillant. Ces fragments peuvent provenir de pots Isings 67b/c ou de bols Isings 44 de grande taille.

• des coupes moulées à grosses côtes

Isings 3 à fond plats ou légèrement rentrant en verre bleuté ou marbré, à lèvre arrondie par meulage, avec parfois des lignes parallèles obtenues par meulage sur la face intérieure.

• les coupes à petites côtes fines (Rütti 1991, AR30.1)

• un gobelet à scène de spectacle (Rütti 1991, AR 31)

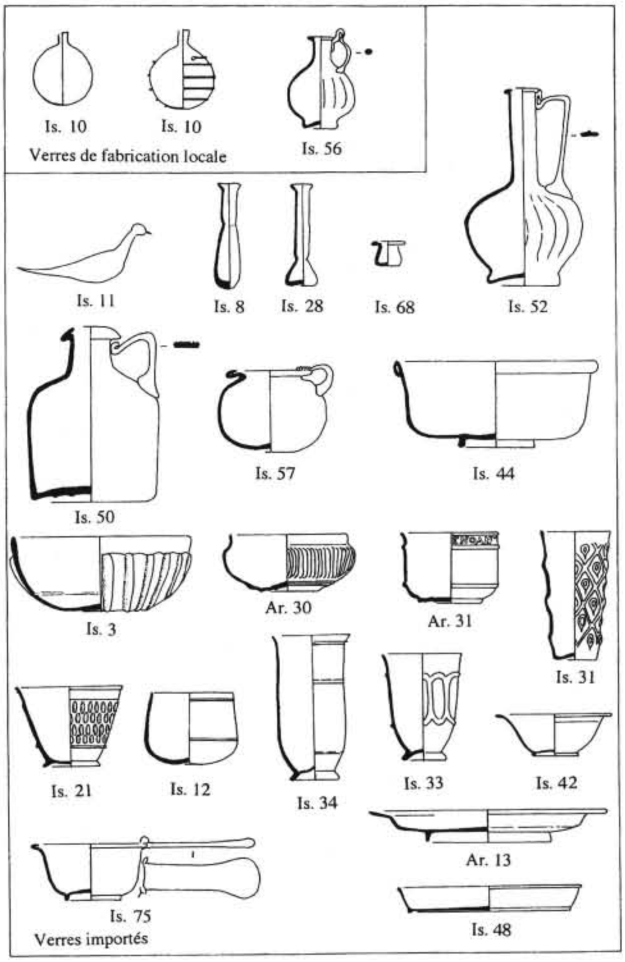

Fig. 2 Reconstitution des formes reconnues sur le site

On dispose d'un seul fragment de gobelet à scène de spectacle en verre bleu cobalt, soufflé dans un moule en plusieurs parties. Il a une panse cylindrique partagée par de grosses moulures horizontales, en verre bleu cobalt transparent. La lèvre est coupée et non arrondie. Le registre supérieur porte une inscription très incomplète ...ENOANT...

• des gobelets coniques à décor de gouttes ou de 'boutons de lotus' (Isings 31)

Ces gobelets sont soufflés dans des moules en plusieurs parties. Les quatre fragments reconnus appartiennent aux panses de quatre gobelets différents dont on ne connaît ni la lèvre, ni le fond.

• des gobelets hémisphériques (Isings 12: Hofheim cup).

Leur décoration consiste en sillons meulés ou fines lignes gravées sous la lèvre ou au milieu de la panse.

• un gobelet à décor de nid d'abeille (Isings 21)

• un gobelet à décor d'arcades (Isings 33) disposées verticalement sur la panse.

• des tasses (Isings 42) réalisées en verre très fin.

• deux morceaux d'une patère (Isings 75)

• une petite assiette à lèvre ourlée vers l'extérieur (Isings 48)

• un plat (Isings 80; Rütti 1991, AR 13) pratiquement incolore. La lèvre est soulignée intérieurement par un sillon meulé.

Le site a livré également des perles 'melons', un peu de verre à vitres et un morceau de plaque décorative en verre noir opaque.

Datation et interprétation

Sous réserve d'une étude complète de la céramique sigillée, la couche archéologique, qui contenait ce matériel vitreux résiduel, peut être datée, par la stratigraphie du site et par la céramique commune, entre le troisième tiers et la fin du Iᵉʳ siècle de notre ère.

Le cas de Reims est, à l'évidence, beaucoup moins simple que l'atelier étudié à Avenches avec ses fours, ses déchets, ses ratés. La fouille de la rue de l'Équerre, à Reims, permet de se représenter les occupations dans une cour, derrière un bâtiment. Dans ce milieu ouvert, à l'extérieur, se développe, dans la deuxième moitié du Iᵉʳ siècle, une activité liée aux arts du feu.

Une fabrication verrière est attestée au voisinage par des indices de travail du verre (meule, traces d'outils sur le verre encore chaud, rebuts). La localisation exacte de l'atelier est inconnue et la nouvelle campagne de fouilles sur le même site, en 2003, n'a pas permis de le découvrir. Cet atelier hypothétique fabriquait :

• Des balsamaires sphériques (Isings 10), avec plusieurs décors (filets, bandes, plomb) et plusieurs couleurs.

• Des petites cruches à anse attestées par un raté de fabrication.

Ces balsamaires sont généralement utilisés pour contenir des parfums, cosmétiques etc. Etaient-ils remplis sur place, ou exportés vides malgré leur fragilité? S'ils étaient emplis, d'où et comment arrivait le contenu? Y-avait-il à Reims un marché suffisant pour commercialiser la production? La principale difficulté pour comprendre le site tient dans le reste du matériel découvert : la céramique luxueuse trouvée au même endroit est cohérente en datation et la quantité présente est trop importante pour une unité domestique. Comment expliquer sa présence? Doit-on imaginer un magasin vendant des produits de luxe (céramiques et parfums). Le même établissement fabriquant sur place les contenants nécessaires? Plus encore que l'absence de découverte de four, c'est la présence de cette importante couche de céramique qui gène pour interpréter le site comme un simple atelier de verrier.

La récupération du verre, considéré comme matière première, est la seule activité, qui semble assurée sur le terrain. Le verre cassé faisait l'objet d'un véritable commerce sur lequel on a peu d'informations. Quelques trouvailles démontrent l'importance de ce négoce : un tonneau de verre brisé dans une épave (fin IIe s. – début IIIe s.) au large de l'île de Grado (Foy et Nenna 2001, 111); une épaisse couche de verre, de la fin du Iᵉʳ s., déchargée dans une cour en vue du recyclage à Augsburg (Rottloff 1996, 166).

Avant d'être refondu, le verre devait être trié par couleur et brisé en petits morceaux. À cette activité, s'ajoutait sans doute un tri sélectif pour séparer les déchets qui ne pouvaient pas être réutilisés : les faïences, le verre opaque, le verre à inclusions, peut-être le verre recouvert de plomb et le verre marbré. Les résidus de cette activité doivent être abordés d'un œil critique: il est évident qu'on ne retrouve que ce que les artisans ont laissé, soit par négligence devant un fragment trop petit pour être ramassé, soit parce que le morceau n'était pas recyclable. Ceci explique peut-être pourquoi il y a si peu de gros échantillons bien épais et que les tessons retrouvés sont toujours petits et minces.

La FIGURE 2 représente les formes attestées sur le site. C'est une verrerie d'excellente qualité, très variée dans ses formes et ses couleurs. Ce témoignage ne représente pas toute la verrerie en circulation à Reims. On remarque une majorité de gobeleteries minces et quelques formes ouvertes (coupes, plat, assiette). Par contre les vases épais, pour conserver, manquent ou sont sous représentés. On ne trouve pas de grands vases à panse sphérique et col plat Isings 67a, de pot à anses Isings 65, pas d'aryballes Isings 61, pas de *modiolus* Isings 37; les bouteilles carrées Isings 50 n'apparaissent que par deux ou trois petits fragments. Ces fabrications sont pourtant présentes à Reims, puisqu'elles ont été découvertes dans les incinérations (Cabart 1998, 20–2, figs 3, 4) et les fouilles d'habitat (Cabart 2003, 164).

Il faut penser que cet état de fait est le résultat de l'activité de recyclage, qui récupère sélectivement les morceaux les plus gros, les plus épais, et abandonne négligemment les fragments les plus petits, jugés peu rentables.

Remerciements

Les fouilles de la rue de l'Equerre à Reims, ont été conduites par Philippe Rollet, INRAP, Reims. Je le remercie de m'avoir laissé étudier le matériel vitreux. Les analyses et l'interprétation des résultats ont été réalisées sous la responsabilité de M. Picon et M. Vichy, UMR Archéométrie et Archéologie, Maison de l'Orient Méditerranéen. à Lyon. Qu'ils reçoivent ici l'expression de ma profonde gratitude. Je dois remercier Heidi Amrein qui a bien voulu regarder le matériel de Reims et identifier ces fragments très particuliers.

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ROMAN ENAMEL AND ENAMELLING: NEW FINDS FROM CASTLEFORD, YORKSHIRE

JUSTINE BAYLEY

There was a Roman fort and *vicus* at Castleford from the later 1st century AD. Some but not all the excavations there have been published (Cool and Philo 1998; Abramson *et al.* 1999). Other excavations, in the Dixon Street area of the town, were carried out in 1987–8 by the West Yorkshire Archaeology Service with Manpower Services Commission funding. Little post-excavation work was done until Hilary Cool and her colleagues assessed the archive and finds from the site in 2002. These included the four lumps of deeply weathered red glass whose investigation is reported here. Three (SF 925, 1136 and 1137) came from trench 51, and the fourth (SF 22) from the adjacent trench 44, in the *vicus* (see Abramson *et al.* 1999, fig. 8 for plan showing location of excavation trenches).

THE GLASS LUMPS

The lumps were irregular fragments of larger glass blocks which showed varying degrees of weathering (corrosion); the largest piece was 56mm long (COLOUR PLATE 18). Their external surfaces were all pale green and brown but recent fractures showed opaque red glass in the interior of three of the pieces, and a translucent dark green/black glass in the fourth. Examination under a low power microscope showed the red colour was due to feathery, dendritic crystals, most probably of cuprite. Small samples were removed from each lump, mounted in resin, polished and examined in a scanning electron microscope (SEM). The three opaque red samples were very similar and showed sparse cuprite (Cu_2O), variable amounts of cassiterite (SnO_2) and occasional wollastonite laths ($CaSiO_3$) (FIG. 1). The dark glass has a completely different structure; it lacks any crystalline phases.

SEM-based energy-dispersive X-ray analysis showed the bulk composition of all four glass samples was very similar, despite the visible submillimetre-scale inhomogeneities. The figures given in TABLE 1 are the means of three area analyses (the overall mean composition has been used in COLOUR PLATES 19 and 20). The relatively uniform composition of the four lumps means it is possible that they were originally pieces of a single block of glass. The atypical piece (SF 1136) has the same composition but the colour has not 'struck'. Replication experiments to produce opaque red glass have demonstrated the variability a single melt can show, with zones that are dull or bright opaque red, opaque orange, and translucent green (Cable and Smedley 1987, fig. 2).

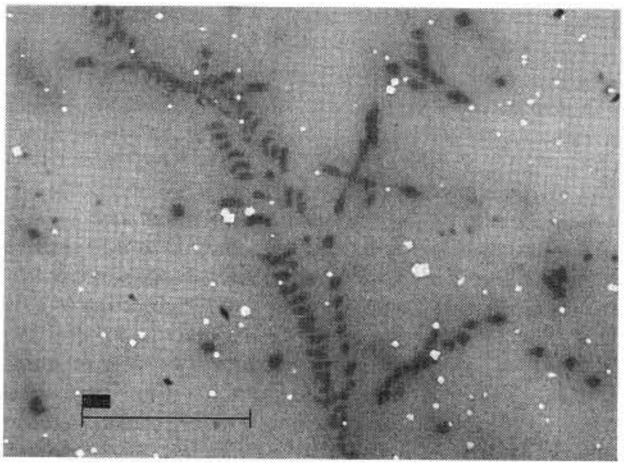

FIG. 1 Back-scattered SEM image of SF 22 showing cuprite dendrites (dark grey) and cassiterite crystals (white) in a lead-rich glass matrix; scale bar 100 microns

If the copper and lead oxide contents are subtracted from the total, the base glass can be seen to have a standard Roman soda-lime-silica composition (TABLE 2). This indicates that the Castleford glass lumps are not metalworking slags, unlike some other red glass samples (e.g., Bayley 2003); they contain far too much soda, and no detectable silver.

In Roman Britain, opaque red glass is most commonly used as enamel, so it is reasonable to assume that these glass lumps were raw enamel. Their composition can be compared with that of other raw enamel such as the pieces from Fish Street Hill in London (Freestone *et al.* 2003), Tara in Ireland (Stapleton *et al.* 1999) and Heybridge in Essex (Bayley 2003). Their composition can also be compared with analyses of red enamel in Roman brooches (Henderson 1991, groups 1 and 4). There is a definite family resemblance between these glass samples, though the quantity of copper and lead added to the base glass is variable (COLOUR PLATE 19).

COLOUR PRODUCTION

All Roman red enamels found in Britain appear to be soda-lime-silica glasses with significant additions of copper and lead. The presence of lead helps the dissolution of copper in the glass melt, and aids the growth of large cuprite crystals as the glass cools, which give it a bright red colour.

Table 1 Normalised analytical data for the four glass lumps (wt %)

Sample no.	22	925	1136	1137	mean values
Na_2O	7.7	8.1	7.1	7.8	7.7
MgO	0.9	0.6	0.6	0.7	0.7
Al_2O_3	1.7	1.7	1.6	1.6	1.7
SiO_2	30.4	29.6	29.1	29.5	29.6
P_2O_5	0.5	0.1	nd	nd	0.2
K_2O	0.6	0.4	0.5	0.5	0.5
CaO	4.0	2.9	3.3	3.1	3.3
SrO	0.8	0.8	0.8	0.7	0.8
Fe_2O_3	2.1	0.9	1.0	0.9	1.2
Cu_2O	4.4	4.6	4.0	4.3	4.3
PbO	45.5	49.2	50.5	50.0	48.8
SnO_2	1.0	0.5	0.8	0.5	0.7
Sb_2O_3	nd	nd	0.4?	nd	0.1
MnO	nd	0.1	nd	nd	0.0

The following elements were sought but not detected: Ag, As, Ba, Cr, Ni, S, Ti, V; nd = not detected

It has recently been suggested (by Mass *et al.* 2002 and Freestone *et al.* 2003) that lead and copper could have been added to a base glass in the form of litharge, which is a lead-rich by-product of silver production and refining. Litharge from silver refining contains significant amounts of copper, and so potentially could have been added to a base glass to make red enamel. If the copper and lead contents of the raw red enamels are plotted (Colour plate 20) the variation in the copper:lead ratio that is also visible in Colour plate 19 can be seen. Henderson's (1991) red enamel groups 1 and 4 are comparable to the raw red enamels, though other low-copper, low-lead red enamels are also found (Henderson 1991, groups 2 and 3). Compared with the enamels, the litharge cakes have far more variable copper:lead ratios which show that most of them could not have been the source of the lead and copper in the red enamels. In addition, even those litharge cakes which have about the right copper:lead ratios also contain other elements which are not found as additions to the base glass in the red enamels. This is because litharge is found absorbed into either bone ash or clay marl hearth linings, known as litharge cakes, and their total PbO+CuO content is only 50–80%. Adding litharge would therefore also add other, non-metallic elements to the glass melt, but the analyses do not show this. It is thus certain that lead and copper were not added to the soda-lime-silica base glass in the form of litharge.

Possible uses for the raw red enamel lumps

The raw red enamel from trench 51 at Castleford was found associated with a timber-framed building of mid 1st to 2nd-century date which had a dense charcoal and slag layer in one room, suggesting industrial activity was taking place there. The fragment from trench 44 came from a gully fill associated with 3rd-century material. Previous excavations found hundreds of mould fragments for casting enamelled vessels (Bayley and Budd 1998), but their late 1st-century context in the fort, some 300m north-north-east of trenches 51 and 44, make any link with the raw enamel unlikely, though they do demonstrate a tradition of metal casting and enamelling at Castleford.

There is an unfinished Alcester brooch from Castleford (Cool 1998, 49–50, fig. 13.81), a type that dates to the 2nd century and which would have been enamelled, which was interpreted as evidence that (enamelled) brooches may have been made at Castleford. More interesting are two metal-detector finds of brooches, one unprovenanced and the other from the Alford area of Lincolnshire, *c.* 115km east-south-east of Castleford. They are of types related to knee brooches (fig. 2), and hence most likely 2nd-century in date; one is enamelled in red (Collingwood and Wright 1991 [RIB II.3], 11, no. 2421.44) and the other in blue (Tomlin and Hassall 2001, 396, no. 39). The inscriptions read: *fibula ex reg[ione] Lagitiense*, which can be translated as 'brooch from the Regio Lagitiensis', which was the Roman name from Castleford.

These two brooches strongly suggest that enamelled brooches were being made in Castleford in the 2nd century. It is possible that the raw red enamel lumps were part of the brooch-maker's stock of materials, and had been intended for use in decorating them. Other finds from the *vicus* are large numbers of opaque blue glass tesserae (Cool and Price 1998) which could also have been used as raw material for enamelling.

Conclusions

The lumps of glass from Castleford have been identified as raw red enamel; their composition and structure compares well with examples from other sites. As yet there

Table 2 Castleford red glass composition compared with that of colourless Roman glass

	Mean values	Normalised minus copper and lead	Average values for Roman glass
Na_2O	7.7	16.5	10–20
SiO_2	29.6	63.9	60–70
CaO	3.3	7.2	5–10
Fe_2O_3	1.2	2.8	~ 1.5
Cu_2O	4.3	–	–
PbO	48.8	–	–
SnO_2	0.7	1.5	–
Sb_2O_3	0.1	0.3	–

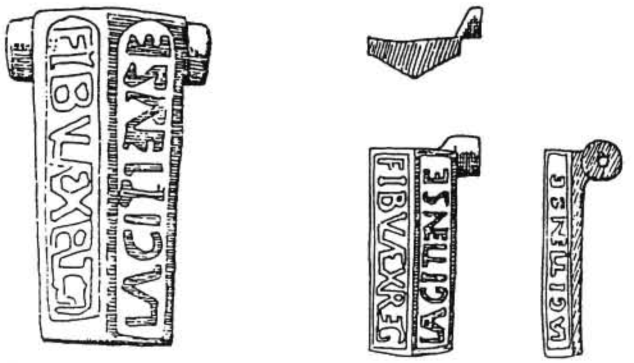

FIG. 2 Enamelled Roman brooches with inscriptions saying they were made in Castleford; scale 1:1 (after drawings by D.F. Mackreth in Collingwood and Wright 1991 – left – and Tomlin and Hassall 2001 – right)

is no evidence where any of the glass lumps found in the British Isles were made, though lead isotope analysis might suggest possible sources for the lead in them. Consideration of the analytical data for Roman litharge cakes shows that they were not the source of the lead and copper in contemporary red enamels.

It is reasonable to assume that the raw enamel lumps found in Castleford were intended for use there. The settlement has a known history of producing vessels that were decorated with enamel in the late 1st century, so a continuity of enamelling into the 2nd century is not unexpected. At this date the products appear to have included brooches.

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ROMAN PERIOD GLASS BEAKERS WITH THREAD DECORATION (EGGERS 188-192) FROM POLAND – TECHNICAL EXAMINATION

TERESA STAWIARSKA

This paper presents and discusses beakers with thread decoration (Eggers 1951, types 188–192, hereafter E188 etc) dating from the end of the 2nd to the mid 3rd century discovered in Poland (FIG. 1). There are about 50 glasses from 15 sites, mainly cemeteries. These are slim or more squat conical beakers with a foot, made of colourless glass proper, colourless glass with a yellowish tint, or glass of a very faint greenish or yellowish tint. The most numerous in the group are E189 beakers with 'snake' ornament (about 30 artefacts); they are morphologically homogenous (Stawiarska 1999, 111–17; Niezabitowska 2000; Machajewski 2001; Andrzejowski and Zórawska 2002; Rudnicka and Mączyńska 2002).

The finds of beakers with thread decoration are concentrated mainly in two regions: in Zeeland and at the territory of the Wielbark culture. There are also some in the area of the Przeworsk culture, the Czerniachowska culture, and on the islands of Bornholm and Jutland, as well as in eastern Sweden (Lund Hansen 1987, 63-70). They were in use for a very short period of time: from the late 2nd to the mid 3rd century (phase B_2/C_1-C_{1b}, Eggers 1951). According to many authors, the Rhineland is thought to be their production centre (Fremersdorf 1959, 43–5; Harden *et al.* 1987, 105–7). These glasses have never been analysed physico-chemically.

My project was to verify hypotheses about the provenance of these glasses. About 100 Roman-period glass vessels have been analysed physico-chemically (Stawiarska 1999, Annex 1); nine of them represented E188–192 types. Their chemical characteristics are presented in TABLE 1 and FIG 2; painted glasses of type E209 (nos 179 from Poland and 406 from Thuringia) are added for comparison.

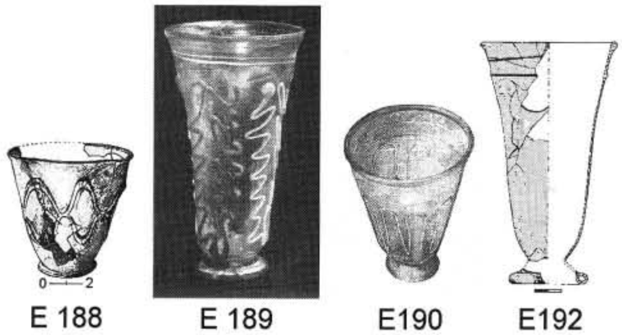

FIG. 1 Beaker types E188–190 and E192 from Poland: E188 – Linówiec, near Gdansk; E189 – Połłowite, near Olsztyn; E190 – Parzeń, near Plock; E192 – Nadkole, near Siedlce

ANALYTICAL TECHNIQUES AND THE METHOD OF COMPARING THE RESULTS

Analytical techniques employed in the Central Laboratory of the Institute of Archaeology and Ethnology, Polish Academy of Sciences, in Warsaw include quantitative spectral analysis of the 23 constituents. This Institute has joined the Corning Museum of Glass in New York in work aimed at the unification of patterns and methods of analysis of glass remains. The analysis was made on a quartz spectrograph, sodium and potassium contents were determined by flame photometry. Loss on ignition was determined by gravimetric analysis. Silica was calculated as the difference to 100%.

The method employed in the comparison of the results of the analyses includes a correlation: chemical types of glass, technology recipes (RN), calcium-magnesium raw material and decolourising agents – antimony and manganese. The glasses containing less than 1.3% K_2O with Na_2O:K_2O ratio equal to or higher than 13:1 are called the sodium type. The limits of other important glass-forming constituent levels which determine the chemical name of glass type are: CaO level exceeding 4%, MgO – 2% and Al_2O_3 – 2%. The method involving (Na_2O+K_2O):(CaO+MgO) ratios reflects technological recipes (RN) used for glassmaking.

The raw materials are characterized by ratios with ($K_2$0) = (K_2O : Na_2O +K_2O) x 100% and (MgO) = (MgO:CaO+MgO) x 100% facilitating the calculation of the potassium fraction in the alkaline raw material and magnesium fraction in the calcium raw material. This (MgO) fraction will be next identified by comparison with the composition of carbonate rock, though one should however bear in mind that such comparisons are purely conventional, as the raw material used for glass-making was probably more diversified mineralogically (eg crushed shell) (Stawiarska 1988; 1993a; 1993b). Considerable Sb_2O_3 levels (greater than 0.2%) and MnO levels (greater than 0.25%) mean that antimony and manganese were deliberately used as decolourants.

The chemical composition of the finds from the areas of Poland noted above was compared to more than 650 glasses from Europe and Middle East (see Stawiarska 1984, Annexes 2-3; 1999, Annex 3), with particular attention being paid to the glasses from the Rhineland (see also Velde 1990 – 60 samples).

FEATURES OF THE GLASSES

The glass which these beakers with thread decoration were made from can be generally defined as a three-component, low magnesium (LMG) glass, melted with the use of sand with a low proportion of iron oxides. The generally homogenous compositions of soda-lime-silica Roman glasses are explained by the use of homogenous raw materials and/or using only one strict formula or recipe (for discussion on the subject see Jackson *et al.* 2003). A more detailed study of the concentrations of only the main components indicates that there existed certain differences between glasses from various parts of the Empire both in the recipes and raw materials. Still greater differences can be seen in the use of decolourising or opacifying elements.

First of all the analysis shows that relatively 'pure' calcium raw material (MgO) and sand with alumina and iron admixtures used for glassmaking are similar to those used in production of the comparative material from Rhineland. This may suggest the same provenance for the glasses.

The glasses from Poland are thus similar due to the low proportion of the magnesium fraction (MgO) in the general sum of CaO + MgO. A look at the results of the analysis of glasses from various areas of Europe and the Middle East reveals that the greatest number of sodium-type glasses (48%) were melted from raw materials with a considerably large admixture of (MgO) – from 10% to more than 20% – indicative of dolomitic limestone (FIG. 3). Among the 60 analysed glasses from Cologne, however, half were melted either from raw material without magnesium, or with a low proportion of the magnesium fraction (less than 10%), similar to the finds from Poland.

Some specialists, interpreting the text by Pliny the Elder (*Natural History* 36, 192, 194), believe that originally glass was melted from sodium and special sands (containing lime), and in the Roman period a third basic component was added, perhaps '*magnes lapis*' as he calls it: probably dolomitic lime, shells, or other lime raw materials (Trowbridge 1930, 100; Knoll *et al.* 1979, 73).

Wedepohl and Baumann (2000) believe that in the Roman period the set of components did not comprise local limestone but only crushed shell. This does not seem to be true of all the workshops of that period. The higher content of (MgO) in Roman glasses indicates that besides shell other, probably more easily accessible lime raw materials with a higher content of magnesium 'impurities,' were also used (mainly in the late Roman period). However, in the case of the Rhineland glassmaking centres, especially the ones at Cologne (as well as of those from Italy), the possibility that 'pure' lime raw materials with virtually no admixtures of MgO in the form of crushed shell (or perhaps chalk?) were used, seems very probable. The glasses from Poland under discussion here are located in the same intervals of the diagram as the glasses from Rhineland, and especially Cologne.

Some glasses from Poland differ slightly in their admixture of aluminium. The majority of these glasses

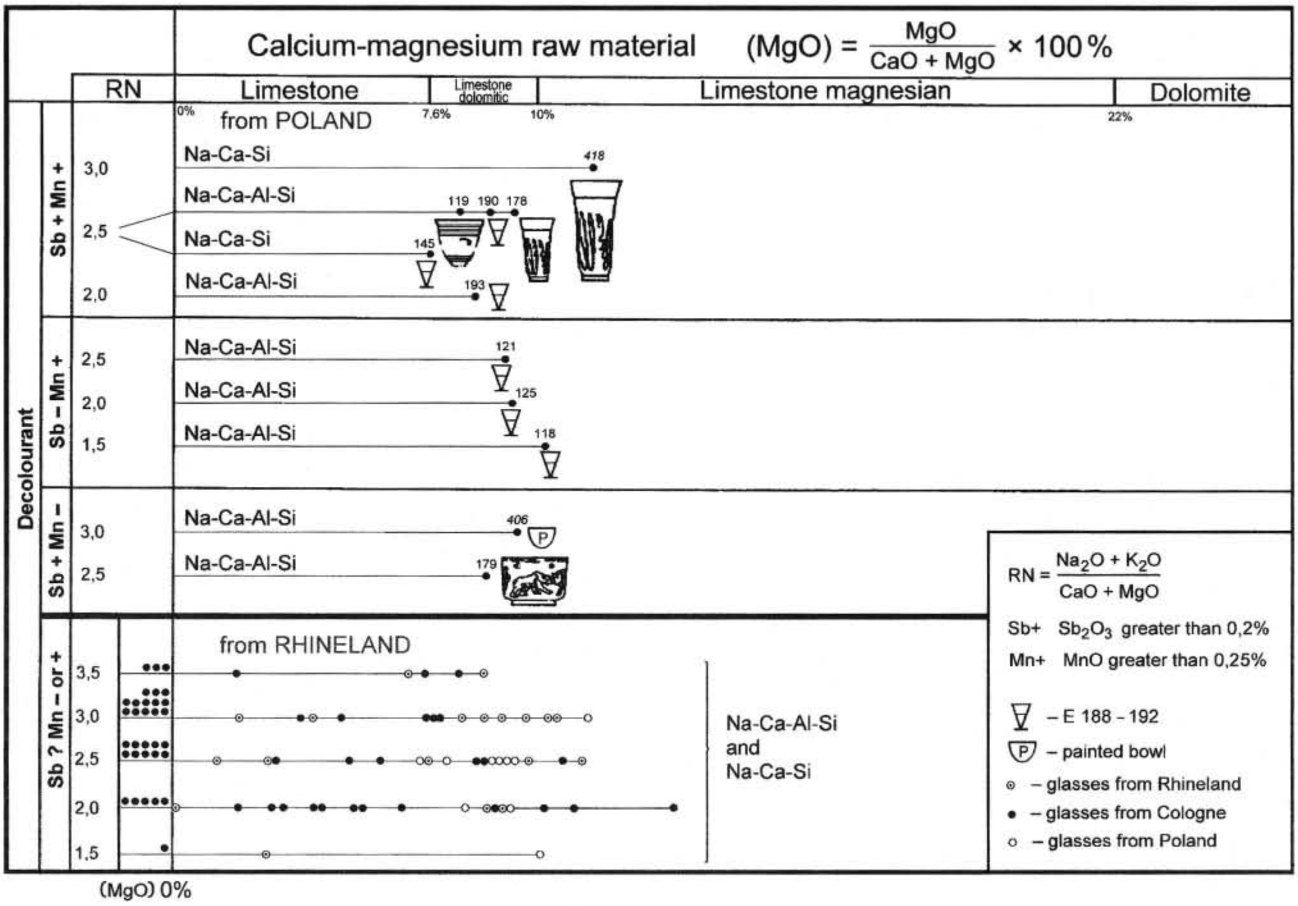

FIG. 2 Chemical characteristics of glass – beaker types E188–192 from Poland and glasses from the Rhineland (see TABLE 1)

TABLE 1 CHEMICAL CHARACTERISTICS OF GLASS FROM POLAND

No.	site	Na_2O	K_2O	CaO	MgO	Al_2O_3	Fe_2O_3	Sb_2O_3	MnO	type	RN	(K_2O)	(MgO)
418	Horodnica	20.0	0.75	5.9	0.66	1.8	0.45	0.22	0.12	Na-Ca-Si	3.16	3.6	10.06
119	Spicymierz	19.2	0.85	6.9	0.52	2.3	0.63	0.46	0.65	Na-Ca-Al-Si	2.70	4.23	7.00
190	Krusza Zamkowa	18.2	0.9	7.0	0.58	2.1	0.71	0.41	0.58	Na-Ca-Al-Si	2.5	4.71	7.65
178	Rosto³ty	18.2	0.8	7.5	0.67	2.5	0.72	0.40	0.28	Na-Ca-Al-Si	2.32	4.21	8.20
145	Zd¿arów	19.0	0.8	7.9	0.53	1.9	0.67	0.40	0.25	Na-Ca-Si	2.34	4.04	6.28
193	Krusza Zamkowa	16.6	1.0	7.7	0.61	2.3	0.76	0.22	0.84	Na-Ca-Al-Si	2.1	5.68	7.34
121	Mierzanowice	~ 20	0.5	7.2	0.64	2.8	1.2	–	0.88	Na-Ca-Al-Si	2.61	2.43	8.16
125	Igo³omia	15.4	0.7	7.9	0.71	2.6	0.60	–	1.6	Na-Ca-Al-Si	1.86	4.34	8.24
118	Rosto³ty	15.6	0.85	1.0	1.0	3.7	0.83	–	1.9	Na-Ca-Al-Si	1.49	5.16	9.09
406	Mühlberg	20.0	0.7	6.60	0.60	2.70	0.62	0.57	0.05	Na-Ca-Al-Si	2.88	3.38	8.35
179	Rosto³ty	19.4	0.7	7.2	0.59	2.0	0.49	0.63	traces	Na-Ca-Al-Si	2.58	3.48	7.57

$$RN = \frac{Na_2O + K_2O}{CaO + MgO} \qquad (K_2O) = \frac{K_2O}{Na_2O + K_2O} \times 100\ \% \qquad (MgO) = \frac{MgO}{CaO + MgO} \times 100\ \%$$

Complete results of analyses of glasses from Poland were published in Stawiarska 1999, Annexes 1–2. Chemical characteristics of glasses from the Rhineland established on the basis of data analyses were published in Velde 1990; Stawiarska 1984, Annexes 2–3; Stawiarska 1999, Annex 3

represent items of type Na-Ca-Al-Si; two of them are of the Na-Ca-Si type. Similarly, among the glasses from Rhineland, the majority contain more than 2% of Al_2O_3.

The concentrations of iron oxides in glasses from Poland are relatively low: 0.45%–0.80% Fe_2O_3; in one glass there is 1.2%. Of about 60 glasses from Cologne, about 20% do not contain admixtures of iron, about 74% have an iron oxide concentration of less than 1%, and only single items contain more than 1% (FIG. 4). The researchers agree with the belief that sands were selected with greater care in the early Roman period, while in the later period there appeared a tendency to use sands with higher iron and titanium content (HIMT, see Freestone *et al.* 2002; and Freestone *et al.* this volume). Isotope analyses have allowed the determination of the sources of sands used for melting glasses by several 4th-century glassmaking centres in Hambach, Rhineland. These glasses contain considerable admixtures of iron: 1.1–2% Fe_2O_3. According to Wedepohl and Baumann (2000) sands from the river Ruhr in the Eifel region were used to melt the glasses from Hambach.

Results of further research (Wedepohl *et al.* 2003), however, have established that in the Rhineland area (i.e. in Cologne) other sources of sand were also used. Some specialists believe that Cologne glassworks melted glass from raw material from the sand deposits of the nearby Frechen area, which are characterized with very low concentrations of Fe_2O_3 (Fremersdorf 1966, 36).

On the other hand, the analysis shows that glasses from Poland are heterogeneous in their technology (see FIG. 2) showing high alkaline (RN *c.* 3.0 – no. 418), medium alkaline (RN *c.* 2.5 and 2.0 – the majority) and low alkaline (RN *c.* 1.5 – no. 118) and also the use of varying levels of decolourants. Three of them (nos 121, 125 and 118) were decoloured only with the use of MnO (0.88–1.9%). The remaining ones were decoloured with antimony and manganese used together. In the latter cases the concentration of Sb_2O_3 amounted to 0.22–0.46% and the concentration of MnO, to 0.24–0.84% (except for no. 418: 0.12%).

Differences in the use of decolorants are significant features which serve as one of the most valid indicators in the comparative analysis of glasses. In the analyses of glasses from Cologne (Velde 1990) the antimony content was, unfortunately, not reported and so in this research the earlier, but still valuable, results of the work by Sayre (1963) have been used.

The use of antimony was not widespread in the Roman period: manganese was more frequently applied. According to Sayre the use of manganese only was characteristic for the Sidonian tradition. In the Roman period manganese was used quite commonly in the West, i.e. in Gaul (e.g. in the glasshouses of Frontinius; see Velde and Sennequier 1985).

Antimony, applied more commonly from the 6th century BC in Mesopotamia and eastern Syria, was used in some Egyptian glasses; the method of using antimony might have come from Mesopotamia together with the knowledge of other techniques for producing high-quality glass. In the Roman period, Sb was used for production of the best colourless glasses. In the production of luxury glasses, such as *diatreta* or 'crystal glass', antimony was the only decolourising agent (Stawiarska 1993a, 145). According

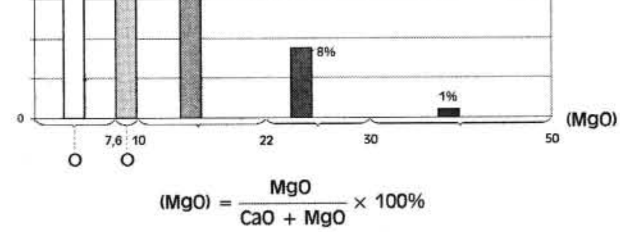

FIG. 3 Calcium-magnesium raw material used in the Roman period for melting sodium-type glasses from Europe and the Middle East (for comparative material on 650 glasses see Stawiarska 1984, Annexes 2–3; 1999, Annex 3)

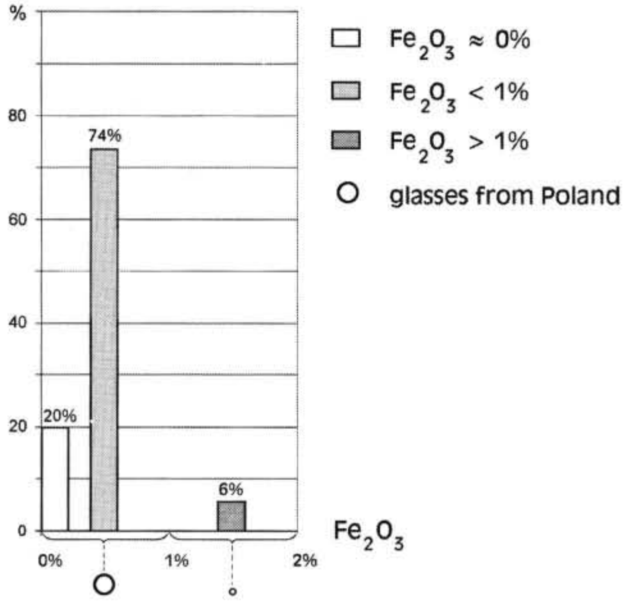

FIG. 4 Iron oxide concentrations in the glasses from Cologne (60 samples from Köln RGM, Velde 1990)

to Sayre the early Roman glasses from Italy contain only manganese; antimony appeared from the late 1st century. Between the 2nd and 5th centuries, in Italy and Rhineland, the colourless glasses contained both these oxides (more frequently than in the Middle East).

In our current state of research it is impossible unequivocally to determine the lower limits of the concentrations of manganese and antimony responsible for decolourising ancient glasses. According to Sayre, the intentional introduction of the antimony or manganese raw material is proved by the presence of Sb_2O_3 or MnO concentrations greater than one-hundredth; today this quantity would be considered too low. Henderson (1985, 284) and Velde and Hochuli-Gysel (1996, 191) believe that for MnO this value is at 0.6%; according to Shchapova (1983, 37) the minimum doses of manganese used as a decolorant are about 0.5%.

It may be assumed that the joint amount of decolorant was important. Among *c.* 100 vessels from the Roman period found in Poland, manganese together with antimony appears most frequently in a concentration of about 1%. Manganese as the only decolorant appears in a concentration of *c.* 0.35% whereas this value for antimony is 0.3% to 1.14% (when together with MnO it appears in the quantity of 0.1% and 0.2%; Stawiarska 1984, 42; 1999, 40, fig. 3). In those cases where another decolorant was used, the intentional addition of antimony may be assumed when the Sb_2O_3 concentration is *c.* 0.2%.

In Poland in contexts from the late 2nd–early 3rd century, vessels decoloured only with antimony appeared. Such more luxurious glasses were discovered in one complex of finds from the late 2nd–mid 3rd century (phase B_2/C_1-C_{1b}) together with the E189 type beaker discussed above (Rostołty, Barrow 4; see Stawiarska 1999, catalogue no. 81). This was a cylindrical, colourless painted bowl (type E209) with representations of animals (FIG. 2, no. 179), undoubtedly coming from the Rhineland, and probably of Cologne provenance (Fremersdorf 1984). Another example of vessels, decoloured with antimony only, are the contemporary colourless bowls with cut decoration of the Cologne type (E216) (Stawiarska 1993a, 143). For their melting too almost entirely pure limestone raw materials were used, as in the case of the beakers discussed above.

Thus it is possible that in Cologne itself, in the late 2nd century and the first half of the 3rd century, there operated workshops using similar sources of basic raw materials (probably the sand from the Frechen area and possibly crushed shells, or other 'pure' calcium sources), but using different recipes and decolorants. This paper is meant to be a voice in the discussion about the primary glasshouses. It seems that in the described period (from the end of the 2nd to the mid-3rd century) glass vessels were made from primary raw material in many workshops. In the later Roman period, glass vessels were formed in secondary workshops from raw glass melted probably in a very few primary glasshouses in the Rhineland.

CONCLUSIONS AND DISCUSSION

The problem of differentiation of glassmaking and glassworking in Roman glass production has been discussed during the last few decades. Many researchers (i.e. Nenna *et al.* 2000; Freestone *et al.* 2002) express the very firm opinion that there existed only a few centres of raw glass production in Egypt and the Syro-Palestinian littoral. Other researchers, however, assume that there also existed numerous local glasshouses, melting glass from primary raw materials, e.g. in Hambach near Cologne (where a large tank furnace was discovered) as well as in Coppergate in York (Cool *et al.* 1999). I believe the latter claims to be true: they have been confirmed by the discoveries of late-Roman tank furnaces also in other Roman provinces (e.g. at Novae, Oescus, Trimontium, Odessus and Sirmium – Olczak 1998, 21).

During the Roman Empire there undoubtedly must have been a considerable demand for good-quality colourless glass. Cologne is considered to be one of the best known centres where such glasses were produced (Harden *et al.* 1987, 107, 241, 263–4). I believe that production on such a large scale would not have been profitable, had it been based only on imported raw glass. From the point of view of economics it was cheaper to melt glass on the spot, using the excellent glassmaking sands to be found in the vicinity of Cologne, and import only the mineral salts.

Researchers have not yet established at which stage the colourising and decolourising media were applied. Two models have been put forward: total batch making and partial batch making. According to Rehren (2000) in the Roman period glass was melted following the second model. It can not be excluded that melted chunks of raw glass containing antimony or 'high quality' colourless cullet (Henderson 1985, 284) were used to make vessels, although the latter is less probable (cullet was commonly used at a later time). I agree with the views of Jackson and her colleagues (Jackson *et al.* 2003, 35) that to melt colourless glasses, found in such large quantities in Rhineland and Britain, cullet must have been used very selectively. This could have been the workshop's 'own' cullet. Larger quantities of 'foreign' cullet could have been added for melting the natural glass, from which *unguentaria* and square bottles were formed.

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ARCHAEOMETRICAL ANALYSIS OF GLASS OF WESTERN EMILIA ROMAGNA (ITALY) FROM THE IMPERIAL AGE

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Introduction (NG)

A fundamental contribution to the study of the economy in ancient times is the identification of centres and modes of production, the reconstruction of distribution networks, and hypotheses on workshop management. The first objective of this type of research, the identification of production centres, can only reasonably be achieved through interdisciplinary archaeological and archaeometric study. A long-standing collaboration between the Soprintendenza per i Beni Archeologici dell'Emilia Romagna and the Earth Science Department of the University of Modena and Reggio Emilia led to the elaboration of a research project on Roman pottery circulating in the Modena region. According to Pliny, Mutina was one of the most important production centres for ceramics in the ancient world (*Natural History* xxxv, 160–1). The present work deals with Roman glass artefacts found in the rural territory in the north of the city, between the Po river and the basins of the Secchia and Panaro rivers (the so-called lower Modena plain) (FIG. 1). Due to its central location in the Po valley, this area was involved in a wide trade network starting from the Bronze Age, with goods distributed either by land or by river (Calzolari 1997a). In Roman times scattered rural settlements (farms and *villae*) appeared in this territory together with small villages (*vici*) cited by historical sources (*vicus Serninus*, *vicus Varianus*, *Colicaria*). Connections were assured along the roads from Mutina to Mantua, Verona, Aquileia, and Altinum. On the upper Adriatic Sea, coastal centres like Aquileia and Ravenna played an important role in production and distribution of goods, as well as the river port Hostiglia (Ostiglia), on the Po (Calzolari *et al.* 2003).

Archaeological context and description of the samples (RT)

On the lower Modena plain over 100 Roman sites have been identified over recent decades, in systematic surface surveys (Calzolari 1997b). The quantity of glass is quite substantial, especially when compared with other areas around Modena. Over 1300 glass fragments were recovered from at least a third of the sites identified: a large part of these (around 900 fragments) come from two important *villae urbanae et rusticae*, Mirandola – La Tesa (no. 65), and Finale Emilia – Il Motto (no. 98), the remainder from more modest rural settlements. Finds from funerary

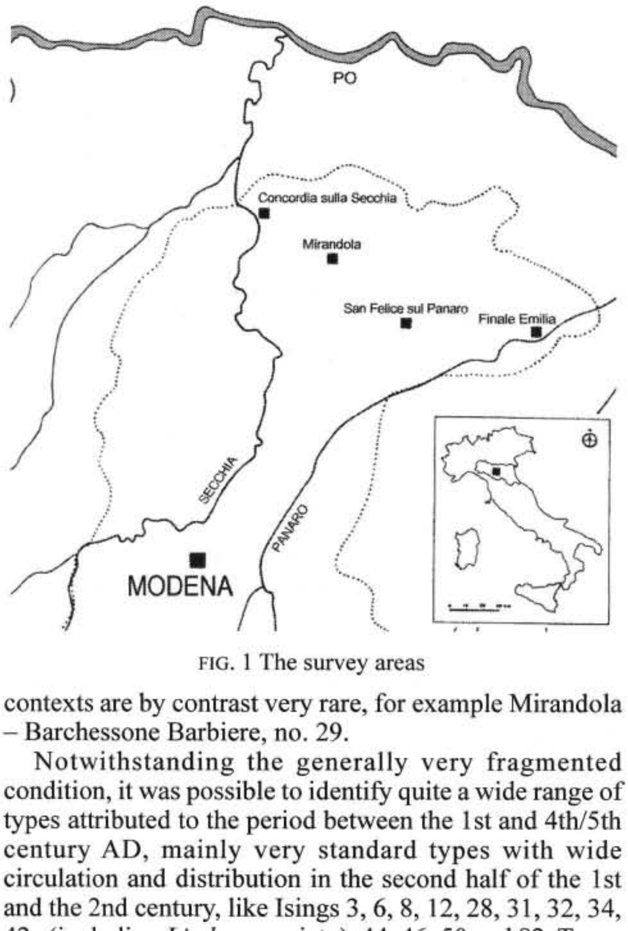

FIG. 1 The survey areas

contexts are by contrast very rare, for example Mirandola – Barchessone Barbiere, no. 29.

Notwithstanding the generally very fragmented condition, it was possible to identify quite a wide range of types attributed to the period between the 1st and 4th/5th century AD, mainly very standard types with wide circulation and distribution in the second half of the 1st and the 2nd century, like Isings 3, 6, 8, 12, 28, 31, 32, 34, 42a (including *Limburg* variety), 44, 46, 50 and 82. Types attributable with a degree of certainty to the 3rd century are very rare; by contrast, the late Roman age is better documented, even if the variety of types is extremely reduced, limited to Isings 96 and 106 (Tarpini 1997a; 1997b; 1998; 2001).

Archaeological finds have not yet provided signs of local glass production. Considering the highly standardized form of the majority of the types identified, it is very difficult to establish convincing hypotheses regarding the provenance of the glass circulating in this area. Morphological studies combined with macroscopic examination of physical and technological features (colour, thickness, glass quality, decoration, surface treatments, etc) would seem to suggest Aquileia as an important reference market for the Modena finds, although it is impossible to exclude importations from other north-eastern Italian centres (like Adria or Ravenna), from central Italy, from Canton Ticino, or even from transalpine or eastern provinces.

With the hope of better describing the circulation of Roman glass in the territories in question, or at least some aspects of the same, a series of archaeometrical analyses were prepared, addressing a relatively large sample of glass fragments (79) coming from different sites, conserved at the 'G. Venturini' Archaeological Collection in San Felice sul Panaro. Preference was given to the types best documented in this area (TABLE 1), other fragments were instead chosen for their morphological or technological peculiarities, and a group of window glass fragments was also included.

EXPERIMENTAL (RA and GV)

The chemical analyses were carried out by electron microprobe (EMPA) for major and minor elements (Si-Ti-Al-Mn-Mg-Fe-Ca-Na-K) and X-ray fluorescence (WDS-XRF) for major, minor and trace elements (Nb-Y-Zr-La-Sr-Ce-Ba-Ni-Co-Cr-Va-Sb-Zn-Cu-As-Pb). All the glass fragments were analysed by EMPA whereas, due to the small size of some samples, complete chemical analysis was only possible for 56 samples.Due to the known loss of light elements (Na, K) under the electron beam, especially in glassy materials, the EMPA analyses were performed checking different electron beam currents, sizes, and counting times, in order to get the best results. This was achieved operating at 15KV, 20 nA with a defocused beam (30ìm beam diameter) and using counting times of 5-10-5 seconds on background-peak-background, respectively. The XRF analyses were performed on 300mg of powder, instead of the 3g commonly used, obtaining a detection limit of about 10ppm. Eleven standard glass types (Institute of Geophysical and Geochemical Exploitation Langfang – China), containing all the analysed trace elements in the range 2 to 5000ppm, were utilized for the calibration curves. The comparison between the results obtained by EMPA and XRF is satisfactory and the standard deviation on six measurements, on the same standard, for trace elements is about 3. In TABLES 1 and 2 the chemical compositions of major and minor elements, obtained by EMPA, and trace elements, obtained by XRF, are reported, respectively.

CHEMICAL RESULTS (RA and GV)

All the samples from the 1st to 4th century AD, even those not suitable for precise morphological attribution (only seven samples out of 79), proved to be silica-soda-lime glass, typical of the Roman period (Turner 1956; Sayre and Smith 1961; Henderson 1985; Verità 1995). The concentration of Al_2O_3 and MgO is almost constant over the sample set: Al_2O_3 content ranges mainly between 2.1 and 3% and MgO between 0.4 and 1.0%, whereas FeO, MnO and TiO_2 have a wider range of variability: FeO 0.1–1.5, MnO 0.1–2.1, TiO_2 0.02–0.5%. Cobalt is present only in the six blue (B) (TABLE 2) samples, with amounts ranging between 250 and 920ppm. Arsenic was detected in only two of these samples, however in lower amounts than those reported by Gratuze (Gratuze *et al.* 1992) for 'cobalt-arsenic' glass. Copper is present in all the analysed fragments and shows a wide variability (mainly from 30 to 500ppm), the higher amounts corresponding to the blue-green samples, moreover, three of the six blue cobalt glass samples are characterized by significantly higher concentrations (1000–2300ppm). Antimony content is related both to the colour and age of the samples. In general it was detected in concentrations ranging from 30 to 2500ppm, the highest value always referring to the most colourless and oldest glass; in particular the 4th-century glass types are antimony free. This result is in agreement with literature data (Sayre and Smith 1961; Sayre 1963; Henderson 1985) because antimony oxide was used as a decolouring agent only until the 1st and 2nd century AD, later being replaced by manganese oxide.

The samples from the 4th century AD show the highest contents of Fe, Mn, Ti, and of the trace elements Zr, Cr, V (FIG. 2). On the basis of the chemical composition, these samples can be classified as HIMT glass (Freestone, 1994 – see also Freestone *et al.* this volume). HIMT Roman glass types of this age have been identified in many sites, including Carthage (Freestone 1994), Augusta Praetoria (Mirti *et al.* 1993), Rome (Verità 1995), the western Mediterranean area (Foy *et al.* 2000), and in Germany and Belgium (Aerts *et al.* 2003). In contrast, glass finds from Middle Eastern sites seem to maintain the composition of earlier glass types (Aerts *et al.* 2003). Since the fusing agent seems always to have been natron, up to the 9th century AD, an enrichment in heavy elements could reflect the use of sands richer in heavy minerals.

DISCUSSION OF THE RESULTS (RA and GV)

The large number of samples and chemical variables available made this experimental data suitable for multivariate analysis. First, the data was subject to z-transformation to remove the errors caused by the great differences between concentrations of minor, major, and trace elements (after autoscaling, all the variables had unit standard deviation and zero mean). Subsequently, hierarchical agglomerative cluster analysis was performed using the Euclidean distance and complete linkage method (Massart and Kaufman 1983). The main clustering factors in the analyses performed on all the chemical variables are the colour of the samples and their age. Further, a second analysis was performed removing the colouring agents (Co, Cu, Sb), and Fe, Mn, Ti, Cr, and V. However, again in this clustering the discriminant factor was the glass age. Three groups were obtained, of which the best defined consisted exclusively of all the 4th-century samples, characterized by higher Al, Mg, Ba, and lower Ca readings. In both cluster analyses the differences in the chemical composition were not directly related to the typology of the artefact or to the archaeological site of the find.

The chemical analyses of glass from Augusta Praetoria (Aosta, Italy, 1st–4th century AD) (Mirti *et al.* 1993), and from Aquileia (1st–2nd century AD) (Calvi 1968) were added to the cluster analysis to check similarities with Modena finds and hence to hypothesize a common site of production. As regards the major elements, only one of the

TABLE 1 CHEMICAL ANALYSES BY EMPA, WT% OXIDE

Sample	Type	Colour	Date AD	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O
MIR-TE 1	Isings 3	G	50–150	70.87	0.10	2.32	0.48	0.46	0.56	6.48	18.05	0.69
MIR-TE 2	Isings 3	BG	50–150	70.49	0.05	2.34	0.29	1.05	0.44	7.00	17.78	0.56
MIR-TE 3	Isings 3	BG	50–150	72.79	0.05	2.66	0.28	0.12	0.40	7.50	15.72	0.46
MIR-TE 4	Isings 3	G	50–150	70.80	0.10	2.35	0.46	0.47	0.55	6.58	18.03	0.67
MIR-TE 5	Isings 3	BG	50–150	70.94	0.08	2.40	0.43	0.50	0.57	6.48	17.87	0.73
MIR-TE 6	Isings 3	BG	50–150	71.08	0.09	2.44	0.47	0.44	0.57	6.90	17.11	0.90
MIR-TE 7	Isings 3	BG	50–150	69.13	0.06	2.45	0.41	0.31	0.50	8.62	17.85	0.67
MIR-TE 8	Isings 46a	BG	50–120	73.07	0.05	2.18	0.24	0.24	0.41	7.30	16.05	0.46
MIR-TE 9	Isings 46a	O	50–120	71.24	0.05	2.33	0.27	0.04	0.43	8.16	16.94	0.53
MIR-TE 10	Is. 42a var. Limb.	PG	C2	70.52	0.15	2.26	0.67	n.d.	0.71	5.03	20.16	0.49
MIR-TE 11	Is. 42a var. Limb.	NC	C2	66.98	0.06	2.41	0.33	1.32	0.60	8.33	19.32	0.65
MIR-TE 12	Is. 42a var. Limb.	NC	C2	68.98	0.21	2.55	0.72	0.03	0.82	6.01	20.13	0.54
MIR-TE 13	Isings 42a	PB	70–130	71.59	0.06	2.43	0.31	0.74	0.52	7.50	16.27	0.59
MIR-TE 14	Frag. plate rim	NC	?C2	71.40	0.05	1.69	0.25	n.d.	0.38	5.42	20.33	0.48
MIR-TE 15	Isings 106c	PYG	C4	64.95	0.32	2.36	1.11	1.82	1.01	6.66	21.30	0.48
MIR-TE 16	Isings 106c	O	C4	66.84	0.43	2.82	1.44	2.14	0.81	4.46	20.63	0.43
MIR-TE 17	Frag.rim	O	C3–4	71.97	0.06	2.46	0.35	0.26	0.47	8.23	15.54	0.66
MIR-TE 18	Isings 32 (?)	G	70–250	67.10	0.06	2.54	0.39	1.57	0.63	8.05	19.03	0.62
MIR-TE 19	Isings 8	BG	0–110	70.71	0.07	2.47	0.43	0.49	0.60	6.89	17.62	0.72
MIR-TE 20	Isings 8	BG	0–110	69.48	0.05	2.56	0.36	0.33	0.51	7.85	18.24	0.61
MIR-TE 21	Isings 50	PB	50–200	71.09	0.09	2.38	0.47	0.44	0.57	7.01	17.20	0.74
MIR-TE 22	Isings 50	BG	50–200	70.03	0.06	2.76	0.34	0.63	0.54	8.31	16.76	0.56
MIR-TE 23	Isings 50	BG	50–200	70.45	0.08	2.46	0.46	0.44	0.58	6.78	18.02	0.73
MIR-TE 24	Isings 50	BG	50–200	70.96	0.08	2.42	0.48	0.54	0.61	6.93	17.32	0.65
MIR-TE 25	Isings 50	BG	50–200	70.70	0.05	2.38	0.31	0.94	0.48	7.04	17.57	0.53
MIR-TE 26	Isings 50	BG	50–200	69.97	0.05	2.56	0.38	0.24	0.55	8.23	17.58	0.44
MIR-TE 27	Isings 50	O	50–200	70.72	0.13	2.16	0.69	0.03	0.98	7.21	17.65	0.42
MIR-TE 28	Isings 50	PG	50–200	69.42	0.10	2.12	0.48	0.28	0.58	6.42	20.04	0.57
MIR-TE 29	Isings 50	BG	50–200	72.32	0.06	2.36	0.30	0.21	0.49	7.86	15.94	0.48
MIR-TE 30	Isings 50	PG	50–200	68.80	0.14	2.29	0.76	0.70	0.95	6.46	19.44	0.46
MIR-TE 31	unguent-bottle	BG	50–150	70.58	0.08	2.37	0.45	0.50	0.62	6.78	17.89	0.73
MIR-TE 32	unguent-bottle	BG	50–150	71.69	0.04	2.27	0.28	0.17	0.45	7.65	17.00	0.44
MIR-TE 33	Window glass	NC	C1–2	70.42	0.08	2.34	0.41	0.99	0.54	7.05	17.60	0.58
MIR-TE 34	Window glass	PG	C1–2	69.65	0.10	2.32	0.53	1.92	0.82	7.64	16.30	0.72
MIR-TE 35	Window glass	BG	C1–2	70.41	0.09	2.18	0.44	0.34	0.58	6.49	18.85	0.63
MIR-TE 36	Window glass	NC	C1–2	69.98	0.05	2.60	0.28	1.13	0.49	8.77	16.05	0.65
MIR-TE 37	Window glass	PG	C1–2	69.81	0.09	2.26	0.47	0.26	0.57	6.43	19.53	0.57
MIR-TE 38	Window glass	BG	C1–2	71.18	0.09	2.35	0.44	0.49	0.60	7.03	17.08	0.74
MIR-TE 39	Window glass	BG	C1–2	72.09	0.06	2.34	0.27	0.32	0.43	7.47	16.59	0.43
MIR-TE 40	Window glass	BG	C1–2	71.55	0.06	2.36	0.29	0.47	0.44	7.80	16.55	0.49
MIR-TE 41	Window glass	PG	C1–2	69.74	0.09	2.34	0.48	0.36	0.58	6.64	19.16	0.59
MIR-TE 42	Window glass	PG	C1–2	70.85	0.09	2.30	0.43	0.50	0.57	6.95	17.58	0.72
MIR-TE 43	Window glass	PG	C1–2	70.45	0.09	2.15	0.49	0.31	0.58	6.15	19.17	0.61
MIR-TE 44	Window glass	PG	C1–2	70.48	0.09	2.10	0.47	0.25	0.55	6.30	19.21	0.55
MIR-MO 45	Isings 3	BG	50–150	71.33	0.09	2.21	0.48	0.53	0.64	6.49	17.46	0.77
MIR-MO 46	Isings 3	PG	50–150	70.72	0.09	2.34	0.46	0.49	0.57	6.32	18.39	0.63
MIR-MO 47	Isings 50	BG	50–200	70.53	0.09	2.33	0.49	0.53	0.56	6.66	18.18	0.63
MIR-BB 48	Isings 3	BG	50–150	70.60	0.07	2.34	0.45	0.53	0.64	6.89	17.71	0.76
MIR-BB 49	Isings 3	BG	50–150	71.04	0.09	2.32	0.44	0.49	0.55	6.56	17.84	0.66
MIR-BB 50	Isings 44	BG	50–110	73.27	0.05	2.43	0.37	0.11	0.51	7.77	14.98	0.51
MIR-BB 51	Isings 14 (?)	B	20–60	70.30	0.07	2.36	0.98	0.61	0.59	7.32	17.05	0.71
MIR-BB 52	Wall (frag.)	B	C1	68.34	0.05	2.32	0.83	0.27	0.52	8.03	19.04	0.59
MIR-BB 53	Wall (frag.)	B	?20–60	69.97	0.09	2.35	1.03	0.65	0.76	7.31	16.98	0.87
MIR-BB 54	Isings 8	BG	0–110	69.77	0.05	2.55	0.30	0.33	0.44	7.55	18.50	0.52
MIR-BB 55	Isings 8	BG	0–110	73.27	0.05	2.43	0.37	0.11	0.51	7.77	14.98	0.51
MIR-BB 56	Frag.of ung.	BG	?0–110	69.97	0.08	2.35	0.52	0.40	0.73	7.51	16.68	1.76
MIR-BB 57	Frag.of ung.	BG	?0–110	70.87	0.08	2.36	0.47	0.44	0.56	7.06	17.14	1.02
MIR-BB 58	Bead	DB-PB		71.77	0.05	2.07	0.39	0.48	0.42	6.46	17.17	1.18
MIR-BM 59	Isings 46a	BG	50–120	72.65	0.06	2.29	0.24	0.18	0.40	7.04	16.63	0.50
MIR-BM 60	Isings 50	BG	50–200	70.77	0.05	2.48	0.27	0.44	0.51	7.72	17.04	0.72
MIR-BM 61	Isings 50 (?)	BG	50–200	70.41	0.09	2.32	0.47	0.50	0.63	6.49	18.42	0.68
MIR-BM 62	Isings 50	BG	50–200	70.11	0.08	2.30	0.48	0.56	0.66	7.26	17.85	0.71
MIR-FI 64	Isings 50	G	50–200	69.77	0.09	2.15	0.46	0.35	0.56	6.48	19.58	0.56
MIR-FI 65	Isings 50	BO	50–200	69.56	0.08	2.15	0.46	0.32	0.56	6.60	19.73	0.55
MIR-AR 66	Isings 106c	YG	C4	66.31	0.57	2.77	1.82	2.02	0.99	5.78	19.38	0.38
MIR-AR 67	Isings 8	BG	0–110	68.56	0.05	2.51	0.40	0.27	0.48	8.29	18.99	0.45
MIR-FA 69	Isings 106c	YG	C4	68.06	0.41	2.61	1.35	1.56	0.97	5.89	18.80	0.34
MIR-FA 70	Frag. Bottom	DB	?C1	70.03	0.06	2.45	0.71	0.41	0.52	8.79	16.38	0.64
CON-CV 71	Isings 106	YG	C4	65.87	0.50	2.60	1.38	2.06	1.19	5.38	20.64	0.40
CON-CV 72	Isings 106	O	C4	68.27	0.45	2.86	1.37	1.65	1.18	5.89	17.91	0.42
CON-CV 73	Isings 106 (?)	PY	C4	64.95	0.60	2.48	1.48	2.43	0.85	5.62	21.17	0.41
CON-CV 74	Isings 8	BG	0–110	69.73	0.06	2.57	0.38	0.36	0.52	8.00	17.71	0.66
CON-CV 75	Frag. Bottom	B	?C1–2	71.13	0.05	2.47	0.42	0.24	0.42	7.20	17.56	0.51
FIN-CSA 77	Isings 106c	G	C4	68.24	0.23	2.31	0.93	1.53	0.91	5.96	19.34	0.54
VM 78	Isings 3	BG	50–150	70.17	0.07	2.50	0.40	0.28	0.53	7.74	17.66	0.64
VM 79	I. 42a var. Limb.	NC	C2	70.24	0.19	2.20	0.66	0.02	0.74	5.19	20.26	0.50
VM 80	I. 42a var. Limb.	NC	C2	70.32	0.05	1.95	0.40	0.15	0.50	5.64	20.50	0.50
VM 81	Frag. Bottle	PG	?50–200	70.03	0.08	2.36	0.42	0.84	0.59	6.86	18.18	0.64
VM 82	Frag. Window	PG	C1–2	70.09	0.09	2.19	0.50	0.36	0.59	6.32	19.14	0.72

MIR-TE: Mirandola (Mo), Tesa (GABM 65); MIR-MO: Mirandola (Mo), Montirone (GABM 6); MIR-BB: Mirandola (Mo), Barchessone Barbiere (GABM 29); MIR-BM: Mirandola (Mo), Baia Masetta (GABM 18); MIR-FI: Mirandola (Mo), Fieniletto (GABM 17); MIR-AR: Mirandola (Mo), Arginone (GABM 4); MIR-FA: Mirandola (Mo), Falconiera (GABM 38); CON-CV: Concordia (Mo), Corte Vanina (GABM 134); FIN-CSA: Finale Emilia (Mo), Corte S. Antonio (GABM 28); VM: 'Valli Mirandolesi'. Site numeration (in brackets) according to Calzolari (1997b).
G: Green; BG: Blue green; O: Olive; PG: Pale green; NC: Nearly colourless; PY: Pale yellow; PB: Paleblue; B: Blue; DB: Dark blue; YG: Yellow green.

TABLE 2 TRACE ELEMENTS COMPOSITION (PPM) BY XRF

Sample	Nb	Zr	Y	Sr	Ce	Ba	La	Ni	Co	Cr	V	Sb	Zn	Cu	As	Pb
MIR-TE 1	n.d	n.d	n.d	559	14	205	n.d	n.d	11	11	17	1472	19	62	30	580
MIR-TE 2	n.d	n.d	n.d	502	9	210	8	n.d	10	7	14	n.d	13	17	n.d	7
MIR-TE 3	n.d	n.d	n.d	509	9	193	n.d	14	4	11	n.d	n.d	n.d	17	n.d	4
MIR-TE 4	n.d	n.d	n.d	537	10	208	n.d	15	9	15	16	1453	17	16	37	557
MIR-TE 5	n.d	n.d	n.d	531	9	212	n.d	16	10	13	14	1350	19	16	20	496
MIR-TE 10	n.d	85	n.d	519	13	133	n.d	14	4	12	14	2281	14	21	40	174
MIR-TE 13	n.d	n.d	n.d	475	9	238	6	n.d	8	11	15	34	20	17	n.d	17
MIR-TE 15	n.d	118	n.d	557	10	300	9	18	8	31	35	n.d	18	33	n.d	11
MIR-TE 17	n.d	42	n.d	581	11	288	8	11	n.d	10	n.d	29	13	17	n.d	5
MIR-TE 18	n.d	n.d	n.d	658	9	269	8	11	9	9	22	n.d	23	25	n.d	3
MIR-TE 21	n.d	n.d	n.d	524	10	212	n.d	n.d	18	11	13	531	23	341	n.d	154
MIR-TE 23	n.d	n.d	n.d	545	12	236	n.d	n.d	23	16	13	530	18	368	n.d	166
MIR-TE 24	n.d	n.d	n.d	562	8	215	6	16	n.d	9	8	n.d	n.d	17	n.d	7
MIR-TE 25	n.d	n.d	n.d	565	9	261	n.d	7	8	8	19	6	14	17	n.d	n.d
MIR-TE 26	n.d	n.d	n.d	538	n.d	196	n.d	14	4	10	11	71	9	31	n.d	11
MIR-TE 27	n.d	74	n.d	692	11	133	n.d	6	n.d	15	13	2547	27	17	n.d	48
MIR-TE 28	n.d	n.d	n.d	508	11	166	n.d	12	n.d	9	12	2184	11	17	n.d	135
MIR-TE 29	n.d	n.d	n.d	534	11	202	n.d	7	8	12	12	1067	15	16	n.d	332
MIR-TE 31	n.d	n.d	n.d	533	8	213	n.d	7	14	11	16	1061	24	234	20	495
MIR-TE 32	n.d	92	n.d	514	8	182	6	10	5	8	n.d	17	8	17	n.d	19
MIR-TE 33	n.d	n.d	n.d	456	9	179	n.d	7	4	11	13	2043	51	16	n.d	144
MIR-TE 34	n.d	n.d	n.d	602	7	369	n.d	n.d	14	11	47	822	15	40	n.d	96
MIR-TE 35	n.d	n.d	n.d	518	9	184	n.d	11	4	9	14	1944	18	17	16	127
MIR-TE 36	n.d	31	n.d	742	7	390	n.d	n.d	13	8	40	29	13	17	n.d	28
MIR-TE 37	n.d	78	21	511	11	167	n.d	13	4	8	14	2192	15	17	19	135
MIR-TE 38	110	n.d	n.d	549	9	214	n.d	6	13	13	13	1041	24	271	n.d	408
MIR-TE 39	n.d	n.d	n.d	550	10	196	n.d	n.d	7	10	10	n.d	n.d	17	n.d	1
MIR-TE 40	n.d	n.d	n.d	575	10	234	6	7	10	10	13	n.d	9	17	n.d	2
MIR-TE 42	n.d	n.d	n.d	514	11	172	n.d	9	n.d	9	12	2115	18	29	19	107
MIR-TE 44	n.d	n.d	n.d	499	9	182	n.d	11	4	11	13	2015	16	17	n.d	123
MIR-MO 45	n.d	n.d	n.d	507	12	199	n.d	9	16	8	13	907	21	291	n.d	363
MIR-MO 46	56	44	n.d	537	14	201	n.d	11	8	10	15	1505	18	16	32	555
MIR-MO 47	n.d	23	n.d	531	7	216	n.d	12	9	11	18	1194	28	66	25	436
MIR-BB 48	n.d	n.d	n.d	554	12	211	n.d	19	15	9	14	967	21	266	n.d	355
MIR-BB 49	n.d	n.d	n.d	521	10	203	n.d	43	15	9	13	947	18	570	n.d	320
MIR-BB 51	n.d	61	20	569	15	258	n.d	9	918	12	16	1881	42	258	43	518
MIR-BB 52	n.d	n.d	n.d	572	n.d	204	8	11	399	9	10	27	30	2396	n.d	17
MIR-BB 54	n.d	n.d	n.d	559	12	212	n.d	7	5	8	10	n.d	8	17	n.d	n.d
MIR-BM 60	84	n.d	n.d	553	n.d	216	n.d	14	6	8	11	93	11	17	n.d	37
MIR-BM 61	n.d	80	n.d	545	12	211	n.d	23	12	10	15	1346	21	242	19	570
MIR-BM 62	n.d	n.d	n.d	556	13	215	n.d	n.d	15	12	15	963	21	319	n.d	366
MIR-FI 64	75	74	n.d	529	8	171	n.d	7	5	8	12	2055	19	17	n.d	117
MIR-FI 65	59	n.d	n.d	562	8	189	n.d	15	6	11	14	2108	14	17	n.d	116
MIR-FA 69	n.d	51	n.d	598	9	799	8	20	9	43	42	23	18	16	n.d	12
MIR-FA 70	n.d	n.d	n.d	600	11	263	n.d	15	779	10	11	902	19	1313	n.d	33
CON-CV 71	n.d	86	n.d	530	10	334	7	15	10	57	45	8	22	17	n.d	21
CON-CV 72	175	44	n.d	565	15	569	11	12	9	46	49	3	20	17	n.d	11
CON-CV 73	n.d	253	n.d	596	8	1641	8	35	9	66	55	n.d	23	36	n.d	32
CON-CV 75	n.d	n.d	n.d	554	n.d	221	n.d	22	689	10	8	20	11	1031	n.d	15
FIN-CSA 77	n.d	n.d	n.d	573	10	354	7	9	11	24	28	31	20	16	n.d	32
VM 78	n.d	n.d	n.d	551	8	236	n.d	7	9	10	8	237	13	16	n.d	106
VM 79	n.d	65	n.d	506	17	128	n.d	7	n.d	16	15	2224	13	17	40	164
VM 82	n.d	n.d	n.d	583	9	296	n.d	n.d	8	10	25	1405	11	17	n.d	54

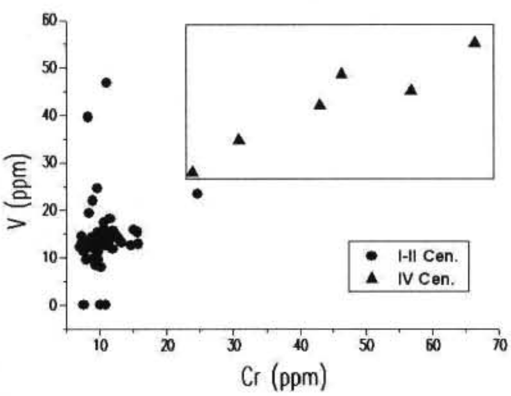

FIG. 2 V *versus* Cr for all the studied samples

ten Aquileia samples showed similarities with our examples, while the others were characterized by significantly lower Si and Na, and higher Al and Ca contents. In contrast, our latest glass and Augusta Praetoria samples from the 4th century showed strong similarities in particular in the amounts of Fe, Mn, and Ti .

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THE IMPERIAL ROMAN WORLD – VESSELS AND THEIR PATTERNS OF USE

ANOMALIES AMONGST EARLY ROMAN MOULD-BLOWN GLASS VESSELS

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Ancient mould-blown glass vessels are generally regarded as forming a distinct and fairly well-defined group. Not only do they provide the names of individual craftsmen, but they are also decorated with distinctive designs that can often be related to each other. In addition, production of multiple copies allows for a close study of types, their development, and even their patterns of distribution. Much effort has been devoted to classifying the various groups, especially amongst the very numerous small bottles, jugs and *amphoriskoi* of the 1st century AD. This paper, drawing principally on examples in the collection of The Metropolitan Museum of Art, presents some examples that may be regarded as not conforming to the normal pattern. It also raises the question of whether the production of mould-blown vessels was distinct from that of free-blown glass. Evidence will be presented to show that mould blowing was at least partially integrated with the free-blowing industry.

Of particular interest are two mould-blown bottles (FIGS 1–2) that were acquired as part of the J.P. Morgan gift bequest in 1917. They previously belonged to the Gréau Collection, which was published along with superb watercolour engravings 100 years ago (Froehner 1903, 162 nos 1172–3, pl. ccxiv.2–3). The two bottles have no provenance and, despite the fact that they appear to have been made in the same mould, there is no way of telling if they were found together. They belong to the class of small hexagonal bottles, blown into a multi-part mould and decorated in high relief around the sides. Such bottles have in recent years been the subject of intensive study. Numerous examples are now known through publication from archaeological contexts and museum collections, and sadly too from sales catalogues. Excavated examples are listed by Stern (1995, 115, 130, 136, 143, with refs in footnotes), to which may be added examples in museums and collections (see *Ancient Glass* 2001, 103, no. 146; Arts 2000, 55, 102–3, no. 40; Kunina 1997, 277–9, nos 131-6; Stern 2001, 51–2, 114–16 nos 44–6, 122, no. 51; Whitehouse 2001, 36–42, nos 506–11; for examples currently on the market, see Christie's 2003, 123 lots 180–1). Indeed, such vessels were clearly intended to be mass-produced, since the moulds could be used repeatedly, and new moulds could be easily created from an existing vessel.

Scholars have, therefore, been able to construct whole typologies and sequences of mould series. The detailed classification of 'hexagonal vessels with high relief' is set out most clearly and exhaustively in the introduction to Marianne Stern's catalogue of *Roman Mold-blown Glass* in the Toledo Museum of Art (Stern 1995, 74–86). However, the different categories of such bottles were first outlined many years ago, primarily by Gustav Eisen (Eisen 1927, I, 233–4, 247–53, pls 50–2). Essentially there are five types, distinguished by the relief designs set in the panels around the body: Vessels (also called the 'Temple' series by Eisen), Masks, Fruit, Mixed Symbols (or 'Athletic Symbols'), and Birds. Stern presented a plausible explanation for the development and relationship of the various types in the Toledo catalogue. It does not, however, represent the only plausible reconstruction, and it does not cover certain anomalies.

The two vessels in the Metropolitan Museum provide a case in point, for they do not fit into any of Stern's categories of types by decoration or mould construction. They are what might be considered 'hybrids' – that is, the six central panels do not conform to a single known type but include vessels (on four of the panels) and fruit (on the remaining two panels). Between the panels are well-delineated columns with capitals and bases, while on the shoulder there are six arches, each containing an ovoid object. These features link the type closely to the main Vessels type. However, the actual vessels depicted on the two bottles are unusual. There are four different shapes: 1) a large, deep bowl, 2) a vessel containing fruit, 3) a footed vessel with long curving handles, and 4) another footed vessel with a conical lid. Tall spouted pitchers or jugs are not represented, whereas they are normally found on the Vessels type. Instead, there is a lidded vessel, which finds no parallel amongst the Vessels or any other type. Moreover, around the bottom in place of the usual decoration of hanging fillets and bunches of fruit, there is a pattern of upturned tongues. This element is only found on Stern's Series C of the Vessels type, although it also occurs on later generations of the Fruit type and other categories of hexagonal bottles.

The mould construction type (Stern's MCT) is also unusual. The Vessels type employs only MCT II or IVA. The bases of the two bottles do not belong to either of these categories. Indeed, they do not fit precisely into any of the MCT groups as tabulated by Stern (Stern 1995, 28, fig. 15). Rather, their MCT is a mixture of Stern's categories I and V, making the bottles more closely related to hexagonal jugs with Dionysiac Symbols (Stern 1995, 160–6, nos 71–4). Finally, whereas most hexagonal bottles are strongly coloured (that is, they are made in either opaque or deeply coloured translucent glass), these two examples are in a naturally coloured blue green and pale green. So they may be taken as evidence for the fact that interrelations between groups are more complex than Stern envisaged. New discoveries may add yet further types and series in due course.

The only parallel for the Metropolitan Museum's vessels is an example that was excavated in a tomb at Kato Paphos on Cyprus in 1988 (Karageorghis 1989a, 59–60, 62, no. 5, fig. 97; 1989b, 846, fig. 140). Not only does this jug have the same arrangement of vessels and fruit around the sides (as well as other identical decorative elements), but it also has the same rather squat body and proportionally taller neck. It, like one of our two bottles, has a handle with a looped, vertical thumb rest. It would appear, therefore, that this type forms a small transitional group not only between types within the standard grouping of hexagonal bottles in high relief, but also between these and the other bottles and jugs whose decoration is more akin to that of mould-blown tablewares.

Another well-known group – namely, vessels belonging to Stern's 'Workshop of the Floating Handles' (Stern 1995, 86-91) – provides further evidence for the complexity of the early mould-blown glass industry. There are five vessels of this group in the Metropolitan Museum. One belongs to the basket amphora type (FIG. 3), while another is a rather poorly defined example of the Ajax bottle (FIG. 4). Two others are piriform jugs of the so-called 'Hunt-and-Scroll' type (FIG. 5 and 17.120. 243, not illustrated), while the remaining vessel is a free-blown amphora (FIG. 6).

Disentangling the web of interrelations between the different types of vessels in the 'Workshop of the Floating Handles' group has not been made any easier by errors in some of the publications. These need to be corrected. For example, the intact Ajax flask from Stratonikeia has been described as 'fragments' (Stern 1995, 91; contrast Özet 1993; 1998, 47–8, no. 15), and the Hunt-and-Scroll bottle from Zadar is, apparently, not in the Murano Museum (Whitehouse 2001, 53). It has been stated (Whitehouse 2001, 51) that Özet identified one side of the Ajax flask as representing the seventh labour of Hercules. In fact, she correctly identified the figure as Ajax, although the animal the hero is about to slay may more correctly be identified as a sheep rather than a bull (Özet 1993, 143–4). The Metropolitan Museum's Ajax bottle, in translucent honey yellow with matching handles, has been overlooked in recent publications. It is not listed by Stern (1995, 89, n.155) or Whitehouse (2001, 49), although it was mentioned by Özet (1993, 144–5). Of the ten known examples of this type, six are in opaque white glass, and two are in translucent manganese purple with opaque white handles, while the purple bottle from Stratonikeia is the only other example entirely made of translucent glass. Although the Ajax vessel in the Museo Vetrario di Murano is said to have 'normal' handles (Stern 1995, 90, n.160; contrast Ravagnan 1994, 34, no. 28), my research seems to indicate that all of the known Ajax vessels, if they had handles, had ones of the 'floating' type, as is clearly indicated on the example in the Metropolitan Museum.

The list of examples of 'Hunt-and-Scroll' vessels in the second volume of *Roman Glass in the Corning Museum of Glass* (Whitehouse 2001, 53, no. 525) includes one of the Metropolitan Museum's examples (17.194.249), citing a reference in Eisen (Eisen 1927, I, 235, pl. 55a). However, the vessel illustrated in Eisen's plate does not match with the actual vessel in the Metropolitan Museum, although the latter does tally with Massias' engraving in the folio illustration to Froehner's catalogue of the Gréau Collection (Froehner 1903, 157, no. 1133, pl. ccv.4). In fact, it has proved impossible to trace such an amphora in the Museum's collection. This is indeed a pity, since the vessel in Eisen clearly has 'normal', not 'floating' handles, making it a singular piece. No other example amongst all the types of mould-blown vessels attributed to the 'Workshop of the Floating Handles' has such 'normal' handles. It would be a great help if Eisen's amphora could be traced and thus examined alongside other examples of the Hunt-and-Scroll type.

The final example from the 'Floating Handles' group (FIG. 6) is one of only two vessels attributed to this workshop that is free-blown, the other being from a grave find at Miletus (Stern 1995, 89–91, fig. 66). Both of these vessels are also unusual because of their size. They are considerably taller than the average mould-blown vessel; for instance, the Metropolitan Museum's example has a height of 124mm. It raises the question of whether the larger size of the free-blown pieces showed the use of 'floating' handles to be impractical because they were less sturdy than 'normal' handles. It may, however, have been merely a matter of technique, for in general ancient glass workers clearly found it easier, regardless of whether they were producing core-formed or blown vessels, to apply the handles to the body and trail them up to the rim.

Certainly the lessons learnt during the Hellenistic period not just in glassworking techniques but also in the mass production of pottery and lamps using moulds were not lost on the craftsmen who established the Roman glass industry. The details of how these craftsmen and their workshops operated remains sketchy, but it would seem that they did not work in isolation. Glass kilns have been found in close proximity to pottery ones (for example, at Lyon: Foy and Nenna 2001, 49–50). Likewise, tomb groups show that core-formed, cast and blown vessels were sometimes deposited together. A good example of a tomb that has yielded cast, free-blown and mould-blown vessels is provided by burial 4466 at Acanthus, Greece (Trakosopoulou 2002, 84–5, figs 12–13; *cf.* also Ravagnan 1994, pl. xxiv (tomb 1b from the cemetery at Nona), while tombs containing core-formed and blown glass have been noted on Rhodes (Jacopi 1932–3, 533–4, nos 11–14, figs 67, 68–9: tomb 41) as well as in Italy (Ravagnan 1994, 164, no. 320, pl. xxiii: tomba di Salizzole, Verona). In the last example one may note especially the 'floating' appearance of the handle, although the vessel itself is quite unlike the *oinochoe* in the Royal Ontario Museum that is

FIG. 1 Mould-blown hexagonal juglet; ht. 95mm, no provenance. The Metropolitan Museum of Art, Gift of J. Pierpont Morgan, 1917 (17.194.229)

FIG. 2 Mould-blown hexagonal bottle; ht. 106mm, no provenance. The Metropolitan Museum of Art, Gift of J. Pierpont Morgan, 1917 (17.194.230)

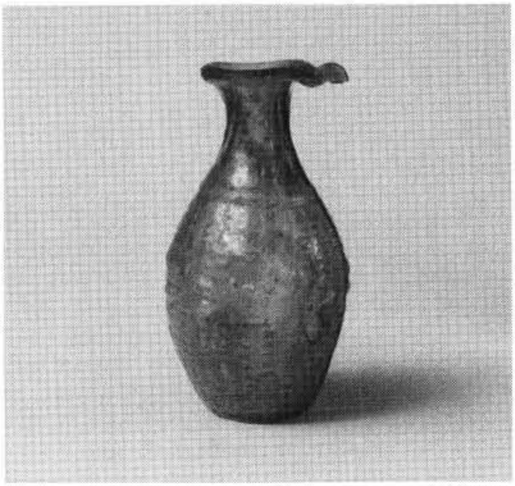

FIG. 3 Mould-blown basket flask (*amphoriskos*); ht. 106mm, no provenance. The Metropolitan Museum of Art, Gift of J. Pierpont Morgan, 1917 (17.194.222)

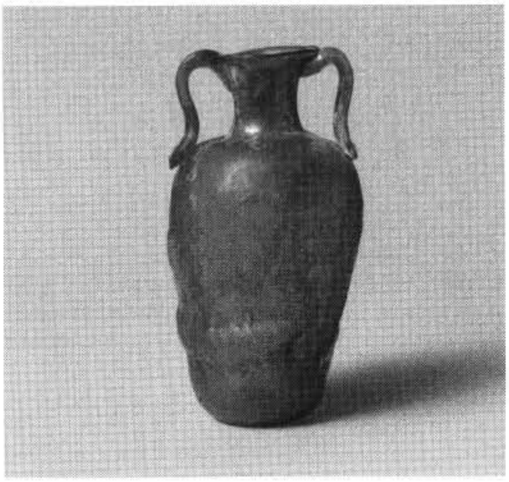

FIG. 4 Mould-blown Ajax flask (*amphoriskos*); ht. 106mm, said to be from Emesa (Homs), Syria. The Metropolitan Museum of Art, Rogers Fund, 1946 (46.11.4)

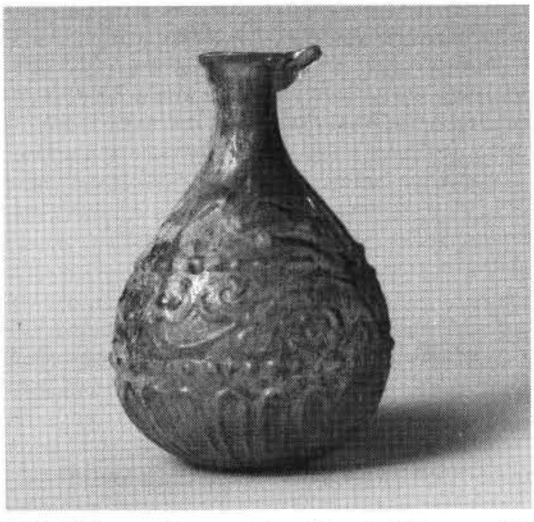

FIG. 5 Mould-blown Hunt-and-Scroll jug; ht. 98mm, said to be from Syria. The Metropolitan Museum of Art, Gift of J. Pierpont Morgan, 1917 (17.194.249)

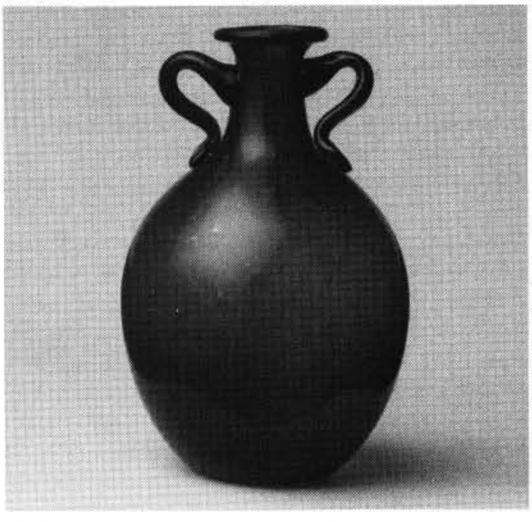

FIG. 6 Free-blown *amphoriskos*; ht. 124mm, no provenance. The Metropolitan Museum of Art, Gift of J. Pierpont Morgan, 1917 (17.194.157)

quoted as a parallel (Hayes 1975, 12, 188, no. 22). These tomb groups, although few in number, at least imply that in the early to mid-1st century AD glassware made in a variety of techniques was circulating in the market

It is to be hoped that further discoveries, especially in the East, will help clarify the interrelationship between the various glassworking techniques. Many questions and areas of uncertainty remain but, as the number of published finds increases, the corpus of types expands. This, too, means that examples of deviations from the set pattern will also become more apparent. The few vessels presented here serve to illustrate one aspect of the diversity and flexibility of the Roman glass industry and warn against the over-classification and compartmentalisation of types.

Acknowledgements

During the 2001 Congress in New York I had the pleasure of showing Dr Yael Israeli around the glass storeroom in the Department of Greek and Roman Art at The Metropolitan Museum of Art. This presentation is, therefore, dedicated to her, since it was Dr Israeli who drew my attention to the significance of the two vessels that form its main subject. I also wish to thank Dr Carlos Picón, Curator in Charge, Department of Greek and Roman Art, for his continued support for and encouragement of my work on ancient glass. All photographs by Paul Lachenauer, The Photograph Studio, The Metropolitan Museum of Art.

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PATTERNS OF USE OF ROMAN GLASS IN SLOVENIA – SOME OBSERVATIONS

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The Roman-period glass found on the territory of present-day Slovenia has been classified into ten groups of vessels (plates, bowls, beakers, ladles, jars, bottles, jugs, cosmetic vessels, lamps, miscellaneous), with 154 different variants distinguished (Lazar 2003a, 24). The classification into variants was carried out using only those fragments preserved to the extent that sufficiently distinctive characteristics could be noted.

The proportions among individual glassworking techniques indicate that blown vessels predominate (Lazar 2003a, 233, fig. 66). This new technique supplanted the more complicated and expensive manufacturing processes and, at the same time, its development coincided with the extension of the Roman state into the territory of Slovenia and the complete Romanization of this area.

The proportions of individual groups of products in reference to their use showed that tableware greatly predominated (70%). Storage and transport was the purpose of 21% of the vessels, primarily represented by various bottles and jars that served for the storage of provisions (Lazar 2003a, 234, fig. 67). The remaining products were various small vessels for cosmetics and medical preparations, and a small group of other forms that appear only as individual examples.

A review of the number of variants per individual form also shows that products that served as part of a table service (groups 1–3) were best represented (FIG. 1). Bowls and beakers (groups 2 and 3) stand out from the remaining glass products in terms of quantity and the number of variants. Their representation and mutual relations could be compared through several centuries. Although beakers exceed bowls in terms of quantity (FIG. 2), a growth in the number of variants was noted for both forms from the end of the 1st century and in the 2nd century, with a subsequent exceptional decline in later centuries. Only groups 5 and 6 (jugs and bottles) could be compared in terms of quantity with these groups; these were fairly well represented in terms of the number of variants and quantity of products. The number of the other products was too modest for suitable comparison.

Jugs were somewhat widespread in the first two centuries, and their use continued into the first half of the 3rd, after which their quantity declined drastically. Comparisons with the bottles show quite well that the proportions between these forms were fairly balanced up to some time in the mid 3rd century, after which bottles were predominant.

Bottles exhibited a relatively uniform representation from the second half of the 1st century onwards and

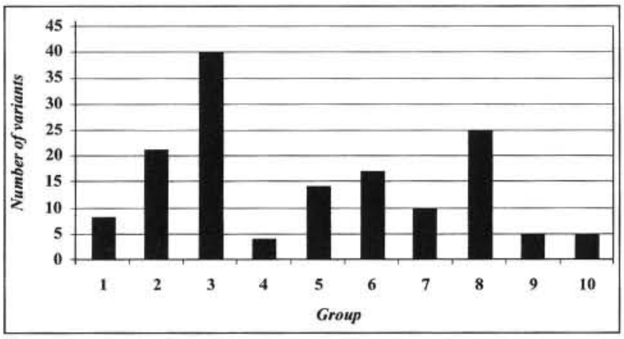

FIG. 1 Number of variants per group

continued in use to the end of the 4th century. The comparison of two sub-groups has shown a predominance of bottles with handles in the first two centuries and their marked decline in the 3rd and 4th centuries. In later centuries bottles without handles predominate.

Comparison of the number of forms and their variants through the centuries shows the increase in the number of variants in the 1st century on the one hand, and the decline in the number of forms and variants in the 4th and 5th centuries on the other, reflecting the development and representation of glass products in the material culture of the Roman period in Slovenia, as well as the economic conditions in the area (FIG. 3).

Even in the 1st century, a change between the first and second halves is evident. Only in the first half of the 1st century were all three manufacturing techniques more or less equally represented, while the quantity of products indicates a relative proportion between them. In the second half of the 1st century, the number of forms increased by more than 100%, showing that the use of glass had spread among all strata of the population, and further indicating the total Romanization of the region of present-day Slovenia. At the end of that century, all larger settlements were awarded *municipium* status, receiving rights of citizenship, and with the establishment of the road network and provincial administration, Roman civilization took over the entire territory of Slovenia.

Within the group of cast products made during the first half of the 1st century ribbed bowls predominate. They are found in various versions among grave and settlement finds. This group of products also includes several luxurious pieces of mosaic glass (Lazar 2003a, 32, fig. 9), which were imported from northern Italian production centres.

Products of blown blue green glass predominated in the second half of the 1st century. Characteristic forms had

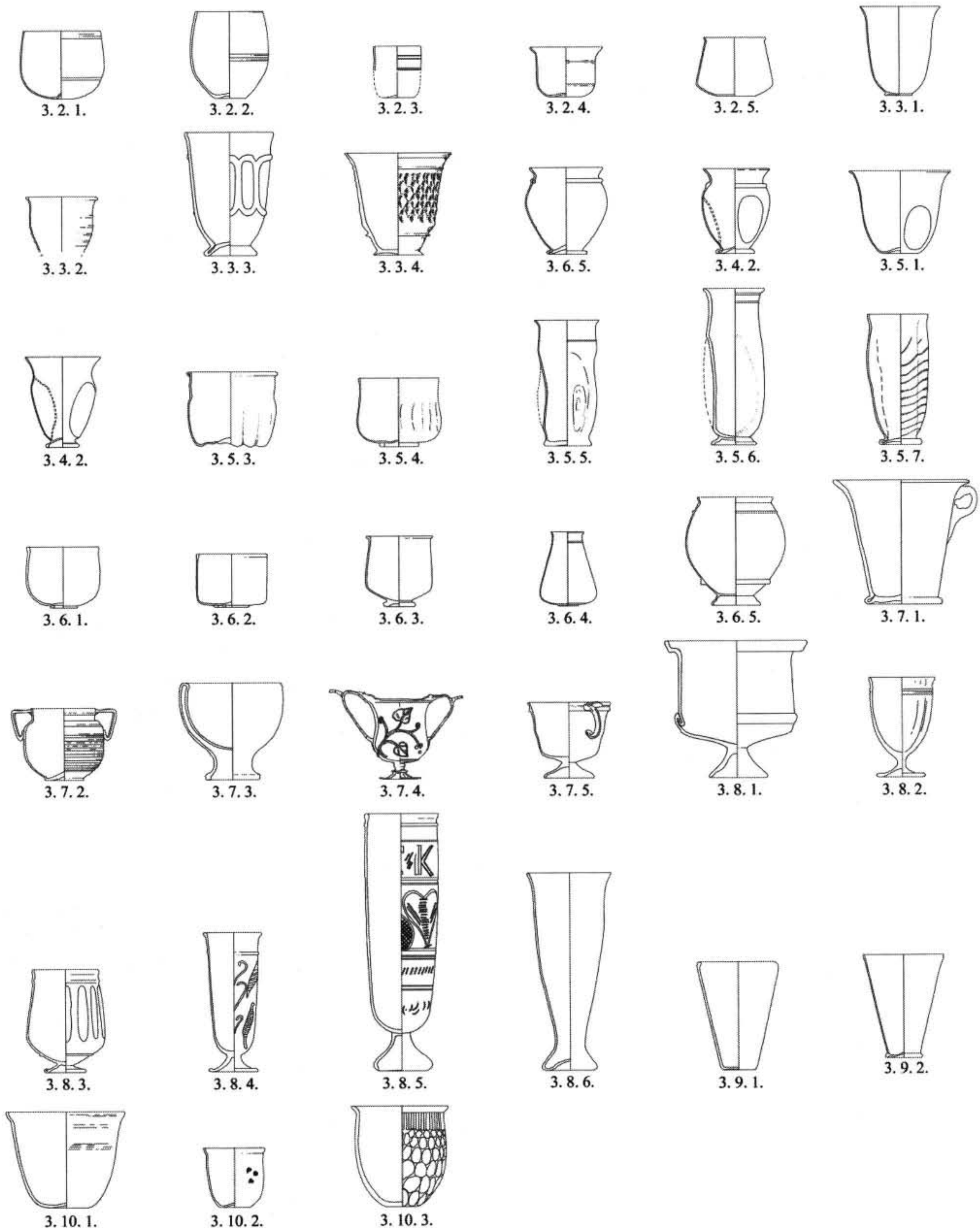

FIG. 2 Group 3 – variants of Roman glass beakers in Slovenia; scale 1:6

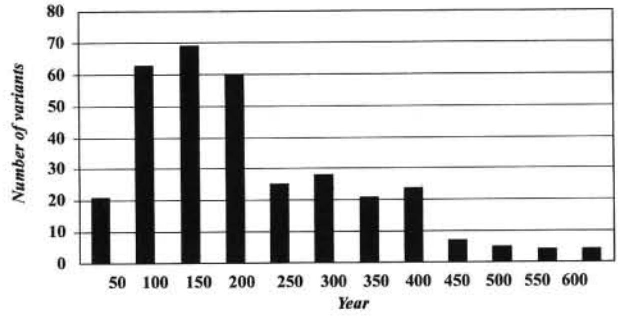

FIG. 3 Number of variants of Roman glass in Slovenia through the centuries

folded back and flattened rims, triangularly shaped or tubular rolled rims; while the bases were often simply formed and concave in the centre, at times with a standing surface drawn out on the edge, and formed or pressed into a low ring base. Some forms imitate products made from precious materials, such as two-handled beakers and footed goblets with a characteristic stepped rim (FIG. 2: 3.7.5.; 3.8.1.). Such forms are no longer found in the following centuries, except as individual pieces. Small ladles with vertical handles (Lazar 2003a, 123) and shallow dishes and jugs of coloured glass are also a special feature of this period.

Small globular bowls with ribs and marvered decoration of horizontal trails (so-called *zarte Rippenschalen*) were also very popular till the mid 1st century. They were discovered both in graves and in settlement strata. The early use of this form in Slovenia is indicated by the graves from the Augustan period from Mihovo (Haevernick 1958, 80). Some bowls are known also in later graves from the second half of the 1st century (Dobova – Petru 1969; Trebnje – Slabe 1993, 25).

Many products from the second half of the 1st century were blown from glass with an emphasized blue shade, as can be noted on artefacts from graves in Celeia (Celje) and in Emona (Ljubljana). This special feature indicates related or identical sources for products that during the 1st century primarily reached Slovenia through Aquileia as the central trade centre for this area.

The 2nd century showed a continuation of the exceptional growth in the use of glass products. Many forms that had appeared as early as the 1st century were still in use. These were primarily bottles with a handle, collared bowls, and some forms of indented beakers (Lazar 2003a, 98–100), which were joined by new variants (FIG. 2: 3.5.1.–4, 3.5.7.). High-quality thinly blown beakers and indented beakers from milky white glass were also popular (FIG. 2: 3.5.5.–6.). Simple cylindrical beakers (FIG.2: 3.6.1.–2.) were very widespread and appeared in many sizes and variants. They were often made of decoloured glass.

Certain special features and changes in production can be noted as characteristic for this and the following century: the formation of the rim was more simple, the edge was fire-rounded or thickened, the rims of bottles were simply turned out, somewhat funnel-like. The base most often had an applied single or double foot-ring. The emphasis was on simple forms; the decoration was reduced, indentations predominating. Two decorative techniques newly appeared in the century: the application of glass threads or trails on the walls, neck, and even all over the vessels, and wheel-cut geometric decoration.

Part of the demand for glass vessels for everyday use in the 2nd century was certainly satisfied by products from local workshops. The finds from Ptuj (Poetovio) and Celje (Celeia) prove the existence of glass production from the 2nd century onwards (Lazar 2003b, 80).

Most of the products, and particularly those of better quality, still came from the northern-Italian workshops (Lazar 2003a, 72, 75, 100). At the end of the 2nd and in the 3rd centuries they were joined by production centres from the Rhine valley (*ibid.*, 83). The applied decoration on higher quality vessels copied floral and figural motifs. These products were imported from eastern workshops, and they were characterized by deliberately decoloured glass with trail decoration. Two footed goblets from Poetovio are a good example of such vessels (FIG. 2: 3.8.4; Lazar 2003a, 115). Products of the western, mostly Köln workshops, where the vessels were decorated with multi-coloured glass threads, at present are not represented to any great extent in Slovenia, as only a few small fragments have been preserved (Lazar 1993, 9, pl. 2.4).

A considerable decline in the quantity of glass products can also be perceived in the 3rd century in the eastern Alpine region. Some individual forms pass out of use. The variety of individual forms and the quantity of vessels was also reduced.

The various simple wheel-cut decorations that appeared on products in the 2nd century, evolved into demanding geometric and figural motifs in the 3rd century. Simple hemispherical forms of bowls and beakers became ever more widespread, and the details of the manufacture also changed, most notably in the forming of the vessel rims. There were increasing numbers of products with cut rims, which were sometimes ground, but not on the simpler products.

Characteristic products of the 3rd century were hemispherical bowls with somewhat thickened walls of colourless or sometimes milky white glass, decorated with wheel-cut geometric decorations of circles, almond-shaped hollows, and rhombs. The most valuable products of this period are vessels with cut figural decoration and decoration in high relief (Lazar and Tomanič Jevremov 2000, 201, pl. 1.2).

In the 4th century, the number of forms was drastically reduced, as was the number of individual variants. Conical glasses predominate (Lazar 2003a, 117–20) and hemispherical bowls with cut, curved rims (FIG. 2: 3.8.6–3.10.3.) and flat, slightly concave and base-rings also appear. The rare decoration consisted only of horizontal wheel-cut lines, later joined by applied drops of glass in contrasting colours. New forms of the late-Roman period were conical lamps and lamps with a handle, although it is sometimes difficult to determine between beakers and lamps (Lazar 2003a, 198).

There are few storage vessels. Bottles frequently have a cut, outward-turned rim, with at times the addition of a thread applied under the rim. The walls of bottles gently taper towards the base. Their quantity was minimal and closed forms slowly disappeared from use. Tablewares predominated, particularly drinking vessels, such as the previously mentioned simple beakers and cups, and at the end of the century also shallow hemispherical bowls. Decoration on these products is rare, usually consisting only of indentations.

Valuable vessels of the late-Roman period, such as bowls with wheel-cut figural decoration, *diatreta* products, and those with gold medallions, are almost unknown in Slovenia. Those that are known are preserved only as modest fragments (Mikl Curk 1963, 492).

The glass product trade routes to Slovenia in the 1st century led mostly through northern Italy. The main merchant centre for trade in the eastern Alps, Pannonia and the Balkans was Aquileia, where the products of the northern Italian and partly the central Italian workshops were gathered. Rare valuable products also arrived from the eastern Mediterranean and Egypt. The Aquileian influence in the south-eastern Alpine region continued into the first half of the 2nd century, as the majority of products still came from Italian workshops, which particularly applies to high-quality vessels of decoloured glass. The influence of the glass production centres in the Rhine valley, particularly the Köln workshops, developed and spread in the middle of the 2nd century. Their production began to displace the influence of the Italian workshops and satisfy demands even in that part of the Empire (Lazar 2003a, 109, 115). In this period, the demand for glass products for everyday use to some extent began to be satisfied by local glass production centres – Celeia and Poetovio.

Political conflicts aggravated economic conditions in the 3rd century and caused considerable changes, which were soon reflected in the glass industry. From the second half of the century demand declined greatly, and most of the trade could be supplied by local and nearby Pannonian production centres, while imports from the Rhine valley declined. Expensive objects appeared only exceptionally.

The regression continued in the 4th and 5th centuries. It is difficult to establish to what extent trade was still extant, and to what extent local industry was active in supplying at least the immediate vicinity. The quality of the glass products was poorer: the walls were full of glass bubbles, and an olive green colour predominated. Conditions in larger towns at that time certainly enabled the continuation of tradition and the use of glass vessels, which in smaller settlement had almost died out because of poor economic conditions.

Glass manufacture took place on the territory of present-day Slovenia from the 2nd century onwards. It probably did not extend beyond a local framework, and the products primarily filled demand for objects of everyday use, such as *balsamaria*, beakers, bottles, and window glass. Finds of furnaces, raw glass, and glassworking waste from Celeia and Poetovio prove that a glass industry developed here as early as the beginning of the 2nd century.

Remains of raw glass, waste from blowing, and destroyed products at Celeia and Poetovio prove the existence of the secondary production of glass, i.e. the manufacture of glass vessels. The craft depended on the use of imported raw glass, which was prepared in larger glass production centres. Primary glass production, i.e. the preparation of raw glass from the basic ingredients, would not, according to the present state of research, have existed in the region of Slovenia.

Judging from the finds known to date, glass manufacture was best developed at Poetovio. The glass furnaces discovered and the remains of crucibles and glass waste directly prove the production of glass and of the developed glassworking craft (Lazar 2003b, 79). The remains of products created in these workshops are not very numerous among the excavated material. On the basis of several fragments it can at least be hypothesized that the Poetovio glassworkers manufactured square bottles with the decoration of a rosette on the base, cylindrical beakers, and *balsamaria* (Lazar 2003a, 230). Chemical analysis of the raw glass and fragments of bottles has shown that the glass had the same composition, further evidence in support of the hypothesis.

The typological analysis of the glass from the Poetovio sites has pointed to some products that stand out in terms of form and could have been produced in local workshops. The largest group consists of *balsamaria* with a stepped widened neck at the juncture with the rim (FIG. 4). The form does not appear at other sites, however it is a characteristic offering in the graves of Poetovio. The second interesting form is a goblet of globular form on a high ringed base (FIG. 2: 3.6.5.), which has no analogies. It was found in a grave from the 2nd century, and its unique nature leads to the assumption that this was a local product. The last group of hypothesized local products is composed of small bottles and jugs with globular bodies and an applied decoration of glass trails, which are numerous among the material from *Poetovio*. Their common characteristic is an almost uniform manner of forming the applied decoration.

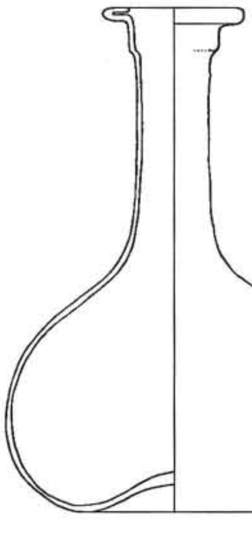

FIG. 4 Local form of *balsamarium* with stepped rim, Poetovio (Ptuj); scale 1:2

On the basis of the glass and pottery finds discovered next to the glass furnaces, it can be established that the workshops were active in the 2nd and 3rd centuries, more specifically at least in the first half of the latter. The finds from the end of the 1st century are too sparse for the beginning of glass manufacture in Poetovio to be placed in an earlier period.

The numerous settlement and grave finds from Poetovio enable analysis and comparison of the development of the town and the reflection of this in the material culture, and in this case the glass products. Poetovio received the status of a *colonia* during the reign of the emperor Trajan, and in the following two centuries it experienced the period of its greatest development in the economic and political sense, as the town was the seat of the Illyrian customs service.

Products from the first half of the 1st century were scarce among the material from Poetovio. From the second half of the 1st century onward, the number of glass vessels increased by almost 300% (Lazar 2001, 34). These were simple and mostly undecorated products for everyday use. The majority of forms remained in use in the following century, when the spectrum of shapes was supplemented and new decorations appeared. The range of forms shrank in the 3rd century, until in the 4th century they were limited primarily to forms intended for drinking. It is interesting that despite the limited spectrum of glass vessels in use in the 4th century, the cemeteries of Poetovio still show regular use of glass objects and their placement in graves. This reflects the still lively pulse of the town, and perhaps the characteristic conical beakers and lamps can be connected to a powerful Christian community and the religious life of the city.

Poetovio stands out among the archaeological heritage of glass material in Slovenia with certain exceptional objects, which were available only to the wealthiest stratum because of their rarity and high price. All these objects came from distant production centres that specialized in particular types of products and often made them to order. The presence of such finds, was a reflection of the great economic power of the town.

The legacy of glass vessels at other centres, such as Emona, Celeia, and many other sites, is extensive, but not yet completely evaluated. Further study will certainly enable numerous comparisons, analyses, and interdisciplinary research.

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LE VERRE ROMAIN D'ÉRÉTRIE, EUBÉE (GRÈCE)

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Une importante quantité de fragments de verre fut découverte lors des fouilles conduites en 1998 à Erétrie, sur l'île d'Eubée, par l'Ecole suisse d'archéologie en Grèce, dans le secteur E/600 NW, baptisé ultérieurement quartier du Sebasteion. Le verre romain n'avait, à ce jour, pas encore fait l'objet d'une étude approfondie, car il n'avait été retrouvé qu'en petite quantité à Erétrie (Ducrey *et al.* 1993, 140–1, pl. 285–9). La concentration de ce matériel sur cette parcelle et le large éventail des formes identifiées m'ont poussée à l'étudier dans le cadre de l'étude du quartier du Sebasteion, dont les résultats paraîtront dans la collection *Eretria, fouilles et recherches*.

Le but de la présente étude est de fournir un catalogue servant de base pour les futures analyses de verre romain découvert à Erétrie et plus généralement en Eubée. Dans le contexte des fouilles du quartier du Sebasteion, la détermination des différents types de récipients était primordiale pour pouvoir proposer des hypothèses sur leur datation, leur provenance, mais aussi pour identifier des formes plus rares.

Le quartier du Sebasteion

Le quartier du Sebasteion, ainsi dénommé en raison de la découverte du temple du culte impérial, s'étend le long de la voie antique ouest-est venant de Chalcis, longeant le pied de l'acropole et se poursuivant en direction d'Amarynthos (pour un plan général, voir Ducrey et Fachard 2003, 93, fig. 1). Une voie nord–sud se détache de l'axe ouest–est, laissant à l'Est la Maison aux Mosaïques, riche demeure d'époque classique (Ducrey *et al.* 1993). Le gymnase se dressait sur le flanc de l'acropole (Mango 2003). Le théâtre et un quartier d'habitations privées des époques classique et hellénistique, le Quartier Ouest, se trouvaient près de l'enceinte occidentale de la ville (Ducrey *et al.* 1998).

Le quartier du Sebasteion (FIG. 1) a connu plusieurs phases d'occupation, dont les plus récentes ont pris fin suite à de violentes destructions, dues vraisemblablement à la Guerre de Chrémonidès à l'époque hellénistique (267–263 avant J.-C.) et à la prise d'Erétrie par Sylla en 86 avant J.-C. (Schmid 1999a, 273–5). A l'époque impériale, de nouvelles constructions s'établissent sur les ruines de l'ancien habitat et témoignent d'un changement dans son organisation et dans sa fonction. Le sol des pièces est rehaussé et de nouveaux murs sont élevés avec des matériaux de récupération (tuiles, fragments de céramique, briques), mode de construction qui diffère radicalement de celui des murs antérieurs en gros blocs polygonaux, sur lesquels ils prennent partiellement appui. Des bassins sont aménagés dans plusieurs pièces. La découverte de couches de coquillages de pourpre entiers et fragmentés et de pesons dans le secteur suggèrent qu'il s'agit d'un atelier de teinturerie.

Le Sebasteion se dresse au Nord du carrefour où la rue nord-sud se dégage de l'axe ouest-est (Schmid 2001a). Un four à chaux (FIG. 1, ST 27) du Ier siècle après J.-C. a été installé une dizaine de mètres plus à l'Ouest (Demierre 2001). Un canal, qui se termine par une fosse, a été aménagé parallèlement à l'artère ouest-est. Sa fonction n'est pas établie avec précision (Schmid 2001b, 81–3).

Localisation du verre sur le site

Les fragments de verre se trouvaient principalement dans la couche de remplissage du four à chaux et au Sud de ce dernier (FIG. 1, FG 4–5) (40.8%). Les autres fragments se répartissent de manière relativement homogène sur toutes les parties fouillées du site, avec une concentration plus forte dans la zone DE 1–2 (20.4%). La proportion des différents types de récipients est égale dans les divers secteurs de découverte.

La concentration de débris de verre dans le four, mêlés à des fragments de céramique et de mosaïque, semble être due à un grand nettoyage effectué au Sud-Est du quartier du Sebasteion (Schmid 1999b, 122), dont les déchets ont été transportés vers le Nord-Ouest pour aboutir dans le four, réduit à la fonction de dépotoir dès le début du IIIème siècle après J.-C.

Formes diverses du verre

Les fouilles du quartier du Sebasteion ont livré un matériel relativement riche: au total, 2575 fragments de verre ont été mis au jour, dont seuls 546 ont été pris en compte pour l'étude typologique. Parmi ceux-ci, 209 pièces sont des fragments de bases ou de lèvres de types non déterminés; 17 pièces sont des objets en verre et deux des éclats de vitres.

Dans cette étude, les récipients ont été regroupés selon leur utilisation et leur morphologie. Ce classement permet d'observer une grande variété de formes à Erétrie. La vaisselle de table est la mieux représentée (96%). Elle se divise en récipients servant à verser (10%), à boire (71%), à contenir des aliments (17%) et à stocker (2%). Les récipients destinés à la toilette sont, quant à eux, peu

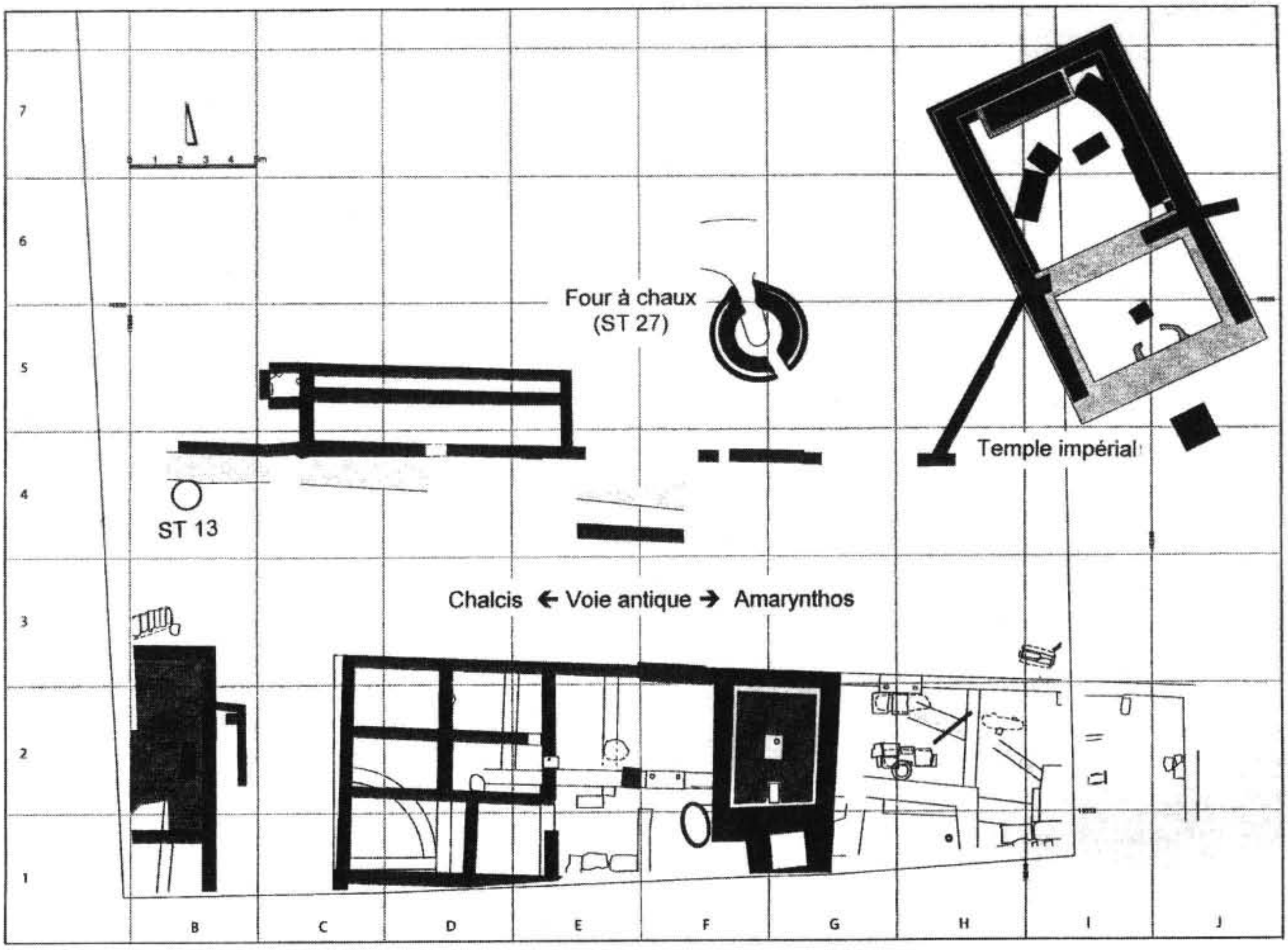

FIG. 1 Plan du quartier du Sebasteion (ESAG)

nombreux (4%). Il est possible que ces résultats soient biaisés par le fait que les lèvres de types non déterminés, qui appartiennent à des formes fermées et qui pourraient se rattacher à des balsamaires par exemple, n'ont pas été prises en compte. Les récipients de toilette pourraient donc être plus nombreux (18%, si nous considérons que toutes les lèvres indéterminées appartiennent à des récipients de toilette).

Les gobelets à lèvre éversée, dont la forme est proche du type AR 77 (Rütti 1991, 82–4, pl. 72-4), sont les formes les plus fréquentes sur le site, ainsi que les gobelets de type AR 98.1B (Rütti 1991, 91, pl. 77–8). Ils sont toutefois assez mal conservés, car seule la partie supérieure (lèvre et col) a subsisté.

Les autres récipients ne se distinguent pas par leur nombre. Ils appartiennent généralement à des formes connues aussi bien en Orient qu'en Occident, dont les parallèles sont répertoriés dans les typologies d'Isings 1957 et de Rütti 1991.

Quelques exemplaires de vaisselle romaine d'Erétrie sont présentés ci-dessous. Leur profil est généralement plus connus dans la partie orientale de la Méditerranée et certaines formes, par leur originalité, pourraient être locales.

Les cruches nos 1–2 (FIG. 2.1–2; Charlesworth 1966, 26–7 no. 2a, fig. 3a), caractérisées par une lèvre ourlée vers l'extérieur en direction du bas, puis du haut, dont le bord part vers l'extérieur, sont des formes rares dans les provinces occidentales, mais beaucoup plus communes dans les régions orientales de la Méditerranée, particulièrement en Syrie et à Chypre, où se situerait leur lieu de fabrication. Le fragment de bouteille ou de flacon no 7 (FIG. 2.3) présente une lèvre identique à celle des cruches, mais un col bombé, forme que l'on retrouve sur une bouteille décrite par J.W. Hayes (Hayes 1975, 59, no. 147, fig. 4).

La lèvre no 38 (FIG. 2.4) s'apparente à celle d'un flacon de la collection du Musée d'Athènes (Davidson Weinberg 1992, 132, no. 107). Le pliage de la paroi sur la partie supérieure du col, formant un cordon décoratif, figure sur des coupes d'Augst et de Kaiseraugst, qui datent de la période augustéenne au IVème siècle (Rütti 1991, 88 no AR 89, pl. 76). Cette décoration se retrouve sur des cruches (Isings 1957, form 123), mais il s'agit le plus souvent d'un cordon appliqué et non d'un pliage de la paroi. Un tel pliage s'observe fréquemment sur des bols (Weinberg and Goldstein 1988, 53, no. 105–6, fig. 4.14) et des coupes du Ier au IVème siècle après J.-C., aussi bien en Orient qu'en Occident. En Italie et dans les régions occidentales, ce décor daterait du Ier au IIème siècle après J.-C.

Le vase à boire no 48 (FIG. 2.5), datable des IIIème et IVème siècles après J.-C., possède un cordon au bas de la lèvre, formé par double ourlage de la paroi, trait courant en Syrie-Palestine, mais qui se rencontre également dans les provinces occidentales (Whitehouse 1997, 79, no. 103).

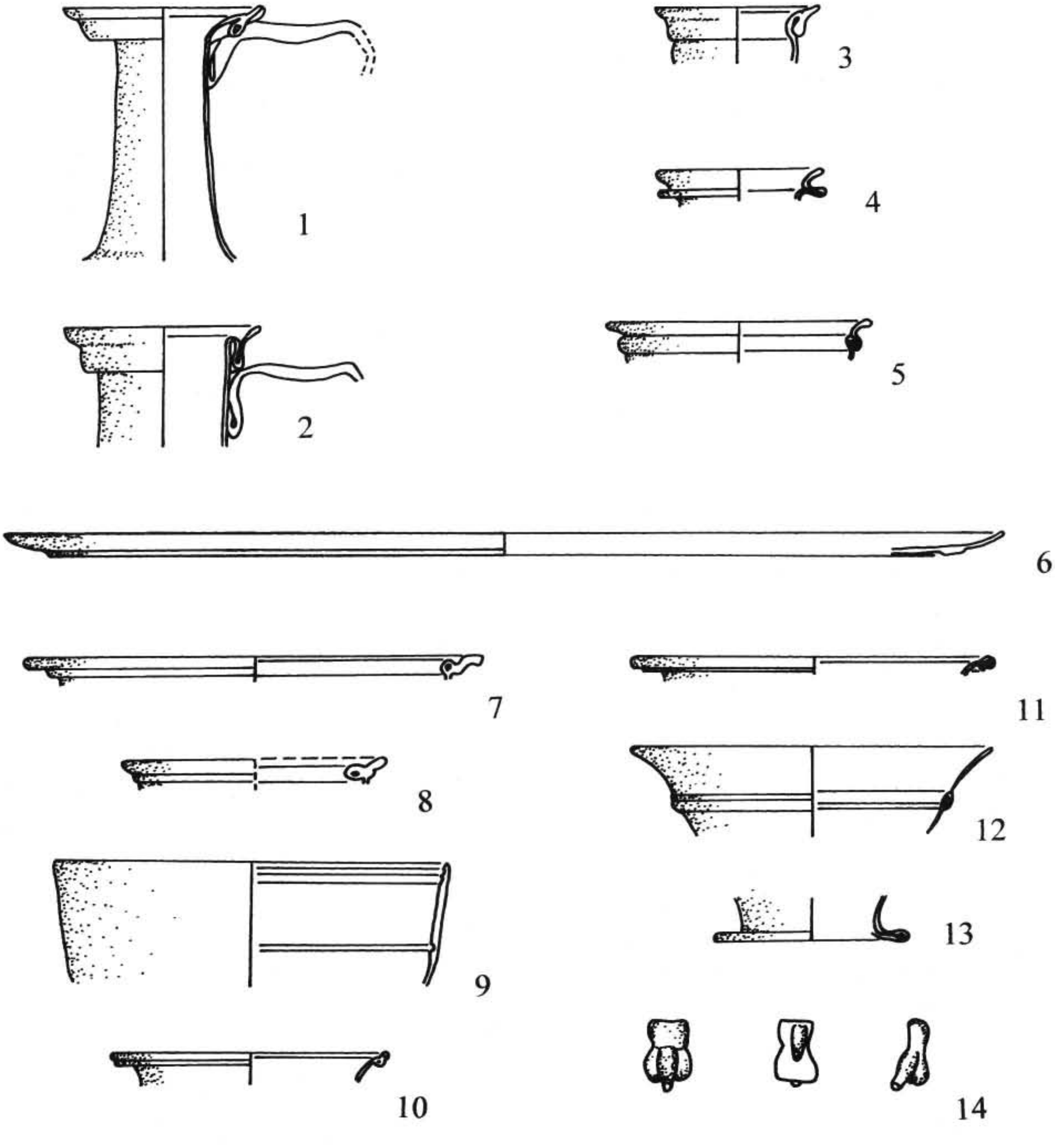

FIG. 2 Formes diverses du verre romain à Erétrie (taille 1:2). 1–2: cruches nos 1–2 ; 3: cruche ou flacon no 7 ; 4: flacon no 38 ; 5: vase à boire no 48; 6: assiette no 123; 7–12: coupes nos 132–4, 151, 149, 157; 13: base no 220; 14: amulette en forme de phallus no 309 (les numéros correspondent au catalogue original; les dessins sont de l'auteur)

Selon J. Price (Price 1992, 432, 450, no. 238–9, pl. 346) et C. Isings (Isings 1957, form 37), cette forme existe déjà vers la fin du Ier siècle après J.-C. dans le monde méditerranéen, mais elle reste rare. Deux zones de distribution ont été identifiées: en Orient, par quelques trouvailles concentrées au bord de la Mer Noire et en Syrie-Palestine; en Occident, avec un groupe en Italie du Sud.

L'assiette no 123 (FIG. 2.6) fait partie de la vaisselle pour laquelle aucun parallèle n'a encore été trouvé. Son profil extrêmement plat la rapproche de la vaisselle moderne, mais cet exemplaire se situait dans une couche archéologique non perturbée.

Les plats no 132 et no 133 (FIG. 2.7–8), caractérisés par une lèvre horizontale et un rebord tubulaire interne, n'ont pas de parallèles exacts. Le pliage de la lèvre s'apparente au vase à boire no 48 (FIG. 2.5), mais il est moins accentué. La forme entière du récipient n'est pas connue et le diamètre du no 133 est indéfini.

La coupe moulée no 134 (FIG. 2.9) est largement distribuée dans la partie orientale de la Méditerranée. Ce type est particulièrement commun en Syrie-Palestine (Price 1992, 419–20), mais on le retrouve également en Grèce, en Turquie, à Chypre, en Jordanie, en Italie du Sud, etc (Nenna 1999, 68).

La coupe no 151 (FIG. 2.10) présente deux bords tubulaires superposés, qui en font une variante du no 149 (FIG. 2.11; Isings 1957, form 115; Rütti 1991, 104–6 no. AR 109.1, pl. 90–2).

Trois fragments de coupes à panse convexe, longue lèvre éversée et renflement tubulaire sur la panse, formé par double pliage de la paroi (no 157, FIG. 2.12), ont été mises au jour à Erétrie. Elles n'ont pas de parallèle exact. Le profil d'une coupe trouvée à Carthage (Fünfschilling 1999, 510, no. 658, fig. 18) est la forme qui s'en approche le plus, bien que la paroi au-dessus du renflement tubulaire soit convexe. Un exemplaire de Conimbriga s'y apparente, mais sa lèvre est beaucoup plus courte au-dessus du renflement (de Alarcaõ 1976, 179, no. 74, pl. 36). Le double pliage de la paroi sur la panse n'est pas un décor inconnu: il se rencontre sur un bol profond d'origine syro-palestinienne répertorié par J.W. Hayes (Hayes 1975, 120, no. 472, fig. 13), ainsi que sur deux vases à boire du musée de Corning (Whitehouse 1997, 79, no. 103) Nous le retrouvons sur des canthares de Badalona (Travieso 1987, 85, no. 364–7, fig. 59–60) et des bols de Jalame (Weinberg and Goldstein 1988, 54, no. 109–12, fig. 4.15) pour ne citer que quelques exemples. Ce type de décoration est assez commun dans la région méditerranéenne et a dû s'utiliser tout au long de la période romaine, mais il semble assez rare sur des coupes comme celles d'Erétrie.

La base no 220 (FIG. 2.13) illustre le profil des bases en verre les plus fréquentes dans le quartier du Sebasteion. Ces bases proviennent principalement du four à chaux. Elles sont caractérisées par un pied fin, horizontal, formé par pliage, un fond voûté et une panse légèrement bombée. Elles se comparent à un pied de gobelet, dont le diamètre est toutefois beaucoup plus petit (Weinberg and Goldstein 1988, 62, no. 189, fig. 4.24).

Parmi les objets figure un petit phallus en pâte de verre blanche (no 309, FIG. 2.14). Sa datation, donnée par des monnaies présentes dans la même couche, se placerait après 180 avant J.-C. Ce type d'amulette, dont la diffusion se concentre en Méditerranée orientale, est bien connu à Délos avec seize exemplaires (Nenna 1999, 139–40, nos E152–E167, pl. 53) et à Chypre (Seefried 1982, 152, nos 1–15, fig. 7, 15, 34, pl. 4), qui aurait abrité des ateliers de fabrication de ces pendentifs. On rencontre également les phallus en Egypte (Müller-Winkler 1987, 49, 192, no. 260, pl. 14). De petites dimensions, ces phallus ont sans doute été directement façonnés par le verrier sur une canne de métal.

Les sources anciennes ne nous renseignent pas sur le rôle joué par ces amulettes. Les phallus en verre étaient vraisemblablement crédités, en sus d'un pouvoir fécondant, d'une vertu prophylactique leur permettant de conjurer le mauvais œil et les mauvais esprits.

Chronologie du verre

Le verre a essentiellement été retrouvé dans des couches perturbées, où la céramique et les monnaies ne peuvent pas nous renseigner précisément sur la chronologie. La datation de notre matériel s'est alors faite sur la base des parallèles répertoriés dans les typologies consultées.

La tranche chronologique dans laquelle se retrouve la majorité des récipients découverts à Erétrie s'étend du Ier au IIIème siècle après J.-C. Seuls un bol (no 39; Dussart 1998, 51, no. AI 1, pl. 1; Nenna 1999, 81, no. C150, pl. 20) et deux coupes (nos 134-5; FIG. 2. 8–9) sont plus anciens, leur durée d'utilisation allant de la fin du IIème siècle avant J.-C. au Ier siècle après J.-C. Certains récipients sont plus tardifs: trois gobelets (nos 51–3: Isings 1957, form 96b1; Rütti 1991, 66–9, no. AR 60.1, pl. 56–62), un plat (no 130: Rütti 1991, 106–7, no. AR 109.2, pl. 92), onze coupes (nos 145–50: Isings 1957, forms 44a and 115; Rütti 1991, 104–6, no. AR 109.1, pl. 90–2; nos 152–4: Isings 1957, form 115; Rütti 1991, 106–7, no. AR 109.2, pl. 92) et deux pots de toilette (nos 299–300: Rütti 1991, 109, no. AR 115, pl. 94) sont des formes qui perdurent jusqu'aux IVème et Vème siècles après J.-C. Il serait intéressant de pouvoir affiner la datation de ces récipients, car, selon la théorie généralement admise, la ville d'Erétrie aurait été abandonnée suite au séisme de 365 après J.-C. et réoccupée sporadiquement au VIème siècle après J.-C. autour du sanctuaire d'Apollon (Thémélis 1975, 44). Si la présence d'objets plus récents pouvait être confirmée, cela irait alors à l'encontre de cette théorie et témoignerait d'une occupation continue du site jusqu'au Vème siècle au moins.

La provenance du verre

Les éléments permettant d'avancer des hypothèses sur la provenance du verre d'Erétrie sont peu nombreux. Quelques scories ont été découvertes sur le site, ainsi qu'au Nord-Ouest de la ville, mais aucun atelier de verriers n'est connu dans la région. Il faut aller de l'autre côté du Golfe euboïque, en face d'Erétrie, à Skala Oropou, pour trouver une attestation probable de production de verre (Anonyme 1990; Pariente 1992). Un four de verrier d'époque romaine y aurait été dégagé; il se situait dans un quartier artisanal, non loin de trois fours céramiques; on a trouvé dans la même région de nombreuses coquilles de pourpre, ce qui n'est pas sans rappeler le quartier du Sebasteion. Un des fours céramiques, datant du Ier siècle après J.-C., a été doté, dans un second état, d'une double chambre de chauffe, l'une rectangulaire, l'autre circulaire. L'abondance des fragments de verre recueillis sur le site suggérerait que ce four a servi au soufflage du verre. Il serait nécessaire d'entreprendre une étude détaillée de ces fragments, car seule la présence de mors, petits déchets de verre qui proviennent de l'extrémité de la canne à souffler, témoignerait incontestablement de l'existence d'un atelier de verriers où l'on a pratiqué le soufflage du verre (Amrein 2001, 22).

Pour ce qui est de la matière brute, une analyse chimique a été effectuée dans les années quatre-vingt-dix sur une partie des verres provenant de la maison aux Mosaïques. Cette recherche se base malheureusement sur un petit échantillon de matériel; de plus, l'analyse n'a pas été menée conjointement à une étude du matériel archéologique et les fragments analysés sont souvent des panses et du matériel découverts en surface, sans contexte ni datation. L'auteur de cette étude a pu, cependant, déterminer l'existence de deux types de verres à Erétrie. La provenance du premier type n'est pas connue, mais celle du second se situerait au bord de la Mer Rouge (Gmür Brianza 1990, 146–7). Les recherches actuelles sur les ateliers primaires ne viennent pas confirmer cette hypothèse. A ce jour, les ateliers de fabrication du verre brut connus se situent en Egypte (Nenna *et al.* 2000; Foy et Nenna 2001, 35–9) et Strabon mentionne l'utilisation des sables provenant de la côte syro-palestinienne dans sa *Géographie* (Strabon XVI, 2, 25). Il n'est cependant pas possible d'exclure l'existence d'ateliers primaires dans d'autres régions du monde antique.

Le manque d'informations sur les ateliers de verriers en Grèce et sur les échanges possibles entre les villes empêche de préciser la provenance du verre d'Erétrie. Si la matière première a bien été importée, elle le fut soit sous forme déjà soufflée, soit sous forme de lingots de verre. Dans ce dernier cas, les récipients étaient alors soufflés dans un atelier local, peut-être dans les environs de la ville.

Pour ce qui concerne le matériel découvert dans le quartier du Sebasteion, il fallait déterminer son lieu d'utilisation, dans la mesure où celui-ci n'avait pas été retrouvé *in situ*, mais dans le four à chaux, transformé en dépotoir dès le IIIème siècle après J.-C.

S.G. Schmid (Schmid 1999a, 284) a émis l'hypothèse que les déchets du dépotoir pourraient provenir des terrains situés directement au Sud et au Sud-Est du quartier du Sebasteion. La fonction des structures qui y ont été dégagées n'est cependant pas bien définie: probablement des thermes au Sud et des magasins au Sud-Est. L'hypothèse des thermes a été retenue pour expliquer la trouvaille de fragments de mosaïques représentant des vagues et peut-être des poissons, de fragments d'hypocaustes et de *tegulae mammatae*. Les récipients de toilette retrouvés dans le mobilier en verre pourraient appuyer cette hypothèse. Toutefois, la quantité importante de vaisselle de table courante fait plutôt penser que celle-ci provient d'habitations privées, qu'il reste encore à localiser. Il est possible également qu'une partie des récipients, les bouteilles principalement, ait été employée dans l'atelier de teinturiers situé à proximité du four, pour entreposer certains produits.

L'analyse du verre du quartier du Sebasteion est un premier pas dans l'étude de ce type de mobilier à Erétrie. Même si nous ne pouvons encore préciser ni sa provenance, ni son lieu d'utilisation, il témoigne d'une ville prospère à l'époque romaine, où la vaisselle en verre côtoyait celle en terre cuite durant les trois premiers siècles de notre ère. Il s'agit d'une vaisselle d'usage courant, qui devait servir pour la table de tous les jours.

Comme il en a déjà été fait mention, beaucoup de questions restent en suspens, notamment en ce qui concerne les ateliers de production dans la région. Dans l'avenir, il serait judicieux de poursuivre l'étude des verres découverts dans les autres secteurs de la ville, ce qui permettrait de compléter certaines formes, dont le profil entier est inconnu, et d'en découvrir de nouvelles. La poursuite des recherches dans ce domaine à Erétrie semble indispensable pour apporter quelques réponses à la problématique, encore souvent délaissée, du verre romain en Grèce.

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GLASS FROM THE FORT AT HOD HILL IN DORSET AND OTHER MID FIRST-CENTURY HILLTOP SITES WITH ROMAN MILITARY OCCUPATION IN SOUTHERN ENGLAND

JENNIFER PRICE

In AD 43 Britain was invaded by a Roman army of four legions with auxiliary units under the command of Aulus Plautius, and Claudius himself travelled to Colchester to receive the surrender of various rulers; much of the detail of this invasion is obscure and hotly debated (for a recent examination of the arguments, see Manley 2002). The subsequent advance along the south coast of England towards the south-west peninsula was led by Vespasian with the legion II Augusta. Suetonius (Divus Vespasianus, 4) recorded that he defeated two powerful tribes, more than 20 native towns and the Isle of Wight. Part of this campaign is thought to have taken place in the modern counties of Dorset, Somerset and Devon, where there were numerous large and well-defended hillforts (FIG. 1).

There is evidence for a substantial amount of early Roman military activity in the region, though it is unlikely that all of it dates from Vespasian's period of command, which must have ended around AD 47, and some may be as late as AD 55 or AD 60/61. In addition to the large military complexes and coastal supply bases, some hilltop sites have produced evidence for short episodes of military occupation, as at Hod Hill (Richmond 1968) and Waddon Hill (Webster 1979) in Dorset, Cadbury Castle (Barrett *et al.* 2000) in Somerset, and Hembury in Devon (Todd 1984).

This paper will investigate the use of glass vessels in the four hilltop sites. The principal focus will be the material from Hod Hill, which will be compared with the finds from the other sites. Two small groups of glass vessel fragments are known from Hod Hill (FIG. 2). One is part of a large assemblage of military equipment, weapons, tools, personal ornaments and other objects found on the hill and collected by Mr Henry Durden of Blandford Forum in the 19th century. His collection was purchased by the British Museum in 1892, but the publication of the Durden Collection (Brailsford 1962) did not include the vessel glass. The second group was found during excavations in the Roman fort directed by Sir Ian Richmond from 1951–1958 (Richmond 1968); a note on the glass was included in the excavation report (Harden 1968), but it is now possible to say a little more about these finds.

Many of the 26 Durden fragments are very small; they represent eleven vessels, six non-blown and five blown. The non-blown pieces include two polychrome mosaic vessels, from a convex bowl with opaque yellow, white and red lengths of cane and a ribbed bowl with purple and white spiral cane sections, and four monochrome vessels, three bluish green ribbed bowls (FIG. 2.1–2) and a greenish colourless bowl with short, close-set ribs on the body (FIG. 2.3). The blown vessels include a purple hemispherical cup with marvered opaque white zigzag trails (FIG. 2.4) and a similar dark blue and white cup, a dark green hemispherical cup with wheel-cut lines (FIG. 2.5), a dark blue blown foot with cracked-off edge from a cup or bowl (FIG. 2.6) and a dark blue convex body fragment with marvered opaque white splashes, perhaps from a jug.

The 23 fragments from the fort excavation complement and extend the Durden group; they come from four vessels, three non-blown and one blown. The non-blown vessels include 19 fragments of a yellow-brown, blue and opaque white polychrome mosaic ribbed bowl with out-turned rim, deep convex body and vertical ribs in low relief (FIG. 2.7), a bluish green ribbed bowl and a greenish colourless shallow ribbed bowl with short, close-set ribs. The blown vessel is a melted rim fragment from a yellow brown and opaque white cased cup or bowl with a stepped rim.

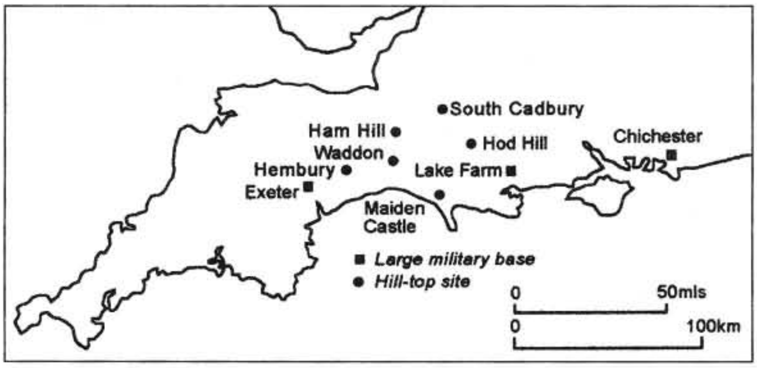

FIG. 1 Some mid 1st-century military sites in southern England

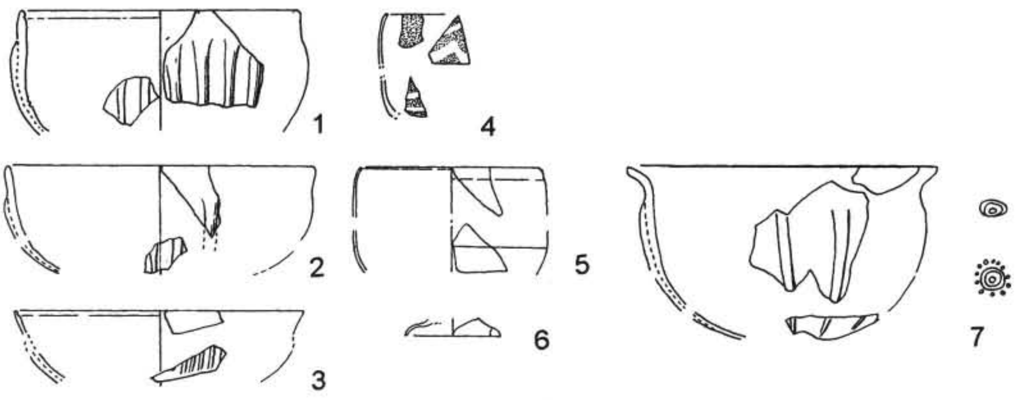

FIG. 2 Glass vessels from Hod Hill (scale 1:4)

Together, the two groups contain 14 cups and small bowls, apparently used as drinking vessels, and one vessel, interpreted as a jug, for serving liquid. It is noteworthy that more of the pieces were non-blown (nine examples) than blown (five examples) and that seven of the pieces (three non-blown and four blown) were polychrome.

Among the non-blown vessels, at least five are unusual in Roman Britain. The strip mosaic fragment is from a convex bowl, probably with a rim finished with a twisted cane (FIG. 3.1). Two or three pieces are known from Augustan and later pre-Conquest contexts at Skeleton Green, Hertfordshire (Charlesworth 1981, 119, no. 3, fig. 64; Partridge 1981, 72, no. 18, fig. 33), and two came from early Roman deposits at Colchester (Sheepen: Harden 1947, 293, no. 2, pl. 87; Culver Street: Cool and Price 1995, 29–30, no. 192, fig. 2.9), and there are unstratified finds from Colchester, Cirencester and perhaps Canterbury (Cool and Price 1995, 29–30). The Hod Hill piece is too small to determine whether the lengths of cane forming the body were arranged in parallel rows or in a quadripartite pattern (Grose 1989, 250–2, 284–91. nos 318–28, 332–50). These vessels belong to the earliest phase of Roman imperial glass production and were no longer current in AD 43.

The cane mosaic tall ribbed bowl with out-turned rim and shallow, widely spaced ribs, which very probably had a foot (FIG. 3.5), also belongs to a very early phase of the Roman imperial glass production. It is not a very common form, and appears to be unique in Britain. Similar bowls have been found in Italy (see Grose 1989, 247–9, 269–77, nos 250–84), and are also known at Fréjus in southern France (Price 1988, 27, no. 11) and in a Tiberian context at Vindonissa in Switzerland (Berger 1960, 16, no. 22).

Two of the monochrome ribbed bowls, a bluish green bowl with long ribs (FIG. 3.4) and a greenish colourless bowl with short, close-set ribs, have a wheel-cut line on the inside surface below the rim. This feature appears to be a characteristic of early ribbed bowls and has seldom been noted in Britain. Among the hundreds of ribbed bowls found at Colchester (e.g. Harden 1947, nos 8, 10–14, 16–18, 60–7; Charlesworth 1985, nos 11–15, 44, 65–81; Cool and Price 1995, nos 1–192) only two polychrome and five monochrome examples with a cut line below the rim have been recorded, and two others are known from Mancetter in Warwickshire and Whitton in South Glamorgan (Cool and Price 1995, 18). The stratified pieces from Colchester came from Claudian or early Neronian contexts and the Mancetter piece is from a Neronian vexillation fortress (Price and Cool 1998, 48, no. 2, fig).

The two shallow bowls with short close-set ribs (FIG. 3.2) form part of a very small group principally found in early military contexts in southern Britain. Cool and Price (1995, 18) listed six bluish green and greenish colourless examples from Colchester, one from London and one from Wroxeter (now in Cool and Price 2002, 228, no. 16, fig. 6.2), and another is known from the vexillation fortress at Lake Farm, Wimborne, in Dorset (unpublished).

Among the blown vessels, brightly coloured and bluish green convex cups with cracked off rims and wheel-cut and abraded lines (FIG. 3. 9) are common finds on Claudian, Neronian and early Flavian military sites in Britain (Price and Cottam 1998, 71–3), but brightly coloured examples with marvered opaque white zigzag trails are much rarer. The only parallels for the purple and dark blue cups from Hod Hill known to me are two dark blue and white examples from contexts dated to *c.* AD 44–60/61 found at the Gilberd School site in Colchester and two blue and white and purple and white fragments from earlier excavations at Sheepen (Cool and Price 1995, 58–9, 61, nos 258–9, fig. 4.1).

Fragments of cased vessels (blown with two layers of glass, the outer being brightly coloured and the inner opaque white) are known in Claudian/Neronian contexts in southern Britain, though bowls with stepped rims are quite unusual. The fragment from Hod Hill is too small to establish whether it was a bowl with two handles or without handles, and distortion by heat has made the rim diameter and shape of the body uncertain, but parallels from the Rhine frontier (van Lith 1991, 106–8) suggest that it may be from a deep bowl with an applied round stem and blown foot (FIG. 3.10). Other fragments from cased bowls with stepped rims and body fragments with handles are known from Sheepen, Colchester (Harden 1947, 297, nos 35–6, pl. 87) and from London (cited in Cool and Price 1995, 60). The dark blue blown foot fragment is probably also from a bowl or cup, but too little survives for any discussion of the form to be possible. Such bases have rarely been recorded in Britain, although they are known on mid 1st-century cups with handles in Italy, and in southern France (Foy and Nenna 2001, 173, no. 269) and in north-eastern Spain (Price 1981, fig. 13, nos 113–16) .

The form of the dark blue fragment with opaque white marvered splashes is uncertain, though it may come from a

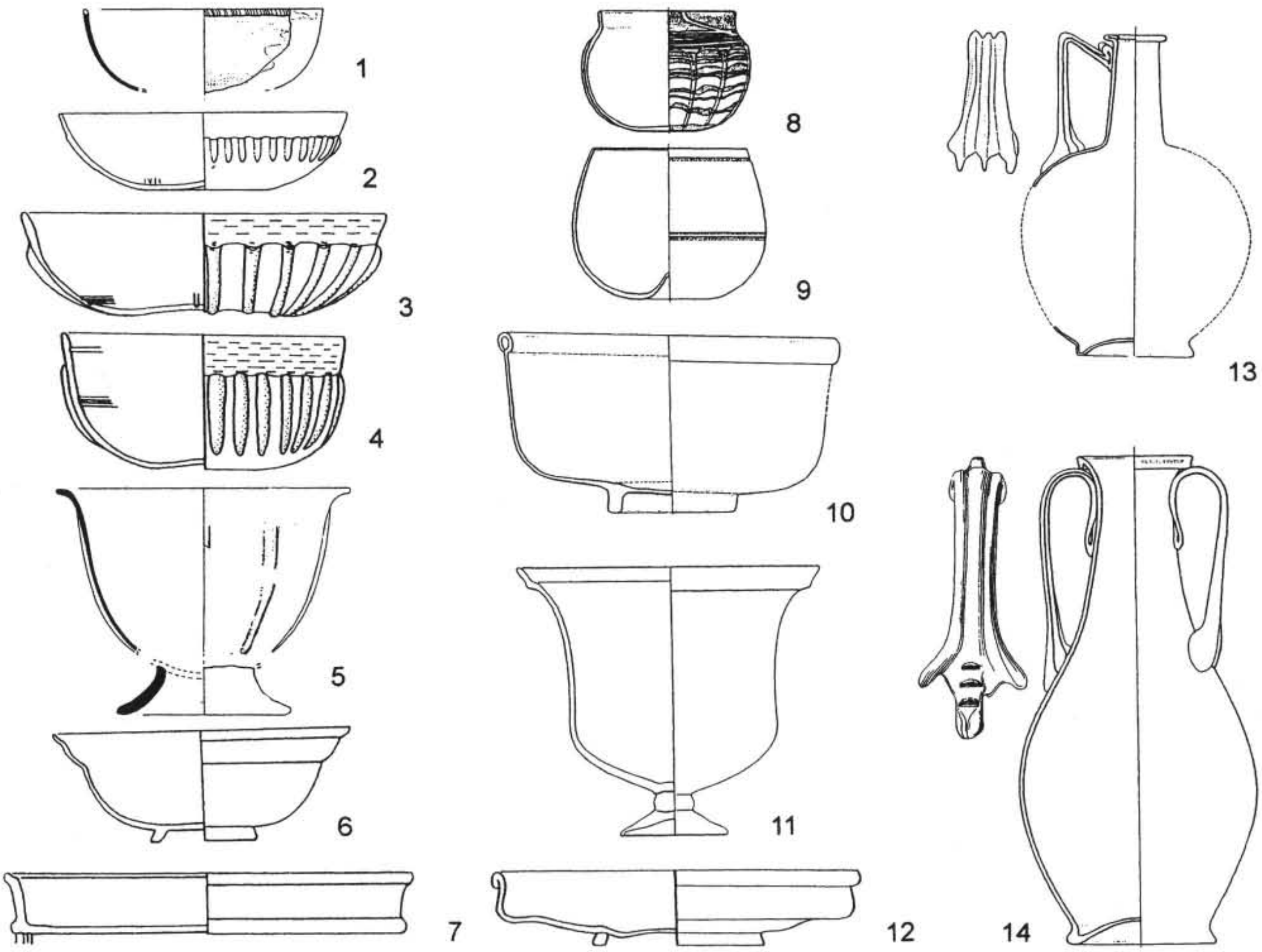

FIG. 3 Mid 1st-century glass tablewares in Britain (various scales)

thin-walled jug with a convex body (FIG. 3.13–14). Polychrome examples are uncommon in Claudian/early Neronian contexts in Britain though two were identified on the evidence of neck, body and base fragments found at Sheepen, Colchester (Harden 1947, 295–6, no. 24, pl. 88). Elsewhere, very similar jugs and *amphoriskoi* with marvered splashes and streaks are found in northern Italy (Valeggio Lomellina: Vecchi and Diani 1998, 64–7, no. 3, fig. 18, pl. 16.3), southern Switzerland (Locarno, Muralto: Biaggio Simona 1991, figs 18, 23–5, 28, 30) and in southern France (Fréjus: Price 1988, 31–2, no. 34; Aoste: Foy and Nenna 2001, 85, no. 94).

A similar pattern of glass use is seen at the contemporary hilltop sites in the region. At Waddon Hill (Harden 1979), there were fragments of six non-blown vessels, two polychrome mosaic, two dark blue and one bluish green ribbed bowls (FIG. 3.3–4), and an opaque light blue constricted convex cup (FIG. 3.6). There were also six blown vessels, two purple and pale bluish green small ribbed cups with opaque white trails (FIG. 3.8), and two yellowish brown and one bluish green convex cups with cracked off rims and wheel-cut or abraded lines (FIG. 3.9), and a dark blue convex jug with concave base (FIG. 3.13–14). At Cadbury Castle (Price and Cottam 2000), there were two certain non-blown vessels, both dark blue ribbed bowls (FIG. 3.4), and melted dark blue, and white and yellowish brown and white fragments probably representing two polychrome mosaic vessels. There were also five blown vessels, including two dark blue and opaque white handles from jugs or *amphoriskoi* (FIG. 3.13–14), a greenish colourless convex cup with wheel-cut lines (FIG. 3.9), and two dark blue and yellowish brown body fragments not closely identifiable. By contrast, no non-blown vessels were identified at Hembury, but four blown vessels were found. These were a dark green and two bluish green convex cups with wheel-cut lines (FIG. 3.9) and an unidentified dark green, thin-walled convex vessel with abraded lines.

Until the Claudian conquest, there is very little evidence for the use of glass vessels in Britain apart from a small quantity found in some high-status burials and settlements (Price 1996). By contrast, from AD 43 onwards, they occur at most military sites, and it is probable that personnel in the Roman army were the principal users of vessel glass in Britain until urban settlements were established. The rather scrappy finds from these hilltop sites are thus significant indicators of the role of glass tablewares in a sector of army life in the newly conquered province, and it is noteworthy that they may plausibly be related to drinking and to a lesser extent, to serving liquids. The vessels themselves are interesting, as both non-blown and blown forms are represented in approximately equal numbers, and the glass is of good quality and often polychrome or brightly coloured. They are closely comparable with finds from Italy and the adjacent provinces, and there is little doubt that they were brought into Britain from the central Mediterranean region. By contrast, vessels likely to have been connected with serving and eating food, such as dishes, bowls and plates (FIG. 3.7, 11–12) are completely absent, as are decorated mould-blown tablewares, and storage and transport containers for unguents or foodstuffs.

A few other defended hilltop sites with early glass finds are known in Britain. Ham Hill in Somerset may have been very similar to the sites discussed above, but it has not been included because too little is known about the settlement there. There is also a hilltop military settlement inside a hillfort near Leintwardine in Herefordshire (Frere 1987), which produced a rather different assemblage of nine glass tablewares, with less emphasis on drinking vessels and more on serving liquids and food. There were two non-blown ribbed bowls, one polychrome mosaic and one dark blue (Fig. 3.3–4), six dark blue, yellowish green and bluish green blown vessels, including five jugs or *amphoriskoi* (FIG. 3.13–14), and perhaps a large bowl with base-ring (FIG. 3.11–12) and a mould-blown ribbed cup (Price 1987). The site is thought have been a temporary campaign base occupied between AD 55 and 60. It is likely to have been occupied a little later than the hilltop sites in southern England, and it may demonstrate a slight change in glass use.

It has already been explained that glass vessels were widely used in early military bases in Britain. The finds from Colchester are well known, and it is noteworthy that a large assemblage is known from the legionary base at Lake Farm, near Wimborne (unpublished). This site is close to Hod Hill and contemporary with the Dorset, Somerset and Devon hilltop sites. The range of vessel forms at Lake Farm is much larger, but some of the material is so similar to the vessels found in the hilltop sites that it may have been supplied from the same sources, and indeed may have been their source of supply.

The circumstances in which military units based in hilltop sites were using this glass are not known. Evidence at Hod Hill and South Cadbury indicates episodes of conflict between the Roman army and the natives, but it is arguable that glass would not have been a very practical material during active campaigning, and the glass in this study is probably associated with small units of infantry and mounted soldiers garrisoned in the hilltop sites after the initial conquest, as part of a signalling and warning system, or to police the region, when living there would have been relatively calm and unthreatening. The episodes of hilltop occupation were probably quite short, and their dates are uncertain, though most if not all are likely to have occurred in the decade or so between the late 40s and early to mid 50s AD, at a time when glass reaching Britain came from Italy, and liquid and semi-liquid foodstuffs were not yet supplied in cylindrical and square containers.

Acknowledgments

The study of the glass from Hod Hill is based on my catalogue of Romano-British Glass Vessels in the British Museum. I am very grateful to Karen Hughes for her work on the drawings for the catalogue, and to Yvonne Beadnell for preparing the map and drawings for this note.

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MOBILIER FUNÉRAIRE AVEC BOL EN VERRE DE LA NÉCROPOLE DE DORNO-CASCINA GRANDE (PAVIA)

MARIA GRAZIA DIANI

Le mobilier funéraire objet du présent étude fait partie d'une nécropole fouillée par la Soprintendenza Archeologica della Lombardia en 1984 et encore inédite. La nécropole retrouvée à Dorno-cascina Grande (Pavia, Italie du Nord) comprend plus que deux cents tombes à incinération (une seule est à inumation). Les sépultures sont datées à partir de la première moitié du I[er] siècle av. J.-Ch. jusqu'à la moitié du I[er] siècle après J.-Ch.

Dorno (ancienne *Duriae*) se trouve dans la Lomellina (qui prend son nom de la localité de *Laumellum*), un territoire qui est délimité au Sud par le cours du fleuve Po, à l'Est par le fleuve Ticino et à l'Ouest par le Sesia. Elle occupe le côté Ouest de la région lombarde, limitrophe au Piemonte (FIG. 1). Une synthèse sur la recherche et la documentation archéologique de la Lomellina a été récemment publiée (*Lomellina Antica* 2002).

Dans l'époque romaine, selon les itinéraires anciens, *Duriae* était une *mutatio*, qui se trouvait sur la route de connexion entre la plaine padane et la *Gallia Transalpina*, qui conduisait de *Ticinum* (Pavie) à *Augusta Taurinorum* (Turin), en traversant aussi la *mansio* de *Laumellum* et la *mutatio* de *Cuttiae*; à partir de *Duriae* il y avait aussi une route qui se dirigeait vers le NNE et le fleuve Ticino (Tozzi 2002, 17–18; 23–4). La position de *Duriae*, au long d'un important nœud de communication et tout près du cours du fleuve Terdoppio – qui descend vers le Po – explique la présence de deux nécropoles significatives, celle de cascina Grande (Allini 1984) et celle de San Materno (Antico Gallina 1985), néanmoins les intéressants recouvrements de la localité de Battera, parmi lesquels il y a plusieurs verres (Ponte 1964, 181–4), en témoignant l'intense fréquentation de la zone à l'époque proto-impériale romaine, en absence des restes de l'ancien habitat.

Comme on a déjà précisé, la nécropole de cascina Grande comprend plus que deux cents sépultures, qui montrent le passage de l'époque celtique à la romanisation en Lomellina. Le rite utilisé est l'incinération, souvent pratiquée dans une fosse dans le sable. Parfois il est possible de distinguer des incinérations directes, avec deux fosses, une pour l'incinération et l'autre pour contenir le mobilier funéraire. Dans certaines cas on note, au contraire, la présence de l'incinération indirecte: on a recueilli les cendres du défunt dans une fosse, ou bien dans une coupe, tandis que le *bustum* se trouvait ailleurs par rapport à la sépulture même.

La tombe 94 de cette nécropole est caractérisée du rite de l'incinération indirecte et probablement appartient à une sépulture féminine (FIG. 2), par la présence d'éléments particuliers (Invernizzi 1998, 21–2).

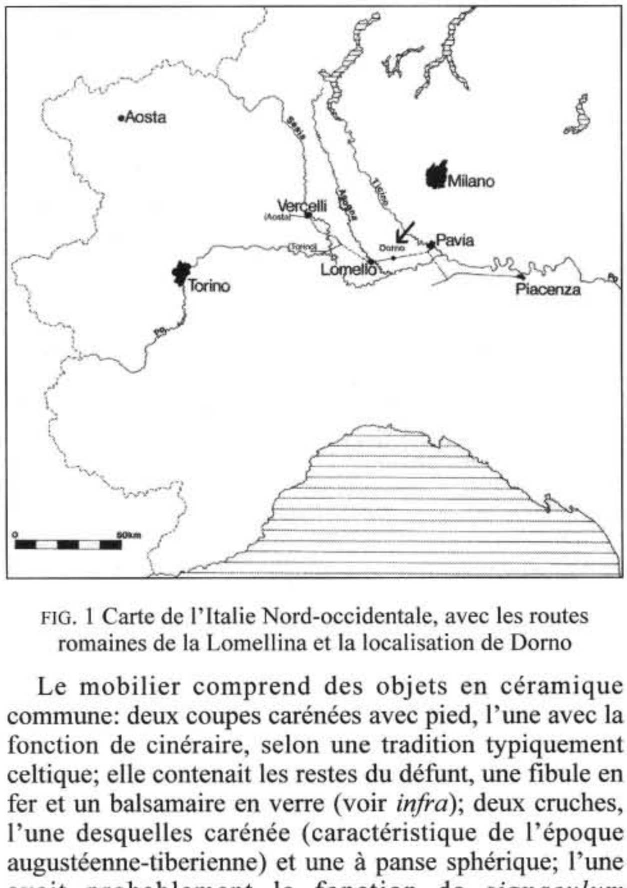


FIG. 1 Carte de l'Italie Nord-occidentale, avec les routes romaines de la Lomellina et la localisation de Dorno

Le mobilier comprend des objets en céramique commune: deux coupes carénées avec pied, l'une avec la fonction de cinéraire, selon une tradition typiquement celtique; elle contenait les restes du défunt, une fibule en fer et un balsamaire en verre (voir *infra*); deux cruches, l'une desquelles carénée (caractéristique de l'époque augustéenne-tiberienne) et une à panse sphérique; l'une avait probablement la fonction de *signaculum* d'identification de la sépulture: elle était en effet déposée au niveau supérieur par rapport au reste du mobilier; un balsamaire piriforme en argile type Haltern 31 (Loeschcke 1909); un poids pour fuseau en argile; un gobelet à tulipe, en céramique à parois fines, typologie commune dans les sépultures de cette époque en Lomellina et qui se rapproche à des exemplaires celtiques.

On a retrouvé aussi une patère à vernis noir Lamboglia 7/16 (Lamboglia 1952), avec le disque rouge d'empilage dérivé de la cuite.

Parmi les objets en bronze, on signale un miroir circulaire simple, avec la surface argentée, un élément de coffret, une fibule assez fragmentaire, dont il est impossible de reconstruire la forme complète, et une monnaie d'Auguste (*As* du 16 av. J.-Ch.).

Le mobilier comprend deux verres: un balsamaire en verre soufflé à la volée (Isings 6 var.,) et un bol moulé, très rare. Il faut d'abord considérer l'intérêt de la présence, dans

FIG. 2 Le mobilier funéraire de la tombe 94 de la nécropole de Dorno-cascina Grande (Pavia)

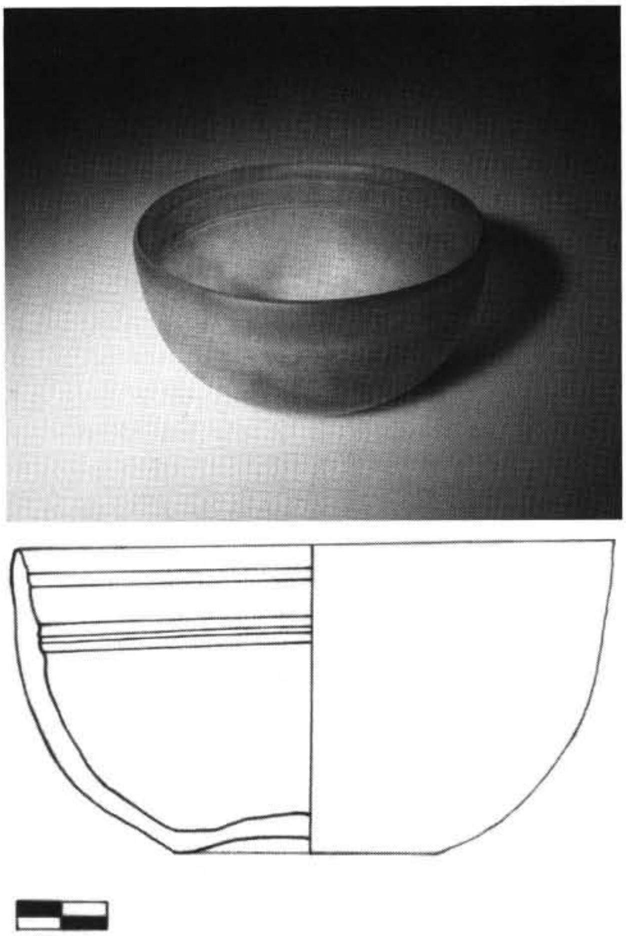
un même mobilier, d'un verre soufflé et d'un verre moulé: il s'agit des premières attestations de vaisselle en verre dans les contextes funéraires de la Lomellina.

Les balsamaires, surtout les types Is. 6 et 8, ou bien les balsamaires sphériques (Is. 10), sont assez communs dans les mobiliers funéraires de la Lomellina, du Canton du Tessin et de l'Italie du Nord en générale, en particulier dans les sépultures féminines, dès la fin du Ier siècle av. J.-Ch., jusqu'à la première moitié du Ier siècle après J.-Ch. Les balsamaires Is. 6 sont en verre incolore ou bien coloré (jaune, bleu foncé, violet, vert), toujours assez fin (pour la chronologie et la diffusion: Maccabruni 1983, 109–10, nos 77–108; 118–24; 140–3).

Il faut dire qu'il n'est pas si fréquent de retrouver un balsamaire en argile associé avec un en verre: en Lomellina on connaît le cas de la nécropole de Dorno-San Materno, tombe 5 (balsamaire en argile et Is. 10, avec un miroir, des poids de fuseau et une monnaie), datée entre la fin du Ier siècle av.J.-Ch. et le début du Ier siècle apr. J.-Ch. et la tombe 15, qui présente toutefois des problèmes quant à l'identification du mobilier (Antico Gallina 1985). Il faut citer aussi, à ce propos, la nécropole de Gropello Cairoli, tombe XXVIII, zone D, datée à la première moitié du Ier siècle après J.-Ch., qui comprend aussi une urne en céramique commune, une fibule et une monnaie d'Auguste (Fortunati Zuccala 1979, 50–1, pl. 34).

À Nave (Brescia) on trouve deux cas d'association de balsamaires en verre (Is. 6 et ses variants) et en argile, dans des sépultures datées toujours à l'époque augustéenne (Passi Pitcher 1987, 37–9, tombes 59 et 2; 138; 145 no. 2; 179). Souvent on retrouve, plutôt, plusieurs balsamaires en verre dans le même mobilier. Par exemple, dans la tombe 4 de la nécropole d'Alagna Lomellina-cascina Guzza (tout près de Dorno), on a douze balsamaires du type Is. 6 et ses variants, en verre incolore et coloré; la sépulture est datée à l'époque augustéenne (Diani 1999, 172–3, no. 9, pl. xliv).

Le bol hémisphérique à larges filets internes, au profil linéaire, 'linear-cut' (Isings 1) est en verre vert clair, moulé et poli à la meule (FIGS 3–4). L'intérêt de la découverte est lié à sa rareté: en effet, jusqu'à ce moment, on n'a pas retrouvé d'autres exemplaires semblables en Lomellina, ni dans les contextes funéraires, ni dans les fouilles d'habitat. D'autre part, il faut remarquer que ce type est



FIGS 3 et 4 Le bol hémisphérique en verre moulé

inconnu même dans le Canton du Tessin, avec lequel la Lomellina dans cette époque avait des rapports commerciaux fréquents à travers du fleuve Tessin et du lac Majeur: ici on connaît seulement un bol hémisphérique en verre 'millefiori' et des exemplaires côtelés en verre monochrome. Le verre moulé en générale est peu présent dans les contextes de la Lomellina, où on signale quelques exemplaires côtelés (par exemple une coupe bleu clair de Dorno-Battera: Maccabruni 1983, 23–7, nos 3–5), datés aux premières années du Ier s. apr. J.-Ch. (Invernizzi et Diani 1998, 169, no. 2).

En ce qui concerne l'Italie du Nord, les bols hémisphériques à filets internes sont en effet plutôt rares: on peu citer des attestations, assez fragmentaires, à Luni (SP), Genova, Milano, Calvatone (CR), Pegognaga (MN), Verona, Trento. Il s'agit de fouilles d'habitats et les contextes en générale sont datés entre les dernières années du Ier s. av. J.-Ch. et le début du Ier s. apr. J.-Ch. (pour la synthèse des attestations en Italie du Nord: Roffia 1993, 60–6; Diani 1998, 32–3, nos 20–6).

En plus, à Adria, dans la tombe 16 de la nécropole du Canal Bianco, on a retrouvé deux coupes basses, moulées et avec filets internes, en verre jaune: S. Bonomi croit qu'il s'agit d'une production de l'Italie centre-méridionale (Bonomi 1996, 149, 152–3, nos 336–7). Il faut considérer que les spécialistes concordent sur la fréquence des flux commerciaux entre la Lomellina et l'aire d'Adria, à travers les voies fluviales du Tessin et du Po et pourtant on pourrait penser – pour le bol de Dorno – à une médiation d'Adria pour une importation de l'Italie centre-méridionale. En effet, il est difficile de penser à une production de l'Italie du Nord, en présence de si peu d'attestations. Toute réflexion ne peut pas être considérée définitive.

L'exemplaire de Dorno pourrait être datable alors vers la fin du I[er] siècle av. J.-Ch.-premières années du I[er] siècle après J.-Ch. (pour la chronologie et la diffusion du verre moulé monochrome: Foy et Nenna 2001, 74; notre exemplaire pourrait faire partie de la troisième génération de pièces moulées. Voir aussi: Grose 1989, 247, fig. 121; Arveiller-Dulong et Nenna 2000, 179; Nenna 1999, 103 suiv.; Foy et Nenna 2003, 232).

En conclusion, on peut dire que le mobilier funéraire de Dorno présente des caractéristiques propres de l'époque de la romanisation en Lomellina: on trouve des éléments celtiques (les coupes carénées, la fibule) associés à des objets de la pleine romanisation (la patère à vernis noir, les cruches, le miroir, les verres). Ce phénomène est assez fréquent en Lomellina, au cours de la fin du I[er] siècle av. J.-Ch. et du début du I[er] siècle après J.-Ch., époque dans laquelle on peut dater la sépulture en examen.

Catalogue

Dorno, cascina Grande, tombe 94 (fin I[er] siècle av. J.-Ch. - début I[er] siècle après J-.Ch.)
Vigevano (Pavie), Musée Archéologique Nationale de la Lomellina

ST. 94634 Coupe carénée
Lèvre évasée, arrondie; panse carénée.
Pâte céramique brune, avec mica et inclusions. Faite à la main; surface lissée.
Recomposée, avec intégrations; sans pied. Légères traces du bûcher.
H. 59mm; diam. lèvre 149mm

ST. 94722 Coupe carénée
Lèvre évasée, arrondie; panse carénée; pied annulaire sur fond plat.
Pâte céramique brune, avec mica et inclusions. Faite à la main; surface lissée.
Recomposée de plusieurs fragments, légères lacunes à la lèvre, pied ébréché. Traces du bûcher.
H. 101mm; diam. lèvre 218mm; diam. pied 81mm

ST. 94723 Cruche piriforme
Col cylindrique, panse piriforme, bas pied annulaire sur fond plat. Anse rubanée de l'épaule au col.
Pâte céramique rouge, dépurée, avec mica. Faite au tour, surface lissée.
Partiellement recomposée de fragments; lacunes au col, sans lèvre.
H. max. 160mm; diam. fond 100mm

ST. 94635 Cruche
Panse carénée; épaule oblique, pied annulaire, fond plat. Départ d'anse sur l'épaule.
Pâte céramique brun rosé, dépurée, avec mica. Traces d'engobe brun clair. Faite au tour.
Recomposée de fragments, avec intégrations; sans col, lèvre, anse.
H. max 88mm; diam. 62.4mm

ST. 94719 Balsamaire type Haltern 31 (Loeschcke 1909)
Lèvre grossie, arrondie; col cylindrique, corps piriforme, fond plat, apode.
Pâte céramique chamois, dépurée, avec mica; légères traces d'engobe. Fait au tour.
Intact; consomption de la surface.
H. 96mm; diam. lèvre 24mm; diam. base 18mm

ST. 94721 Poids pour fuseau
Disque épais, à section sphérique écrasée, avec un trou central, souligné supérieurement d'un petit carré, peu régulier.
Pâte céramique brune, avec mica, non dépurée. Fait à la main.
Intact.
H. 21mm; diam. 32mm

ST. 94716 Goblet à tulipe
Lèvre droite, arrondie; corps tronconique, avec étranglement, au-dessous du quel est globulaire; fond légèrement concave, apode.
Pâte céramique grise, avec mica et inclusions. Fait au tour.
Intact; traces du bûcher.
H. 91mm; diam. lèvre 96mm; diam. fond 38mm

ST. 94720 Patère à vernis noir type Lamboglia 7/16 (Lamboglia 1952)
Lèvre oblique, arrondie; corps caréné; pied annulaire oblique; fond avec ombilic centrale.
Sur le fond interne, trois cercles concentriques gravés et bande avec gravures à molette. Cercle rouge d'empilage centrale.
Pâte céramique beige, dépurée. Faite au tour. Vernis luisant; le pied est épargné.
Recomposée de fragments; consomptions du vernis sur la lèvre et sur le fond interne.
H. 49mm; diam. lèvre 270mm; diam. pied 104.4mm

ST. 94633 Bol hémisphérique à larges filets internes type Isings 1 (FIGS 3-4)
Bord arrondi et aminci à l'extrémité, panse globulaire avec fond légèrement concave, apode; trois rainures sur la paroi interne, l'une directement sous la lèvre et un couple au-dessous.
Verre vert clair, un peu opaque, avec des petites bulles internes. Moulé et poli à la meule; on note aussi, sur la surface externe, les traces de la pince à feu utilisée.
Intact.
H. 69mm; diam. bord 133mm; diam. base 56mm
Rütti 1991, type AR 3.2, 33; no. 717, tab. 30.
Grose 1989, Family I, 247, fig. 121 (Monochrome Linear-Cut Bowls).

ST. 94718 Balsamaire type Isings 6 var.
Embouchure évasée, coupée et arrondie. Col cylindrique, panse sphérique, fond aplati, apode.
Verre incolore, soufflé à la volée.
Recomposé de fragments, avec des lacunes au corps et incrustations à l'intérieur.
H. 65mm; diam. lèvre 16mm; diam. max 53mm
De Tommaso 1990, type 5, 39–40.

ST. 94782 Miroir
Disque circulaire, convexe supérieurement.
Bronze argenté; fusion. Lacunes; surface corrodée et consomption au bord.
Diam. 96mm; épaisseur 7mm

ST. 94675 Elément de coffret
Barre à section circulaire, fixé sur un élément aplati avec la terminaison en forme circulaire, à section aplatie.
Bronze, fusion.
Fragmentaire.
Long. 30mm; larg. max 18mm; épaisseur 3mm

ST. 94674 Fibule
Ressort de 3–4 replis de chaque côté; arc à section circulaire; ardillon à section circulaire.
Fer, fusion.
Fragmentaire.
Long. cons. 36mm; épaisseur 3mm

ST. 94676 As d'Auguste (16 a.C.), monnaie de Rome
Avers/ Tête d'Auguste, nue, à droit. Coin décentré.
Legenda: CAESAR (AVG)[VSTVS TRIB]VNIC POTEST.
Revers/ SC
C GALLIVS [LVP]ERCVS II VIR AAA[FF]
Bronze; corrosion.
diam. 26mm; épaiss. 2.7mm
RIC I, 70, n. 379.

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QUELQUES VERRES À DÉCOR GRAVÉ DU MUSÉ ARCHÉOLOGIQUE NATIONAL DE NAPLES

VERONIQUE ARVEILLER-DULONG AND CARMEN ZIVIELLO

Cette communication tente de faire le point sur quelques objets en verres à décor en haut relief ou à décor gravé conservés au Musée Archéologique National de Naples. De la très riche collection du musée de Naples, nous avons choisi de présenter un nombre restreint de pièces classées en différents groupes afin de mieux cerner leurs caractéristiques.

LES VERRES À 'FACETTES'

Nous présentons ici deux coupes jumelles provenant de Pompéi (inv no 12004/876 et inv. no. 11998). Attardons-nous sur celle portant le numéro d'inventaire 12004 (FIG. 1). Elle est en verre incolore de belle qualité et mesure 43mm de hauteur et 170mm de diamètre. La pièce est incomplète: deux grands fragments sont préservés. Le décor couvre la panse et le fond. Il s'agit d'un décor très original, non pas à proprement parler de 'facettes', mais de lignes sinueuses formant un réseau irrégulier sur toute la surface extérieure de la panse. Le fond est orné d'un petit cercle en relief de deux centimètres de diamètre, entouré d'une rangée de facettes ovales (dont il ne reste que deux éléments), puis d'une rangée de facettes ovales plus petites (il n'en reste que trois et demi) insérée entre deux minces filets concentriques en relief. La seconde coupe, exposée dans les salles du musée, inv. no. 11998 , restaurée , présente des dimensions très proches de la précédente: 41mm de hauteur et 171mm de diamètre. Ce type de décor est très rare et se retrouve sur un gobelet à pied également conservé au musée de Naples (Harden *et al* 1987, no. 102): le verre est de la même couleur et de la même qualité. Une petite

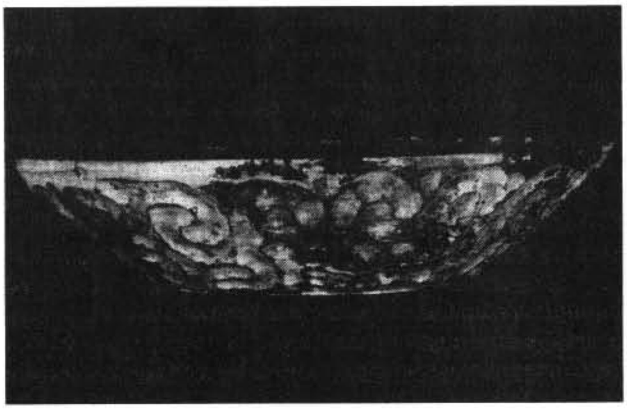

FIG. 1 Coupe à facettes (inv. no. 12004) (Soprintendenza Archeologica di Napoli e Caserta)

bouteille de Pompéi exposée (inv. no. 109540 et Spinazzola 1928, 228, troisième étagère en partant du haut) à panse cylindrique et et épaule oblique comporte également un décor de facettes mais celui-ci est plus régulier et représente peut-être un exemplaire intermédiaire. Il est possible que nous ayons ici affaire à un répertoire d'origine locale, limité probablement dans l'espace et dans le temps, de passage, de transition avec le large groupe de verres à décor 'gravé de facettes' , chronologiquement plus tardif et diffusé dans tout le monde romain (Fremersdorf 1967; Oliver 1984).

LES VERRES À 'PÉTALES'

Ces verres se rattachent à un groupe étudié par Axel von Saldern en1985 et plus récemment en 1991 : les verres à décor en haut-relief (Saldern 1985; 1991). Nous souhaitons présenter un peu plus longuement les deux coupes apodes de Pompéi dans leur contexte de découverte et ajouter au corpus une nouvelle pièce conservée dans le dépôt du musée de Naples.

La coupe inv. no. 133273 (FIG. 2) fut découverte à Pompéi le 6 octobre 1904 dans le tablinum F à l'est de l'atrium de la maison no 28 , R VI, I 16, avec la coupe no 133274, qui lui fait pendant, et beaucoup d'autres objets en verre (Barnabei 1908, 276, fig. 4, 277, fig. 4a).

Voici le matériel retrouvé avec les deux coupes:

Or: un petit fragment de pelote de fil d'or.

Bronze: un candelabre à tige à nœud tripode également à nœud, en excellent état de conservation (h. 1.19m) ,une balance, serrures et clé, clou, un miroir, petites chaînes et une forme elliptique pour la patisserie (lo. 60mm).

Verre: une grande coupe à lèvre évasée, à deux anses et contenant des restes organiques et deux coquilles d'œufs (h. 120mm) .Un vase à panse cylindrique (h. 140mm) . Un vase à panse cubique avec embouchure ronde (h. 150mm). Trois bouteilles piriformes à long col, l'une d'elles avec des restes de substance colorée foncée (h. 160–180–190mm). Quatre petits flacons de formes variées et un fond d'unguentarium avec des restes de substance colorée noire. Une paire de coupes à deux anses, très belles, avec des reliefs externes en forme de cœurs (d. 130mm). Une petite coupelle en cloche à pied rond (d. 60mm). Une sphère vide, bleu azur, perforée avec un filet blanc enroulé en spirale.

Pâte de verre: 17 boutons de taille et de forme variées.

Fer: ciseaux et trois clefs.

Os: un fuseau et trois tiges de fuseau sans la fusaiole (lo. de 17 à 27mm.).

Albâtre: fragment d'une statuette méconnaissable couverte de feuille d'or.

Ambre: torse d'Eros.

Terre cuite: petites statues de Vénus et de Lare. Une coupe, un contenant pour l'huile et deux vases en céramique commune de forme ovoïde (h. 270mm).

La coupe inv no 133273 (FIG. 2) est en verre incolore de très belle qualité, sans bulle, ni filandre. Elle est intacte et mesure 40mm de hauteur et 126mm de diamètre. Elle comporte une rainure sous la lèvre sur la paroi interne et deux cercles en léger relief sur le fond. Le décor est constitué de 'pétales' en relief disposés verticalement sur la panse: trois sur chaque face. Deux anses en demi anneau complètent l'ensemble. Il s'agit d'une forme peu répandue dans la verrerie romaine: elle correspond au type Isings 25. On peut les rapprocher des fragments de coupe du palais de Fishbourne (période 1: 43–75 ap J.-C.) décrits comme des importations en provenance d'ateliers italiens (Harden et Price 1971, 332, no. 29, fig. 138,29, pl. 26,29) et du fragment de coupe découvert à Weisenau près de Mayence (Harter 1999, 184, no. 185). Ce motif de 'pétales' se rencontre aussi sur des formes comme l'amphorisque de Cologne(Harden *et al.* 1987, 191, no. 101) ou le gobelet de Cologne (Lierke 1999, 101, fig. 252). Ce décor de pétales survivra sur des pièces plus tardives (Fremersdorf 1967, pl. 28 en haut; Boon 1985).

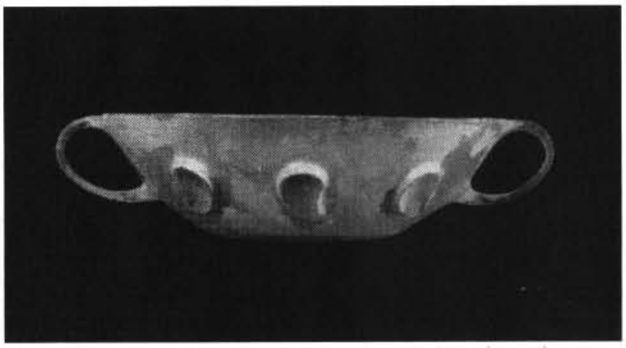

FIG. 2 Coupe à pétales (inv. no. 133273) (Soprintendenza Archeologica di Napoli e Caserta)

Le dépôt du Musée de Naples possède également un skyphos à décor de 'pétales' que l'on peut rattacher à ce groupe: il s'agit du no inv 109428 (FIG. 3) découvert à Pompéi et entré au musée en 1872. La pièce en verre incolore, est complète, mais elle a été déformée par la chaleur. Elle mesure 60mm de hauteur, 115mm de diamètre au bord et le pied a un diamètre de 60mm. Le skyphos présente une panse à paroi verticale, un pied annulaire vertical déformé et deux anses à poucier. Les anses comportent trois éléments: une partie supérieure plate servant de poucier, qui se rattache à la lèvre par deux appendices dessinant deux volutes; un demi-anneau vertical, et une pièce oblique contre laquelle s'appuyait le médius. Le décor sur la panse est formée de deux rangées de quatre 'pétales' de chaque côté. Ces 'pétales' à extrémité pointue sont très proches de celles qui ornent le gobelet de Vysokwa en Slovaquie (Lierke 1999, 101, fig. 253 a): celui-ci fut découvert dans une tombe avec un riche matériel, daté de la fin du Ier siècle ap. J.-C. Il faut également signaler un gobelet découvert à Reims en France, orné d'un décor en relief constitué d'un motif de feuilles à extrémité effilée, disposées en quinconce sur cinq registres (Cabart et Rollet 1997). C'est à ce jour, le seul vase à decor en haut-relief découvert en France.

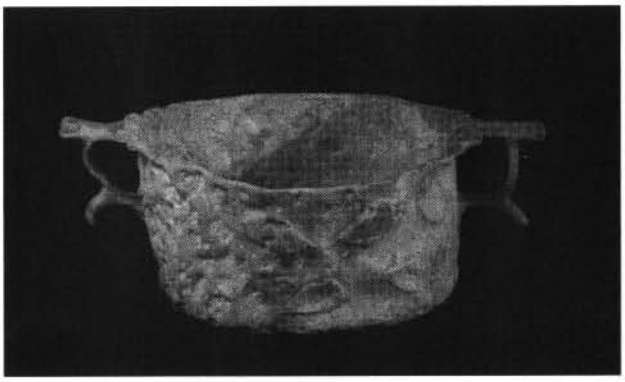

FIG. 3 Skyphos à pétales (inv no 109428) (Soprintendenza Archeologica di Napoli e Caserta)

Le motif de 'pétales' se rencontre sur diverses formes de vases : gobelets, coupes , ou amphorisques, et l'ensemble du groupe est daté par A. v. Saldern du troisième quart du Ier siècle et localisé dans la région de Naples-Rome. Ce groupe possède un répertoire de formes et de motifs décoratifs assez limités qui renvoient aux modèles métalliques. En ce qui concerne la technique de fabrication, elle a été longtemps décrite comme une technique de taille en haut relief (Saldern 1991). Plus récemment, Rosemarie Lierke (Lierke 1999) estime que cette méthode est fort improbable au regard des pièces qu'elle a pu observées et elle pense que les éléments en relief sont obtenus par 'moulage ou formage sur un tour' 'Pressen ou Formdrehen' et ensuite ils peuvent être éventuellement taillés ou gravés.

LES VERRE GRAVÉS

Une paire de cruches à panse arrondie et anse surélevée mérite une attention particulière. La pièce portant le no inv 11986 (FIG. 4) est en verre incolore de belle qualité. Son état de conservation est incomplet: il manque l'extrémité du bec verseur. La hauteur est de 108mm, le diamètre de la panse de 50mm et le diamètre du pied de 43mm. La provenance n'est pas absolument certaine mais il est probable que ce soit Pompéi. Ces objets (la seconde pièce porte le no. 11982) sont entrés au musée en 1868. Ils présentent une panse renflée, une anse surélevée, un petit col cylindrique concave, un bec verseur et un pied annulaire. Le décor gravé couvre la panse et l'anse. La base du col est soulignée par un filet en creux. Le haut de la panse est orné d'une rangée de cinq éléments en demi-cercles (peltae stylisées) et la moitié inférieure est couverte d'un calice de feuilles allongées. L'anse est ornée d'un motif incisé en arêtes de poisson et de petites feuilles stylisées ornent les extrémités de l'anse. Le décor de la panse de cette pièce est très proche de celui d'une petite cruche en argent découverte à Pompéi (Boriello *et al.* 1986, 210, no. 41); on peut aussi évoquer le décor du kalathiskos en argent d'Herculanum (*ibid.*, 212, no. 55). Quant au décor de l'anse,

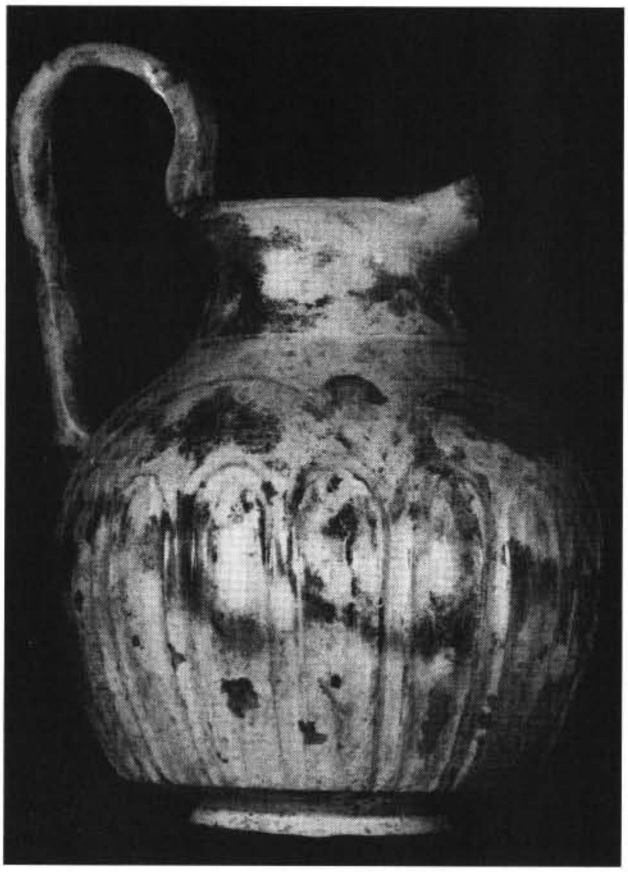

FIG. 4 Cruche (inv. no. 11986) (Soprintendenza Archeologica di Napoli e Caserta)

il rappelle celui qui orne l'anse de la paire d'askoi retrouvés à Pompéi (*ibid.,* 224, no. 39)

Pastiche ou faux?

La forme de cette bouteille (FIG. 5) est inconnue à ce jour et cette pièce paraît assez insolite. Elle est en verre incolore, intacte et le décor est gravé (inv. no. 11985). Ses dimensions sont les suivantes: hauteur 150mm et diamètre 80mm.

Provenance: les inventaires ne mentionnent pas de provenance.

Le décor est organisé en registres: de haut en bas: une rangée de 3 peltes , une rangée de quatre losanges quadrillés encadrée en haut et en bas de quatre éléments horizontaux en amandes, une rangée de sept éléments ovales disposés obliquement et séparés par des traits; sur le fond une rosace à 20 pétales en 'tourbillon'. Le petit col court est taillé en huit pans et semble destiner à recevoir un bouchon.

Nous ne pensons pas que cet exemplaire soit campanien. Il s'agit peut-être d'un pastiche voulant imiter une pièce antique en utilisant un répertoire décoratif inspiré de l'antiquité.

Conclusion

Mis à part le dernier objet présenté, nous pensons que ces pièces proviennent d'un ou plusieurs ateliers où travaillaient

FIG. 5 Bouteille (inv. no. 11985) (Soprintendenza Archeologica di Napoli e Caserta)

des artisans d'origine orientale qui connaissaient la technique du verre moulé, taillé et gravé et qui avaient leurs ateliers peut-être depuis longtemps à Naples ou à Pouzzoles. Ici on a récemment reconnu l'existence d'un four de verrier qui est daté seulement au III siècle ap.J.C. (Gialanella 1999) et qui pourrait plutôt être relié à la prodution plus tardive des bouteilles gravées de la série 'Baiae-Puteoli' (Painter 1975; Ostrow 1981). Il faut toutefois considérer le rôle très important que Pouzzoles a joué pour les relations commerciales entre Orient et Occident,surtout après la chute de Délos et ses liaisons avec l'Egypte Ptolémaique bien attestées à la fin du II siècle av. J. C. , mais probablement encore plus anciennes: il faut rappeler à ce propos le document épigraphique de la *Lex parieti faciendo* (CIL X, 1781 et Ziviello 1990, 50, n.6).

La présence de marchands étrangers à Pouzzoles continue avec Nabatéens, Juifs, Heliopolitains et Tyriens avec la 'lettre' écrite par ces derniers au sénat de Tyr en 174 ap. J.C. (Dubois 1907, 83–97 et I.G. XIV 830) dans laquelle ils invoquent la mère-patrie pour leurs problèmes économiques liés à la 'concurrence' d'Ostie.

Dans la toponymie de Naples il y a encore un quartier appelé 'Regio Nilensis' et au Moyen Age 'vico degli Alessandrini' où l'on peut encore aujourd'hui admirer une statue du 'Nil' (De Caro 1983): il faut donc imaginer un réseau de relations diversifiées avec les pays méditerranéens qui nous conduisent à Naples mais à Rome aussi. Il faut à ce propos souligner les relations Neapolis-Puteoli-Rome, qui était le centre du pouvoir, et un marché potentiellement plus réceptif pour les objets produits ou importés par les villes campaniennes. L'ensemble de ces vases luxueux appartient probablement au troisième quart du Ier siècle ap. J.-C. (probablement av. 79 ap. J.-C.) et on peut vraisemblablement les considérer comme les premiers témoignages de verres gravés dans la région vésuvienne.

La rareté de ces objets , souvent trouvés par paires, dans la région vésuvienne nous confirme qu'ils sont des 'achats' importants. Ce sont sans doute des 'beni di famiglia' qui témoignent un goût recherché et il serait intéressant de continuer ces études pour mieux comprendre le milieu des propriétaires (Camodeca 1996) de ces objets qui donnaient beaucoup de prestige à leur maison.

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BLACK GLASS OF SECOND TO THIRD-CENTURY DATE IN NORTHERN GAUL: A PRELIMINARY SURVEY

PETER COSYNS AND FRÉDÉRIC HANUT

INTRODUCTION

At first this paper was meant to result in a survey of black glass vessels in Belgium; but it soon became clear that many sites in the north-western provinces also provided similar material. Therefore research was extended to the borderland of Belgium's neighbouring countries. An attempt was made to get through as many forms and sites as possible, without the intention of being exhaustive. The result is a distribution map showing a concentration of black glass in the *Civitas Tungrorum* (FIG. 1).

Although the Romans used black glass to make gaming counters, rings, beads and bangles as well as vessels, this paper will primarily focus on free-blown black glass vessels dating from the 2nd–3rd century AD. First-century AD black glass cast vessels like those from Magdalensberg (Czurda-Ruth 1979, 72–8), Asberg (Van Lith 1983, 269, no. 326), Augst (Rütti 1991, 44, no. 895), Colchester (Cool and Price 1995, 30–5) and Calvatone (Diani 1998, 34) are therefore not taken into consideration. Neither are the 1st-century AD black glass vessels from the Gulf of Naples, as for example a baseless shallow handled cup (Isings 25) with the inside decorated with inlay in gold leaf, silver, bronze and cornelian (Isings 1957, 39–40) found in Pompeii.

The problem of the heuristic issue about black glass is that in the first place, most publications contain no detailed description or confusing information on the colour. As the so-called black glass of itself does not exist, it is important to know if the glass is opaque deep blue, green, purple or brown. The black glass objects found in the north-western provinces are in reality a very dark bottle green to olive brownish-green opaque glass. This is only noticeable when put to light or when the glass is very thin, like the thin walled *carchesia* (see form 1). Exceptions like the fragments of a *carchesium* from the villa of Hoogeloon in opaque dark purple glass (Van Lith, pers. comm.) or the two-handled bulbous flask (see form 14) from a tomb in Elsdorf-Esch in opaque deep blue glass (Gaitzsch, 1999, 79) can occur. These examples demonstrate the necessity to know more about the composition and technology of black glass through chemical analyses and optical research on chromatics. For example late Iron Age black glass beads are known, like the ones from the chariot grave III, 2 in Neufchâteau-le-Sart (Cahen-Delhaye 1997, 25–6). Except for these beads, which have recently undergone an optical investigation, it is, at present, unknown in what colour of glass the late Iron Age black glass beads are made. Although dating from the beginning of the 3rd century BC these beads are optically similar to the Roman very dark olive green opaque glass appearing black. Chemical analysis will have to bear out any differences and/or similarities with the Roman black glass. It will give the opportunity to discover if the black glass was produced in a similar way during the pre-Roman and Roman period.

TYPOLOGY (FIG. 2)

All the vessels are tableware and are exclusively used for drinking: beakers, cups, bowls, jugs and jars. Most of the 14 free-blown vessel forms distinguished are produced in a monochrome black glass. Some (Forms 4, 5, 12 and 14) are known with a marvered festoon-patterned (*Federmuster*) decoration in opaque white glass in sharp contrast to the black glass. A very few are decorated with applied threads on the shoulder and/or at the lower part of the body. These threads can be in black, white or blue opaque glass.

In what follows Isings forms are derived from Isings 1957, Trier forms from Goethert-Polaschek 1977, and AR forms from Rütti 1991.

Form 1 (Isings 36b)

Wide-mouthed beaker with carinated body and base-ring, known as a *carchesium*. This very thin-walled vessel shape (1.5mm or less) is the most frequent type of all black glass vessel forms and, in Belgium, nearly exclusively produced in black glass – one example in colourless glass is known from Couvin (Archaeological Museum, Namur). Some *carchesia* such as those from Amay (Lehance and Willems 1987, 52, fig. 4, no. 9), Wancennes (Mignot 1984, 224–7, fig. 37, no. 1) and Esch IV (van den Hurk 1975, 82, fig. 19) have a slender cylindrical shape. Others, like the three from grave no. 176, Cutry (Liéger 1997, 148, fig. 28, nos 3–5), are more compact and have a concave body. The height of these vessels averages out at 90–100mm. On some beakers decoration of applied glass threads exists, in the same colour as the vessel, around the top of the body and just below the carinated body, like the example from Esch IV. A fragment of this type of vessel is also attested in Colchester (Cool and Price 1995, 93, no. 615).

Hitherto unknown in black glass are the stemmed *carchesia* (Isings 36c). As they have mostly snake-thread decoration they are assumed to originate from Cologne workshops.

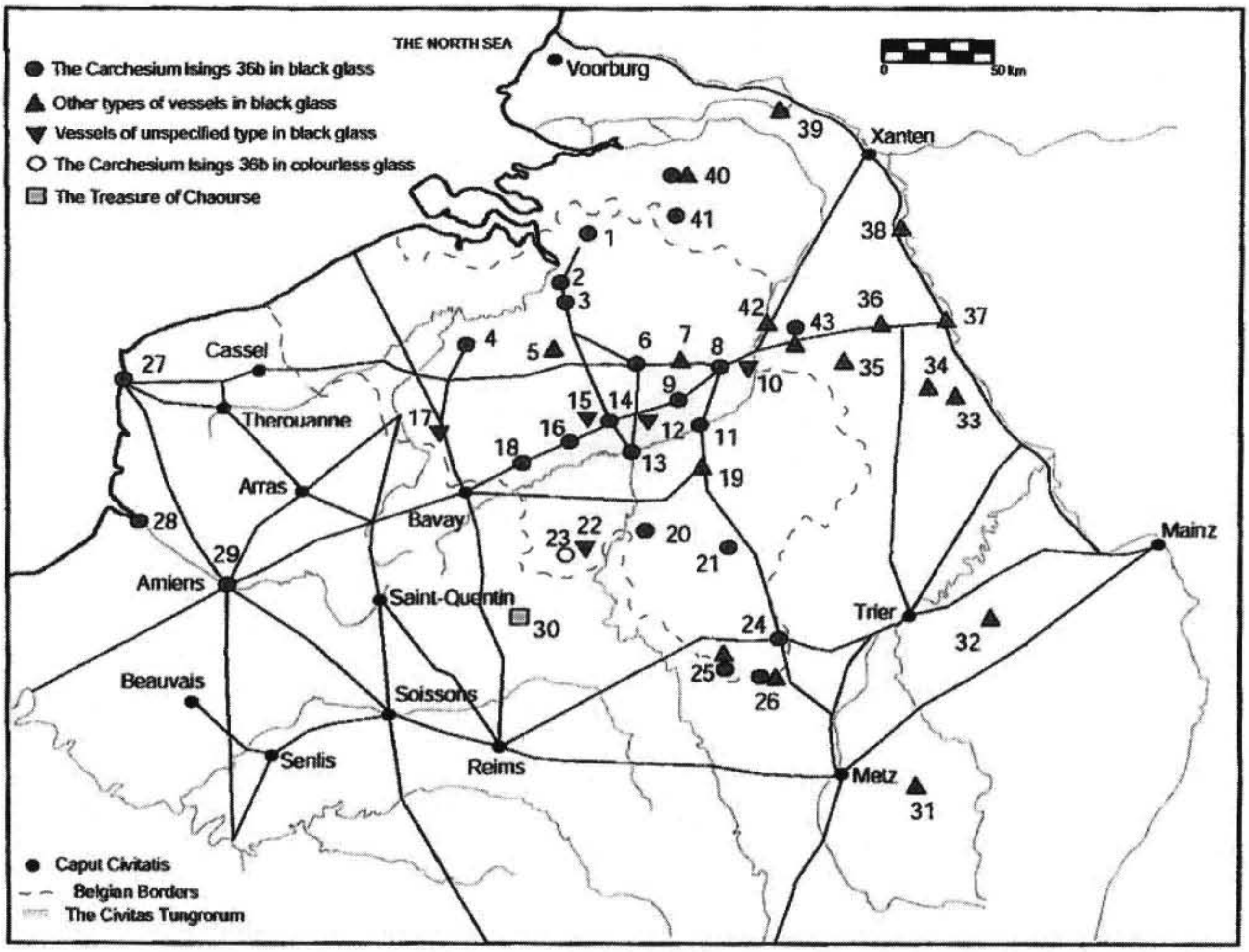

FIG. 1 Distribution map of the Roman black glass in Northern Gaul. Key: 1 Brecht-Zoegweg (Belgium); 2 Kontich (Belgium); 3 Rumst (Belgium); 4 Velzeke (Belgium); 5 Schaerbeek (Belgium); 6 Tienen (Belgium); 7 Straten (Belgium); 8 Tongeren (Belgium); 9 Braives (Belgium); 10 Eben (Belgium); 11 Amay (Belgium); 12 Hanret (Belgium); 13 Jambes (Belgium); 14 Baudecet (Belgium); 15 Chastre-Villeroux (Belgium); 16 Liberchies (Belgium); 17 Ellignies-Sainte-Anne (Belgium); 18 Waudrez (Belgium); 19 Bois-et-Borsu (Belgium); 20 Wancennes (Belgium); 21 Lavacherie (Belgium); 22 Nismes (Belgium); 23 Couvin (Belgium); 24 Arlon (Belgium); 25 Virton/Saint-Mard (Belgium); 26 Cutry (France); 27 Boulogne-sur-Mer (France); 28 Abbeville (France); 29 Amiens (France); 30 Chaourse (France); 31 Chemery-Faulquemont (France); 32 Siesbach (Germany); 33 Rheinbach-Flerzheim (Germany); 34 Hausweiler (Germany); 35 Eschweiler-Hastenrath (Germany); 36 Elsdorf-Esch (Germany); 37 Köln (Germany); 38 Krefeld-Gellep (Germany); 39 Nijmegen (Netherlands); 40 Esch (Netherlands); 41 Hoogeloon (Netherlands); 42 Stein (Netherlands); 43 Heerlen (Netherlands)

Form 2 (Isings 88-variant)

Spouted jug with carinated body and base-ring. Only one example of this type is known and comes from a grave in Schaarbeek (Hanut 1999, 8–9, fig. 6). This 105mm high vessel is a combination of forms 1 and 3. The general profile is that of a carinated beaker with pulled-out spout and ribbon handle, attached to the rim edge with a thumb rest and therefore mistakenly classified by C. Isings as a type 88b (Isings 1957, 105). A glass thread in the same colour is applied around the top of the body and just below the carinated body.

Form 3 (Isings 88b/Trier 116c)

One-handled spouted jug with globular body and concave base with central kick. This type is very rare in black glass and is usually produced in blue green, greenish or colourless glass. The example of grave no. 176 of the Cutry cemetery was found in association with another small jug *Isings* 88b in green glass (Liéger 1997, 148, fig. 28, no. 2).

Form 4 (Isings 94/Trier 37/AR104)

Small bulbous jar with short concave neck and wide-mouthed rim and base-ring. This shape is mainly blown in blue green glass, but known in black glass especially in the Rhine region as far south as Augst (Rütti 1991, nos 1997, 1999–2003). An intact Belgian example comes from Thier-Laurent, Bois-et-Borsu, not far from Clavier-Vervoz (Royal Museums of Art and History, Brussels, inv. B 4438). Striking for this type of vessel shape are the opaque white marvered festoons. Examples of ones with this decoration are known from a stone box grave at Heerlen (Brouwer 1991, 47, no. 16) and from the ash pits 2/3 of the Siesbach barrow (Abegg 1989, 209, nos 312, 319–26).

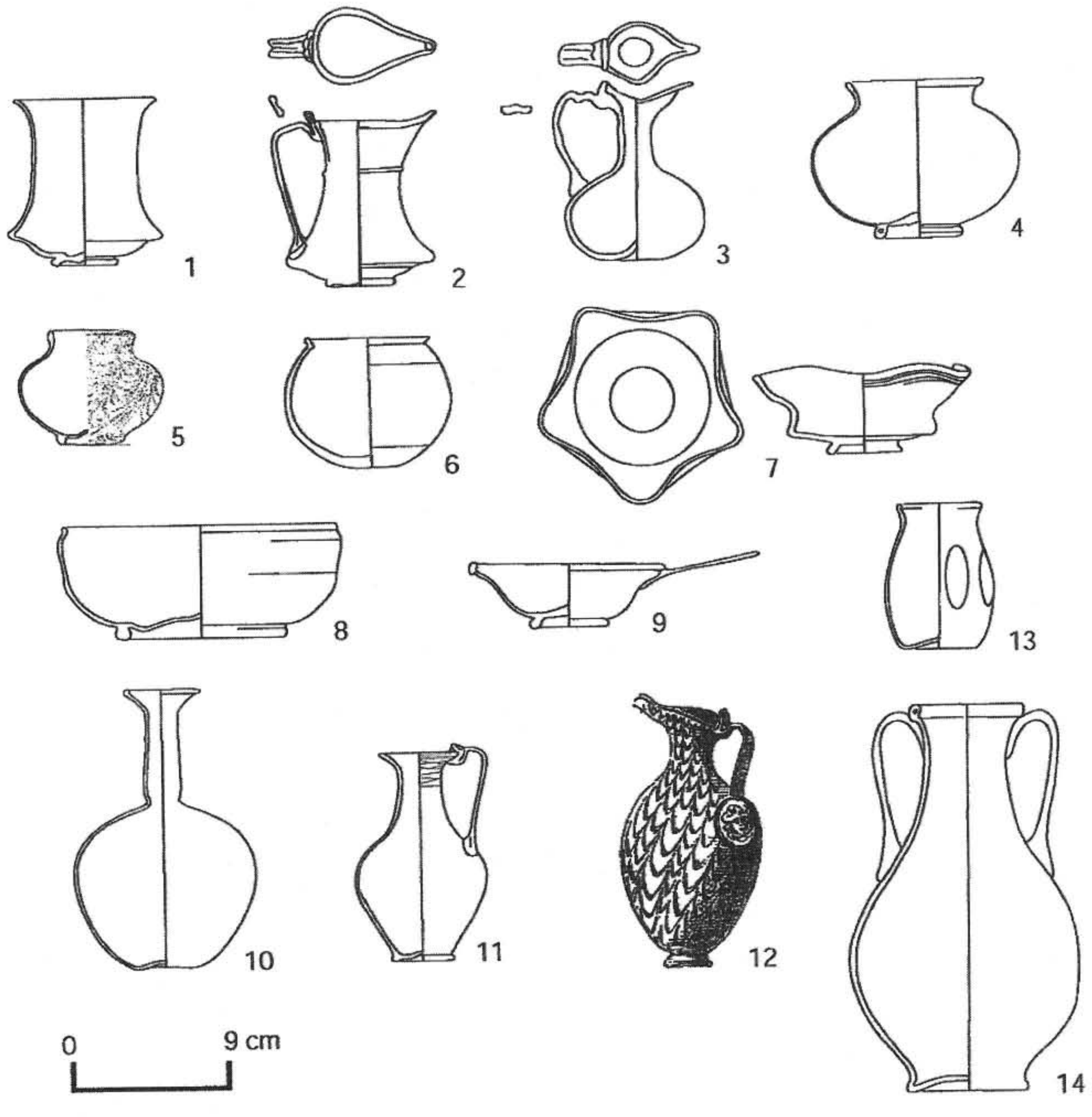

FIG. 2 Typology of Roman black glass. 1 Form 1 (Amay; Belgium), 2 Form 2 (Schaerbeek; Belgium), 3 Form 3 (Cutry; France), 4 Form 4 (Heerlen; Netherlands), 5 Form 5 (Rheinbach-Flerzheim; Germany), 6 Form 6 (Esch III; Netherlands), 7 Form 7 (Esch III; Netherlands), 8 Form 8 (Krefeld-Gellep; Germany), 9 Form 9 (Stein; Netherlands), 10 Form 10 (Stein; Netherlands), 11 Form 11 (Esch VI; Netherlands), 12 Form 12 (Weilerwist-Hausweiler; Germany; by courtesy of Rheinisches Landesmuseum Bonn LVR), 13 Form 13 (Eschweiler-Hastenrath; Germany) and 14 Form 14 (Elsdorf-Esch; Germany); scale 1:4

Form 5 (Trier 38)

Bulbous beaker with short vertical neck and thickened rim and base-ring. These vessels were known in monochrome black glass as well as with opaque white marvered festoon-patterned decoration. The beaker (Stern 2001, 193, no. 84), probably from Cologne, is 73mm high and has a single thread in opaque white glass applied on the top of the body and above the base-ring. This type of beaker is also known from Vieux-Virton and from Rheinbach-Flerzheim (Follmann-Schulz, pers. comm.). The latter shows a white opaque marvered decoration.

Form 6 (Isings 94-variant/AR 40)

Bulbous cup with outsplayed rim and flat base. One intact example of this type is known and was discovered in Esch III (van den Hurk 1973, 224–5, no. III, 36) another, although incomplete, example is known from Augst (Rütti 1991, no. 1186). Parallels in other colours are very rare.

Form 7 (Isings 42d)

Wide-mouthed bowl with scalloped edge and base-ring. This shape is extremely rare. The only example known in black glass comes from Esch III (van den Hurk 1973, 225, no. III, 37). Only one similar vessel in colourless glass is known and comes from barrow III, Champion, near Namur (Isings 1957, 59).

Form 8

Hemispherical shallow bowl with thickened rim and base-ring. This unique vessel form in glass is only known from grave no. 3815, Krefeld-Gellep (Pirling 1997, 36, no. 3815, 2).

Form 9 (Isings 75a)

Shallow saucepan (*trulla*) with thickened, vertical rim, flat handle and base-ring. The only example registered in black glass comes from sarcophagus II, Stein (Isings 1971, 25, no. 78). Most examples of this type are greenish or colourless and similar glass vessels are known with snake-thread decoration.

Form 10 (Isings 92)

Bulbous flask with high narrow neck and funnel-mouth and concave base. The only example of this type has been discovered in sarcophagus II, Stein (Isings 1971, 11–12, no. 19).

Form 11 (Isings 120 variant)

Ovoid one-handled jug with concave neck, funnel-shaped mouth and rounded rim on base-ring. The one from Esch VI (van den Hurk 1977, 120, no. VI, 25) is the only example known in black glass. A spiral coil of similar glass was wound up many times around the top of the neck.

Form 12 (Isings 54)

One-handled jug with spouted mouth, ovoid body and base-ring. The handle bears a vertical scalloped thumb-rest at the top and, in some cases, has an applied mask (Bacchus?) on the body. The black glass jugs are always decorated with opaque white marvered festoons. Examples are known from Nijmegen (Isings 1964, 176, fig. 4, no. 4), from the cemetery of the Luxemburgerstraße, Cologne (Isings 1964, 176, fig. 5) and from Weilerwist-Hausweiler (Follmann-Schulz 1992, 21–2, no. 10).

Form 13

Ovoid indented beaker with outsplayed rim and concave base. The shape is clearly inspired by pottery from the 3rd century AD. Very alike to the Eschweiler-Hastenrath beaker in a coarse black glass (Follmann-Schulz 1992, 87–8, no. 47) is a beaker from Lisieux in very dark bottle green (Sennequier 1985, 63, no. 36) although the latter has no indented decoration and has a base-ring.

Form 14 (Isings 15)

Amphoriskoi or two-handled jug with tall ovoid body and base-ring, wide neck and out-turned tubular rim. These *amphoriskoi* are normally pre-Flavian and have been made in blue-green glass or in strong coloured glass, particularly dark blue. This type is also illustrated by a unique example in black glass with opaque white marvered festoons found in a 3rd-century grave at Elsdorf-Esch (Gaitzsch 1999).

Chronology

The use of black glass for making free-blown vessels coincides with the expansion of the production of tableware from the last quarter of the 2nd century AD. Nevertheless vessels in this 'colour' remain very scarce, as for example at Augst where only 0.1% of the 5118 vessels were in black glass (Rütti 1991, 109).

In Northern Gaul free-blown black glass vessels do not appear in closed contexts earlier than the mid 2nd century AD. The earliest dated contexts containing black glass vessels in the north-western provinces appear during the third quarter of the 2nd century AD.

The *carchesium* (form 1) belongs to a chronologically homogeneous horizon dated between AD 170/180 and 230/240. This vessel form is therefore contemporary with the snake-thread decorated glass vessels from the Cologne workshops which are very common in *Germania Inferior*. Black glass vessels were found in association with snake-thread glass tableware in Esch IV (van den Hurk 1975, 79–80, no. IV.11; IV.12) and in the grave of Elsdorf-Esch (Gaitzsch 1999, 79). The three jars (form 4) registered among the burnt material from pits 2/3 of the Siesbach barrow belong to a context which was dated by dendrochronology to the years AD 173–174 (Abegg 1989, 227).

From the middle of the 3rd century AD the black glass *carchesium* went out of circulation, while other vessel forms remained in production up to the second half of the 3rd century AD such as the shallow saucepan form 9 (Isings 1971, 25, no. 78) and the bulbous flask form 10 (Isings 1971, 11–12, no. 19) from sarcophagus II in Stein or the *amphoriskoi* Form 14 from the grave of Elsdorf-Esch (Gaitzsch 1999, 79).

About 90% of all free-blown black glass vessels can be dated between AD 180 and 230 and no context gives a date before AD 150 or after AD 270/280 (TABLE 1). However, the use of black glass remained popular for the production of jewellery and lasted until the end of the Late Empire (end 4th–early 5th century AD).

Morphological parallels

The *carchesium* (Form 1) can be connected morphologically and chromatically with the biconical *terra nigra* goblets with low carinated body Deru P56.1/2 (Deru 1996, 130–1, fig. 56). The distribution of this ceramic form is widespread in the *civitas Tungrorum* and in the *civitas Nerviorum* from the end of the 1st century until the beginning of the 3rd century AD. In funerary context the goblet is attested until AD 170/80. This goblet form is found in Bois-de-Buis I (AD 125–150) and in Walsbets (AD 150–180) (Lefranq 1983, 12, no. 26). From the last quarter of the 2nd century AD it seems that in the tombs the *terra nigra* goblet is replaced by the black glass *carchesium*.

The silver treasure of Chaourse (dept. Aisne, France, 1883) shows that the *carchesium* also has a counterpart with silver cups. The three silver cups similar to the black glass carinated cups on ring bases are dated between AD 200 and 270 (Baratte 1989, 117–18, nos 55–7).

TABLE 1 DATED CLOSED CONTEXTS PROVIDING BLACK GLASS

Site	Context	Typology	Chronology (AD)	References
Jambes – B	Grave at Basse-Enhaive	Form 1	170–200	Van Ossel 1986, 203, no. 5
Esch – NL	Barrow IV	Form 1	170–200	van den Hurk 1975, 82, no. IV.16
Velzeke – B	Well K 14 in the *vicus*	Form 1 (3x)	170–200	unpublished material
Wancennes – B	Grave no. 3 of the cemetery	Form 1	170–230	Mignot 1983/4, 224, no. 1
Liberchies – B	Well H 5 of the tannery	Form 1	after 180	Brulet *et al.* 2001, 106, fig. 67, no. 17
Amay – B	Grave no. 37 of the cemetery	Form 1	200–260/270	Lehance and Willems 1987, 52, no. 9
Vieux-Virton – B	Cellar no. 1	Form 1	250–260	unpublished material
Cutry – F	Grave no. 176 of the cemetery	Form 1 (3x)	180–250	Liéger 1997, 148, fig. 28, nos 3–5
Braives – B	Cellar no. 4 (sector I) in the *vicus*	Form 1	180–230/240	Brulet 1985, 51, fig. 17, no. 10
Schaerbeek – B	Grave no. 2	Form 2	180–230	Hanut 1999, 7–9, fig. 3, no. 3
Cutry – F	Grave no. 176 of the cemetery	Form 3	180–250	Liéger 1997, 148, fig. 28, no. 2
Heerlen – NL	Grave no. 2	Form 4	160–180	Brouwer 1991, 47, no. 16
Siesbach – D	Pits 2/3 of the Siesbach barrow	Form 4 (3x)	173–174	Abegg 1989, 209, fig. 17
Esch – NL	Barrow III	Form 6	160–170/180	van den Hurk 1973, 224–5, no. III.36
Esch – NL	Barrow III	Form 7	160–170/180	van den Hurk 1973, 225, no. III.37
Krefeld – D	Grave no. 3815 of the cemetery	Form 8	3rd century	Pirling 1997, 36, pl. 16, fig. 3
Stein – NL	Sarcophagus II	Form 9	250–300	Isings 1970, 25, no. 78
Stein – NL	Sarcophagus II	Form 10	250–300	Isings 1970, 11–12, no. 19
Esch – NL	Barrow VI	Form 11	170–200	van den Hurk 1977, 120, no. VI.25
Elsdorf-Esch – D	Grave	Form 14	230–270	Gaitzsch 1999, 79

Forms 4, 5 and 6 are obviously inspired by cups in ceramics, as Form 5 corresponds with type Niederbieber 33 in metallescent ceramics (Oelmann 1976, 40–2). Not only is there a morphological relationship, but also a chromatic one.

To obtain a better understanding of Roman black glass many questions remain. How did the Romans manage to colour the glass black? When and where was this type of glass produced? When and why did black glass go out of production? What made the glass workshops in Northern Gaul decide quite suddenly to stop the production of vessels in black glass, while for about 150 years more this 'colour' of glass was used to produce jewellery? Was it because this glass became too difficult to obtain, resulting in it becoming too expensive a material? Or was it because another material supplied an easier and more competitive alternative?

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COLOUR PLATES

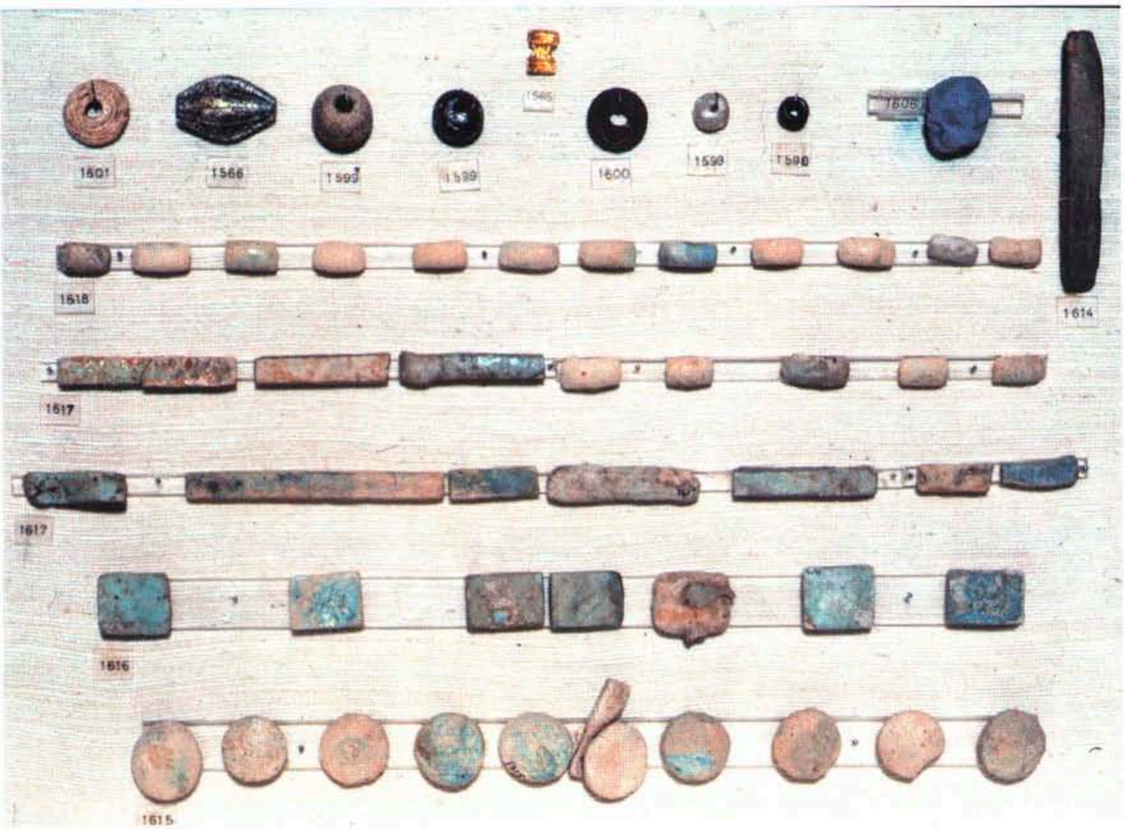
COLOUR PLATE 1 Standard type of the glass vessels in Egypt; No. 1011-1868, The Victoria and Albert Museum, London

COLOUR PLATE 2 Glass vessels from Ghurab; EA64338, EA67027, EA65661, EA64339, The British Museum, London

COLOUR PLATE 3 Fragments of glass vessels from Ghurab; EA67751, UC22857, UC22852, UC22856, UC22851, UC22846, EA67760, EA: The British Museum, UC: Petrie Museum of Egyptian Archaeology, University College London

COLOUR PLATE 4 Fragments of glass vessels from Amarna; EA66973, EA68419, EA68421, EA68423, EA68426, EA68447, EA66979, EA67003, EA68424, The British Museum, London

Glass vessels from Ghurab and Amarna (pp. 6–9)

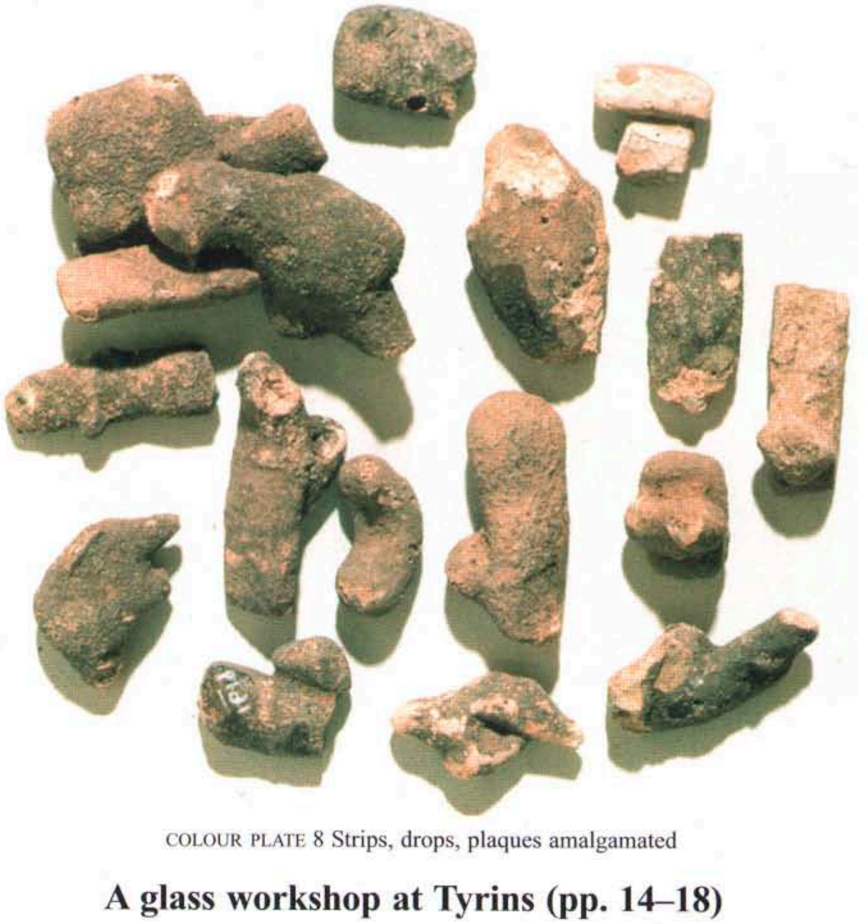


COLOUR PLATE 5 Finished glass products (beads, strips and knobs) and some failures


COLOUR PLATE 6 Glass drops

A glass workshop at Tyrins (pp. 14–18)

COLOUR PLATE 7 Glass strips



COLOUR PLATE 8 Strips, drops, plaques amalgamated

A glass workshop at Tyrins (pp. 14–18)

COLOUR PLATE 9 Blue and white glass rosette plaques (cleaned) set in frames of opaque red glass (weathered green, but some red seen in second piece on right, second row), found at Arslan-Tash; largest diam. 17x17mm; BLMJ 2080-E35B. Photo Z. Radovan

COLOUR PLATE 10 Blue and white glass rosette plaques (cleaned), found at Arslan-Tash; most pieces diam. 5–6mm; BLMJ 2080-E35B. Photo Z. Radovan

COLOUR PLATE 11 Blue and white glass rosette plaques (strongly weathered), found at Arslan-Tash; most pieces 6–7mm in diameter; BLMJ 2080-E35B. Photo Z. Radovan

COLOUR PLATE 12 Piece in COLOUR PLATE 9 (bottom right) shown from both sides; BLMJ 2080-E35B. Photo Z. Radovan

Iron Age glass inlays (pp. 28–31)

COLOUR PLATE 13 Glass fragments from the Hellenistic workshop in Jerusalem

Jerusalem's 1st-century BCE glass workshop (pp. 54–7)

COLOUR PLATE 14 Pikrolimni in May 2003

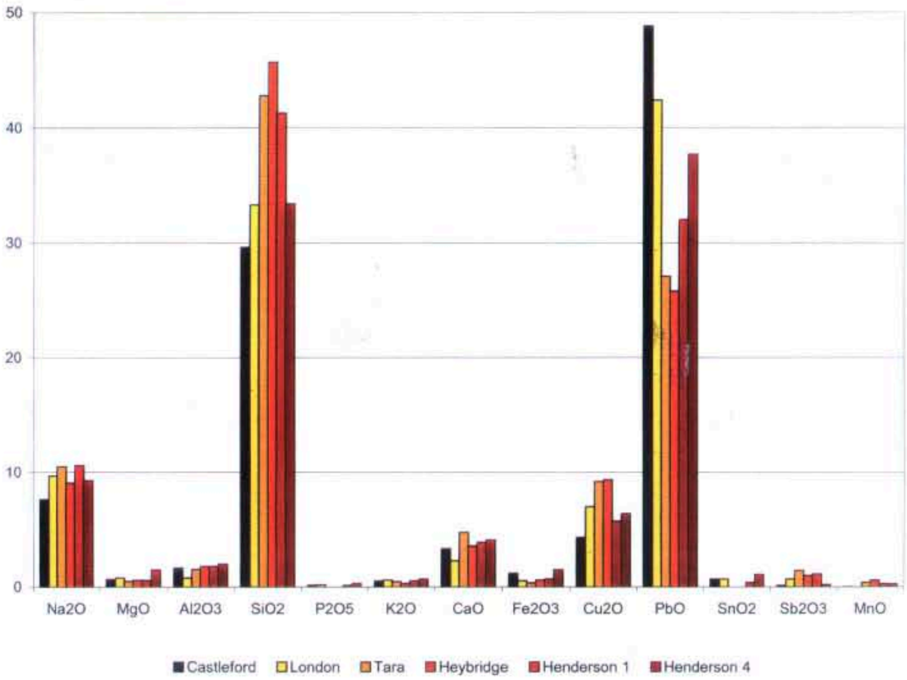
COLOUR PLATE 15 Pikrolimni in August 2002

COLOUR PLATE 16 Natron formed on drying footsteps

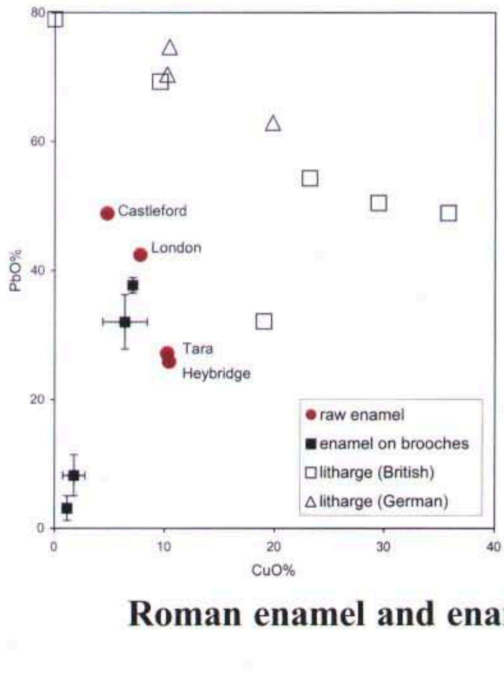
COLOUR PLATE 17 Natron collected for analysis

Nitrum chalestricum (pp. 64–7)

COLOUR PLATE 18 The largest lump of weathered red glass from Castleford (SF 22); length 56mm



COLOUR PLATE 19 Comparative data for raw red enamel lumps (from the references given in the text) and enamel in Roman brooches (from Henderson 1991)

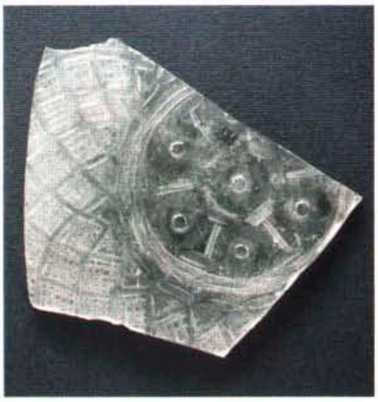


COLOUR PLATE 20 Graph showing the variable amounts of lead and copper oxides present in red enamel lumps, red enamels on Roman brooches and in Roman litharge cakes from Britain and Germany. Data for enamel lumps is taken from the references given in the text; for enamel on objects from Henderson 1991; and for litharge cakes from Gowland 1900, Rehren and Kraus 1999 and unpublished analyses by Kerstin Eckstein

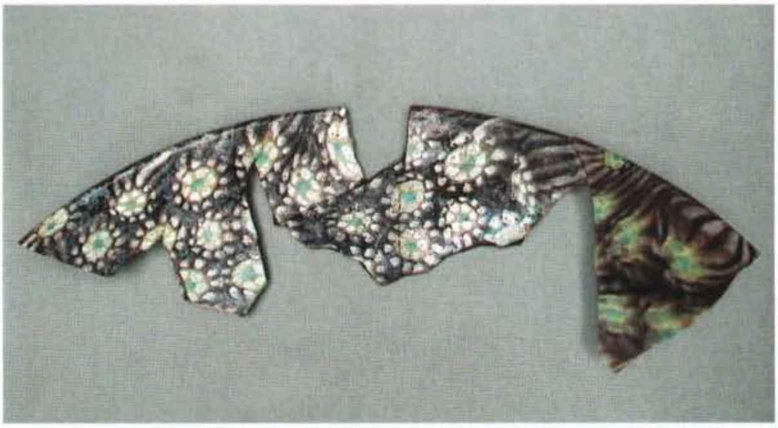
Roman enamel and enamelling (pp. 72–4)

COLOUR PLATE 21 Engraved beaker from Medinet Madi; © Pisa University, Archeological Missions in Egypt

COLOUR PLATE 22 3D reconstruction of the beaker; © Computing Lab, ISTI-CNR in Pisa



COLOUR PLATE 23 Engraved bowl from Medinet Madi; © Pisa University, Archeological Missions in Egypt



COLOUR PLATE 24 Mosaic glass from Medinet Madi; © Pisa University, Archeological Missions in Egypt

Colour plates 21–5: Glass from Medinet Madi (pp. 119–21)

COLOUR PLATE 25 Fragmentary bead showing a lozenge pattern; © Pisa University, Archeological Missions in Egypt

COLOUR PLATE 26 Ce bloc de verre brut (no. 0136) et la vaisselle (no. 0106, 0110) sont, malgré leur aspect différent dû à l'épaisseur à l'altération, de même composition chimique. Photo :Loïc Damelet, CCJ-CNRS, Aix-en-Provence

L'Épave Ouest Embiez 1 (pp. 122–6)

COLOUR PLATE 27 Schale Isings 12 mit figürlichem Schliff

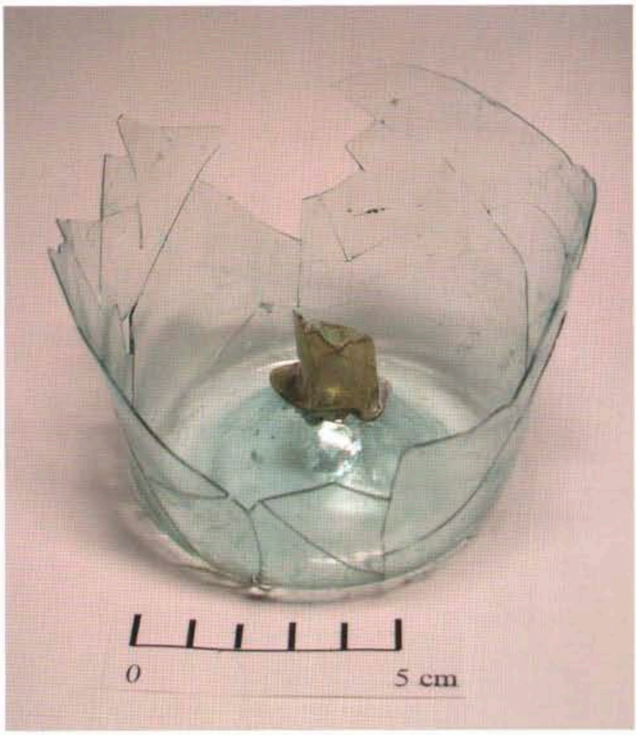
COLOUR PLATE 28 Kammer J: Ofen auf Boden 1

COLOUR PLATE 29 Fragment von Ofenwand oder Schmelztiegel

COLOUR PLATE 30 Fragment einer Tonröhre mit Glasüberzug

COLOUR PLATE 31 Rohglasbrocken

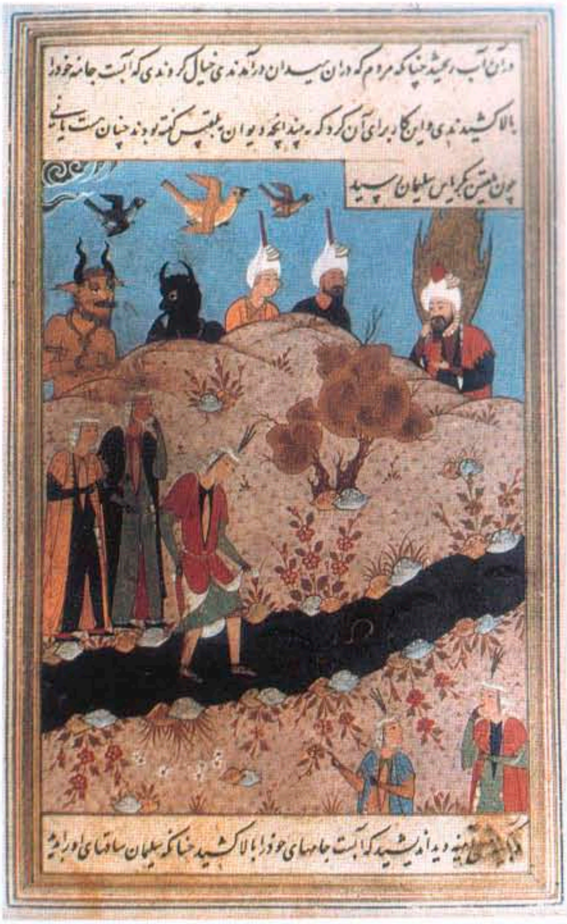
Glas aus Ephesos (pp. 158–61)



COLOUR PLATE 32 Lamp with yellow wick holder

COLOUR PLATE 33 Fragments with yellow impurity in the glass material

Glass lamps from Jabal Harûn (pp. 162–6)



COLOUR PLATE 34 'Bilqis meeting Solomon' 1552 Persian ms. *Majalis al-Ushshaq* (Ousley ms. Add. 24, fol. 127b, Bodleian Library, Oxford)

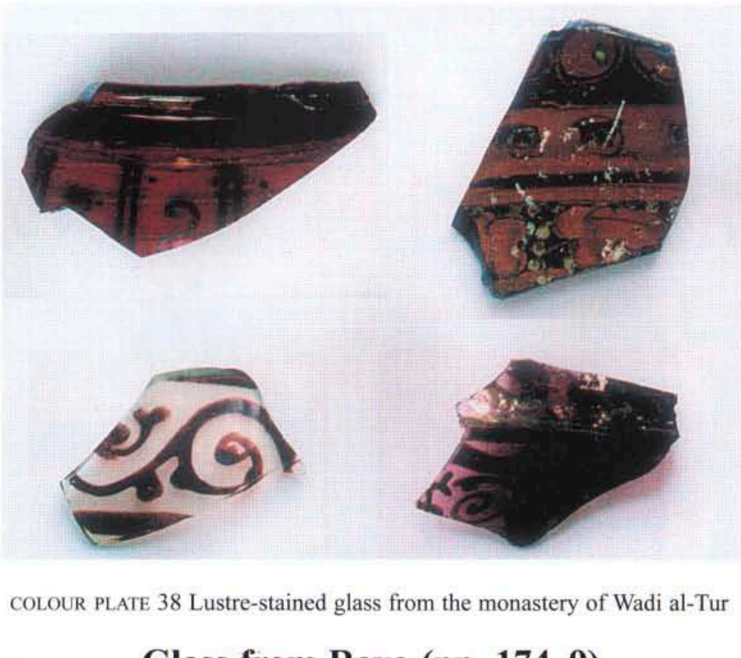
The new age of Solomon (pp. 167–70)

COLOUR PLATE 35 Lustre-painted glass

COLOUR PLATE 36 Cosmetic bottle decorated by cutting

Colour plates 35–7: glass from Ramla (pp. 171–3)

COLOUR PLATE 37 Fragment of relief-cut decorated ewer



COLOUR PLATE 38 Lustre-stained glass from the monastery of Wadi al-Tur

Glass from Raya (pp. 174–9)

COLOUR PLATE 39 The Rothschild bucket, gilded and enamelled glass; H 210mm; private collection

PLATE 41 Candlestick, gilded and enamelled glass; H. 222mm; Corning Museum of Glass no. 90.1.1

COLOUR PLATE 40 The Kassel bucket, gilded and enamelled glass; H. 265mm; Historisches Landesmuseum, Kassel. (after Schmoranz, 1899, pl. xxxii)

Big Mamluk buckets (pp. 182–5)

COLOUR PLATE 42 Fragments of prunted beakers; Ht. (largest fragment) 44mm

COLOUR PLATE 43 Necks of bottles; Ht. (largest fragment) 79mm

COLOUR PLATE 44 Bases of bottles; Diam. (largest foot-ring) 80mm

COLOUR PLATE 45 Neck of bottle; Ht. 46mm

COLOUR PLATE 46 Necks of bottles; H. (largest fragment) 64mm

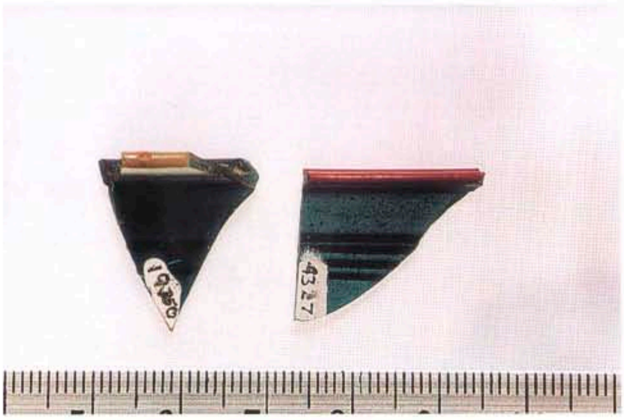
COLOUR PLATE 47 Handles of hanging lamp. L. (largest fragment) 62mm

Glass from the Crusader castle at Montfort (pp. 191–3)

COLOUR PLATE 48 Translucent purple glass fragments FTC 10913, 9962, and IX

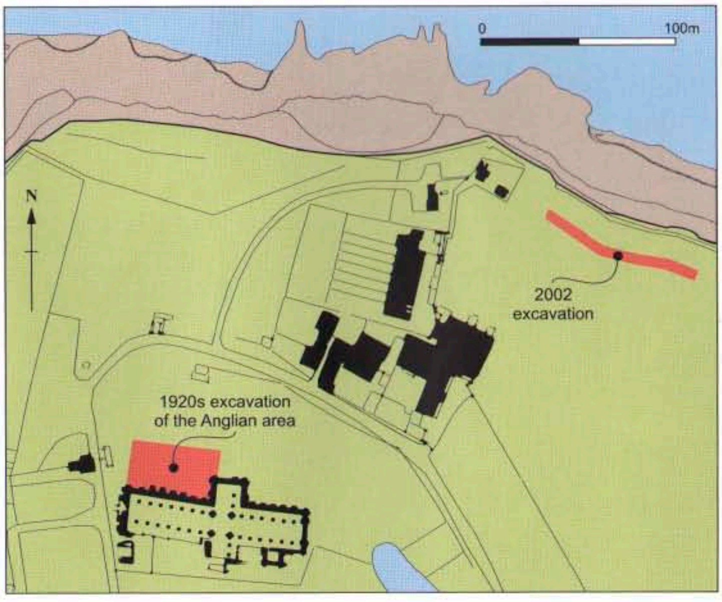
COLOUR PLATE 50 Translucent blue glass fragments FTC 19350 and FTC 4327

COLOUR PLATE 49 Translucent purple glass fragment FTC 24314



COLOUR PLATE 51 Translucent blue glass fragments FTC 19350 (inside) and FTC 4327 (inside)

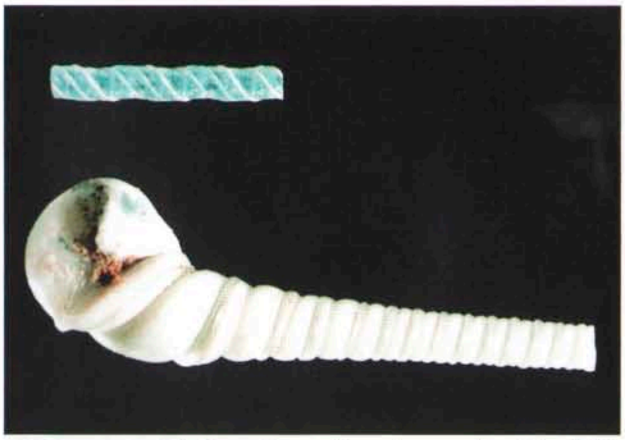
Glass from Singapore (pp. 199–202)



COLOUR PLATE 52 Location map of Whitby headland and the areas of excavation. © English Heritage

Glass from Whitby (pp. 207–9)

COLOUR PLATE 53 Two glass plaques found in the 1920s. The square plaque (acc no W506) measures 11x 10.5mm. The precise colours of the thin trails are difficult to determine because of decomposition of the glass. Rectangular plaque (acc no W507) 12.5x7mm © English Heritage



COLOUR PLATE 54 Two pieces of waste cane found in 2002. White cane length 23.5mm (490/200136099); blue/green cane length 9.5mm (490/200136097) © English Heritage

COLOUR PLATE 55 L to R: lump (22.5 x 12mm), trail, and two chips © English Heritage

COLOUR PLATE 56 Plaque, length of cane (9.5mm), and chips of blue/green glass © English Heritage

Glass from Whitby (pp. 207–9)

COLOUR PLATE 57 Map of the former Duchy of Brabant (after Blondé & Van Uytven, 1999, 157) with indication of all the selected sites

COLOUR PLATE 58 Green forest glass types. A–C: Antwerp Steen, 15d–17a; A: wrythen ribbed beaker; B: low shallow cup with wrythen ribbed beaker, C: high cylindrical prunted beaker; D Mechelen, 15d–16A, prunted beaker, *berkemeier*

COLOUR PLATE 59 Colourless and green forest glass pedestal beakers. A Mechelen, 15d–16a, pedestal beaker; B Antwerp Steen 15d-17a, pedestal beakers, plain, with wrythen ribs and *vetro a fili* trailing

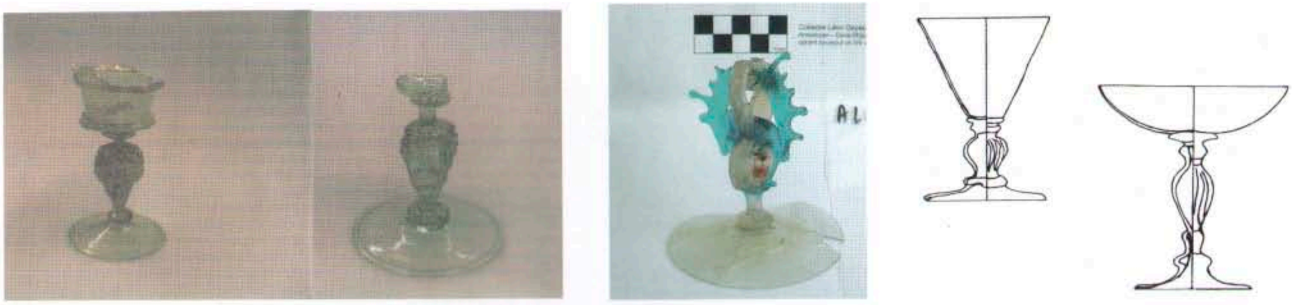
COLOUR PLATE 60 Coastal Flanders: archaeological glass finds, photos Gevaert *et al.* 2003, by courtesy of the Museum Walraversijde, Provinciedomein Raversijde, Oostende. A Vrouwenklooster, Zeeland, multicoloured phial, 16th century, probably of Italian provenance; B Raversijde, octagonal wrythen ribbed beaker, 15B; C Sluis and Middelburg, Zeeland, 14d–15a, thin-walled, optic blown conical beakers, probable provenance Italy

COLOUR PLATE 61 Antwerp Steen, 15d–17a, range of green prunted beakers

COLOUR PLATE 62 's-Hertogenbosch, Boerenmouw 16d, *berkemeier*, a luxury vessel

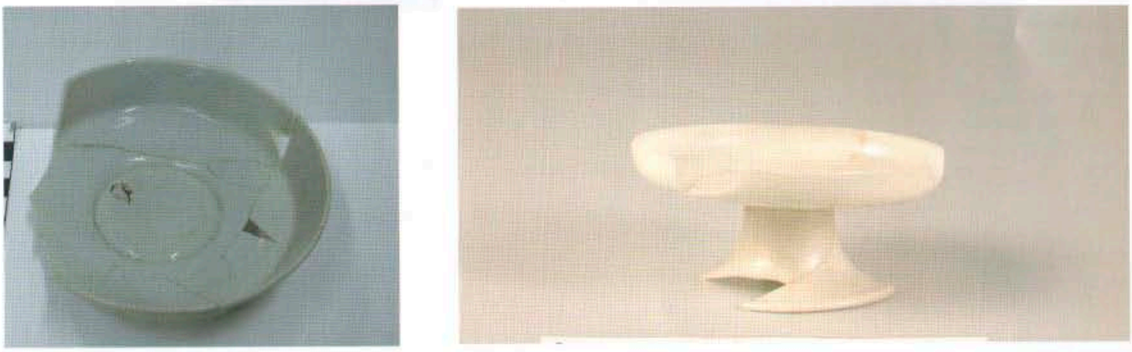
COLOUR PLATE 63 Cylindrical beakers with everted rim in colourless, green and *façon-de-Venise* glass. A Breda, House Merwede, 16d, cylindrical beaker with vertical ribs; B Antwerp Steen, 15d–17a, beaker with horizontal trails; C Breda, House Merwede, 16d, cylindrical beaker with marvered spiral *vetro a fili* trailing

Glass from Brabant (pp. 219–22)



COLOUR PLATE 64 Compound vessels. A 's-Hertogenbosch, Boerenmouw 16d, gilded lion mask stems; B Antwerp, Rijkenhoek, 17A, coiled and winged serpentine; C Middelburg, Flanders, 16d–17a, knopped-stem goblets

COLOUR PLATE 65 Antwerp Steen, 15d–17a, footed beaker with bosses and a *cristallo* composition



COLOUR PLATE 66 Opaque white pedestal bowls, 17A. A Antwerp, Stadsparking; B Breda, House Ocrum

COLOUR PLATE 67 Antwerp, House Karbonkel, 17A

COLOUR PLATE 68 Green pedestal beakers. A Antwerp Steen 15d–17a; B 's-Hertogenbosch, Boerenmouw, 16d

Glass from Brabant (219–22)

COLOUR PLATE 69 Bruxelles, sélection de verres trouvés dans l'ancienne Cour d'Hoogstraeten © IRPA-KIK

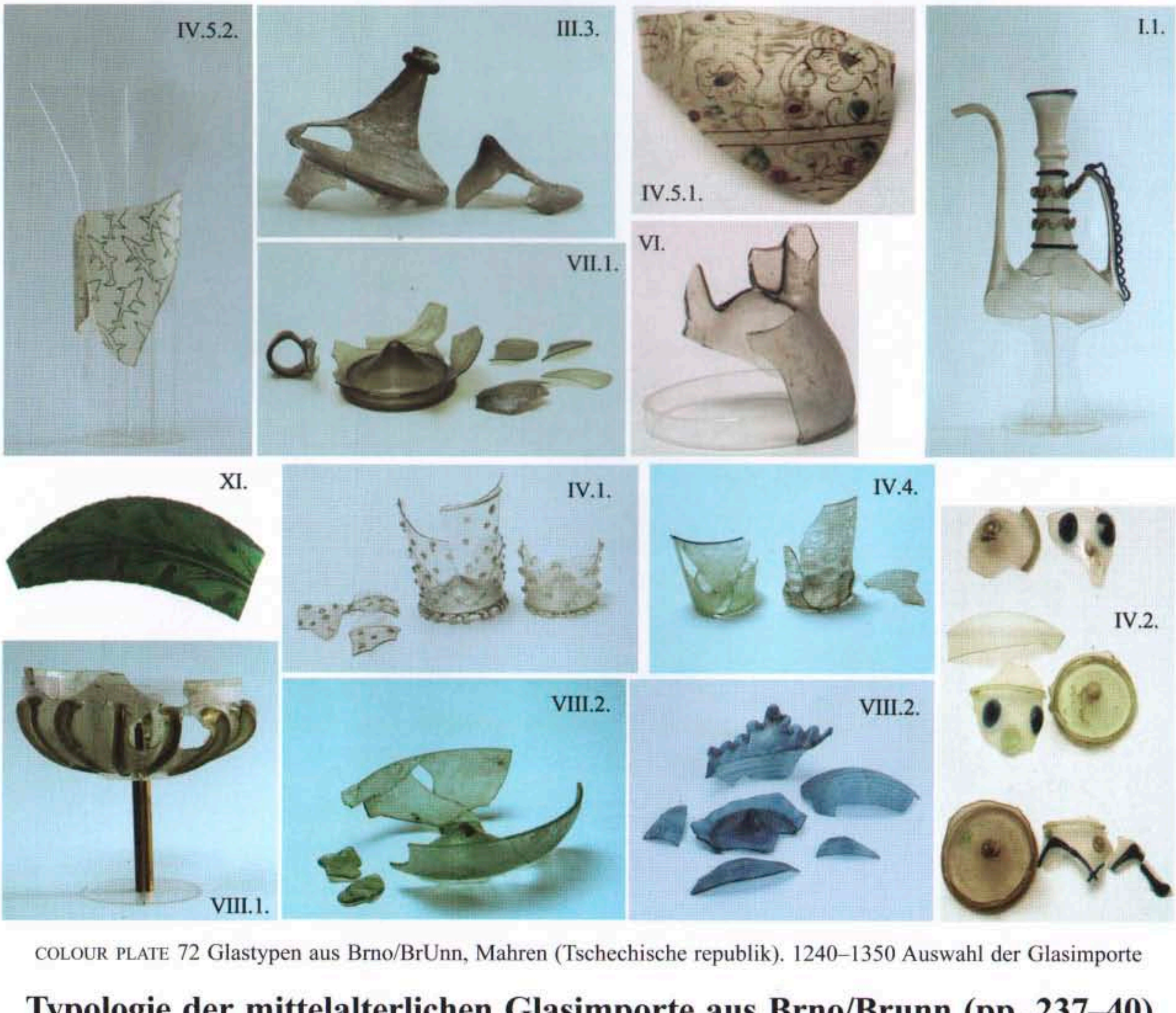
COLOUR PLATE 70 Bruxelles, sélection de verres trouvés rue du Vieux-Marché-aux-Grains © IRPA-KIK

COLOUR PLATE 71 Bruxelles, sélection de verres trouvés rue de Dinant © IRPA-KIK

La verrerie dans les anciens Pays-Bas (227–31)

1240 - 1270

1270 - 1350



COLOUR PLATE 72 Glastypen aus Brno/BrUnn, Mahren (Tschechische republik). 1240–1350 Auswahl der Glasimporte

Typologie der mittelalterlichen Glasimporte aus Brno/Brunn (pp. 237–40)

1350 - 1400

1450 - 1550

COLOUR PLATE 73 Glastypen aus Brno/Brunn, Mahren (Tschechische republik); 1350–1400 und 1450–1550 Auswahl der Glasimporte

Typologie der mittelalterlichen Glasimporte aus Brno/Brunn (pp. 237–40)

COLOUR PLATE 74 A sample of the excavated fragments included in the first phase of the study.

COLOUR PLATE 75 Photograph of stem (Wells 1993.2/1095) taken under filtered 254nm UV light

17th-century English glass (pp. 249–53)

COLOUR PLATE 76 *Càntir*, Catalonia, end of the 17th century; Cau Ferrat Museum, Sitges, Barcelona

COLOUR PLATE 77 Three *càntirs*, Catalonia, end of the 18th century; Cau Ferrat Museum, Sitges, Barcelona

COLOUR PLATE 78 *Porró*, Catalonia, 18th century; Cau Ferrat Museum, Sitges, Barcelona

COLOUR PLATE 79 Three free-standing and one hand-held *almorratxa*s, 18th cemtury; Museum of Decorative Arts, Barcelona

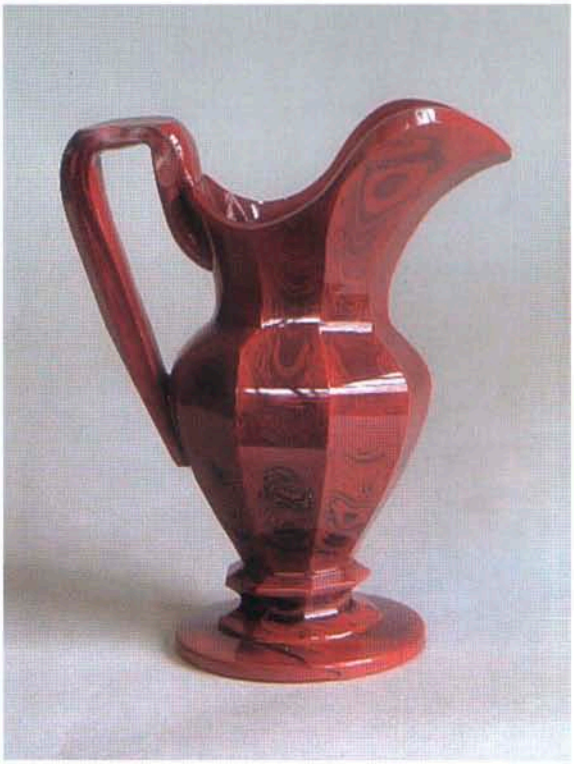
COLOUR PLATE 80 Salt cellar, Catalonia, 18th century; Cau Ferrat Museum, Sitges, Barcelona

COLOUR PLATE 81 Decorative spindle, Catalonia, 18th century; Cau Ferrat Museum, Sitges, Barcelona

Catalan façon de Venise (pp. 276–8)

COLOUR PLATE 82 Service of Waterford glass now in the collection of the Provost's House, Trinity College, Dublin (courtesy of Mrs Mary Boydell)

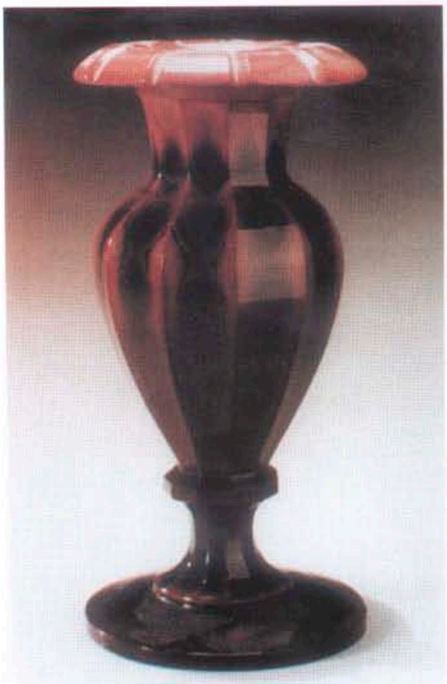
On hearing it was Irish ..... (pp. 291–4)



COLOUR PLATE 83 A small jug in brick-red jasper, showing marked marbling on the broad flutes; 154mm high (Museum of Edinburgh LR30/161/58)

John Ford's Jasper ware (pp. 295–7)

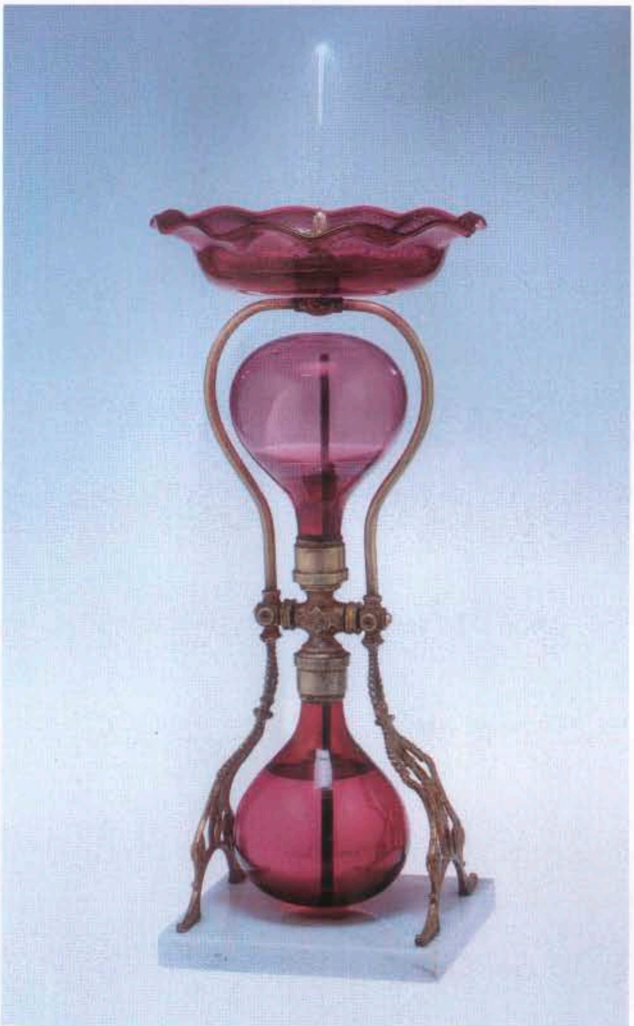
COLOUR PLATES 84, 85 Two vases belonging to the Ford-Ranken family, in dark marbled jasper cut in broad flutes; 84 is 197mm high (Museum of Edinburgh LR30/162/58), 85 is slightly broader and is taller at 243mm (LR30/163 /58)



COLOUR PLATE 86 A vase incised on the base 'Alexander Cunningham July 1842', 243mm high; sold at Sotheby's December 1998 (Courtesy of Sotheby's London)

COLOUR PLATE 87 A small wine glass corresponding to a design in the Holyrood pattern book at Corning Museum of Glass (Museum of Edinburgh LR30/160/58)

John Ford's Jasper ware (pp. 295–7)

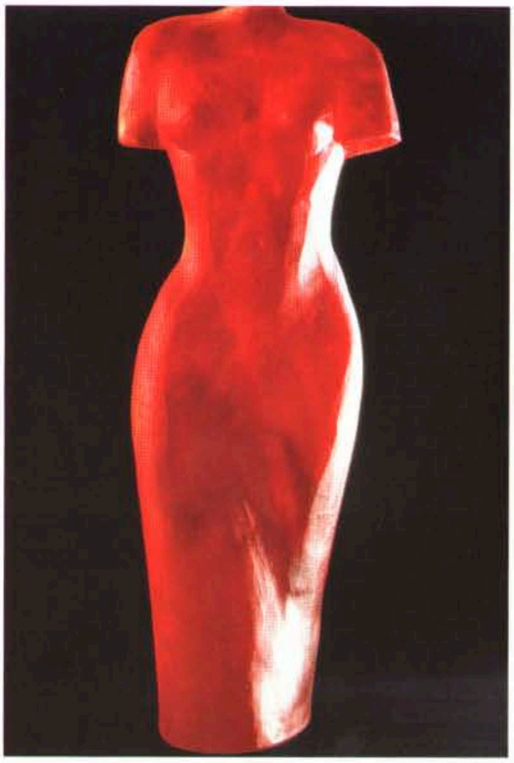


COLOUR PLATE 88 Revolving crystal fountain of red glass and brass with a marble base, made by James W. Tufts & Company, Boston, Massachusetts, *c.* 1875–1880; The Corning Museum of Glass, 2000.4.96, Gift of Gladys M, and Harry A. Snyder Memorial Trust

COLOUR PLATE 89 Revolving crystal fountain of colourless glass and brass, marble base missing, probably made by James W. Tufts & Company of Boston, Massachusetts, *c.* 1880–1884 or possibly English; The Corning Museum of Glass, 2000.2.1

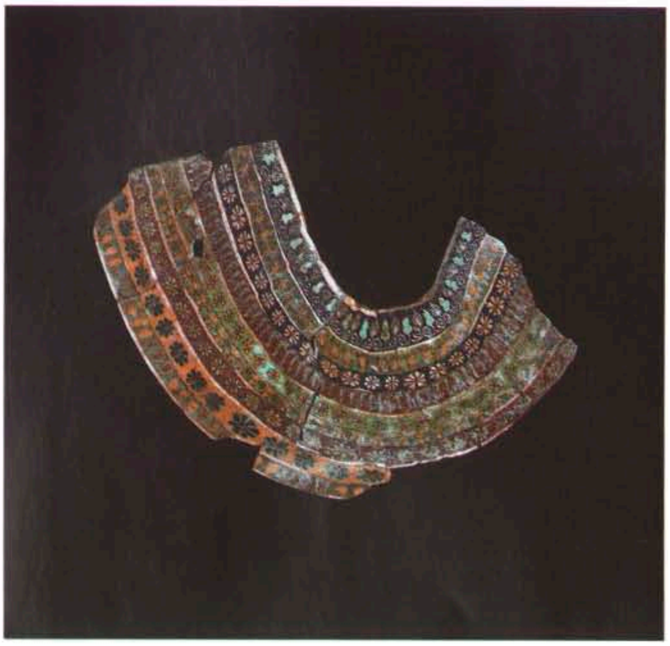
The automatic crystal fountain (pp. 298–300)

Lost clay moulding (pp. 308–13)



COLOUR PLATE 90 Frédéric Morin's sculpture *Isis* (N°F-2001-177, ht. 580mm, wt. 21kg) is a good example of sumptuous red glass – strong, transparent and luminous even though some 100mm thick; ektachrome Bernard Coste

Mosaic glass necklaces (pp. 315–19)



COLOUR PLATE 91 Mosaic glass broad collar. The Corning Museum of Glass 94.1.1 Photo courtesy of The Corning Museum of Glass

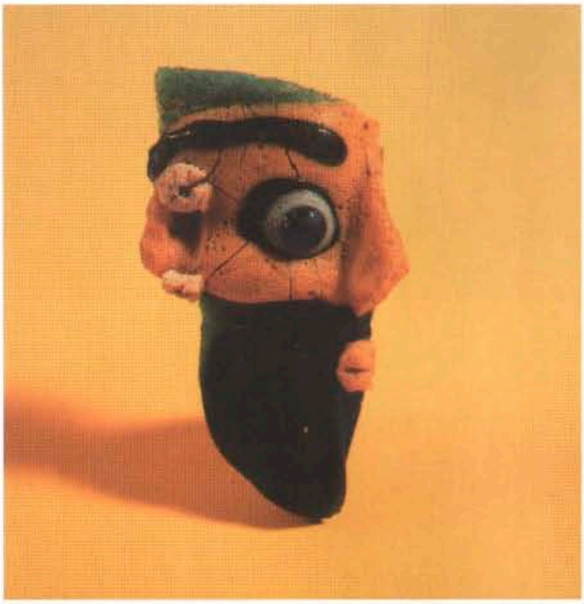
COLOUR PLATE 92 Broad collar on the coffin lid of Henet-Mer. The Collection of The Newark Museum Purchase 1965, John J. O'Neill Bequest Fund 65.65

COLOUR PLATE 93 Mosaic glass broad collar. Detail. The Corning Museum of Glass 94.1.1 Photo courtesy of The Corning Museum of Glass

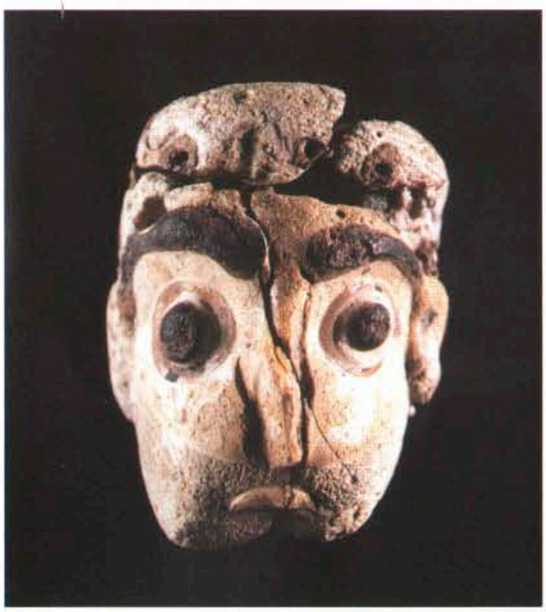
COLOUR PLATE 94 Masque de Sant Juliá de Ramis (Girona) inv. no. 2.371

COLOUR PLATE 95 Masque de Empúries (Girona) inv. no. 23.387

Pendentifs en verre sur noyau (pp. 320–2)



COLOUR PLATE 96 Masque de El Turó del Montgròs (El Brull, Barcelona) inv. no. 29.203



COLOUR PLATE 97 Masque de Barcelona, provenance inconnue, inv. no. 17.218

COLOUR PLATE 98

1a Noseo-ri A, showing diagonal yellow stripes and a band of thin yellow lines; the surface decoration is pulled toward the perforation; photographs by author (JWL), courtesy of the Seoul National Museum

1b Cornelian, amber and jasper beads, along with two possibly jadeite gokok, found together with Noseo-ri A

2 Sikrochong A (2a–c) and Sikrichong B (2d–g): side and end views; photographs by author (JWL), courtesy of the Seoul National Museum

3a–d Inwangdong A: four views, showing two sides and both perforations; photographs by author (JWL), courtesy of the Yeungnam University Museum

4a NT634, along with cornelian, jasper, and rock crystal beads from the same tomb

4b NT634, face and bird canes, with face distorted toward the perforation; photographs by author (JWL), courtesy of the Gyeongju National Museum

4c NT634, side view showing tree or flower cane pattern; photograph from Gyeongju National Museum catalog, with permission Gyeongju National Museum

5a–d Multiple views of mosaic face bead, collection of The Bead Museum, Glendale, Arizona, showing side views and both perforations; photographs by author (JWL), courtesy of The Bead Museum, Glendale, Arizona

Javanese (Jatim) beads (pp. 327–30)

COLOUR PLATE 99 Metal rings embellished with a piece of flat glass, roughly cut around, 11th–12th century (copyright Hellenic Ministry of Culture)

COLOUR PLATE 100 Metal ring embellished with plain lentoid gem, 11th–12th century (copyright Hellenic Ministry of Culture)

COLOUR PLATE 101 Metal rings embellished with lentoid gems, plain and with impressed decoration, 11th–12th century (copyright Hellenic Ministry of Culture)

COLOUR PLATE 102 Metal rings embellished with lentoid gems bearing impressed decoration, 11th–12th century (copyright Hellenic Ministry of Culture)

COLOUR PLATE 103 Glass bracelet with painted decoration, 10th–12th century (copyright Hellenic Ministry of Culture)

PLATE 104 Glass bracelets, 10th–13th century (copyright Hellenic Ministry of Culture)

Glass in Byzantine jewellery (pp. 331–4)

COLOUR PLATE 105 Types of beads from Prague Castle and its surroundings; I.1–50 simple monochrome, II.1–8 polychrome

Glass beads from Prague Castle (235–9)

COLOUR PLATE 106 Two monks attending Saint Benedict's Elevation to Heaven; Royal Abbey of Saint-Denis, 12th century

COLOUR PLATE 107 Four people; Sainte Chapelle, 13th century

French stained glass compositions (pp. 341–6)

COLOUR PLATE 108A *The Adoration of Saint Norbertus after his Death* (1636–1644) by Jan de Caumont of Leuven, Belgium; before conservation

COLOUR PLATE 108B The same after conservation

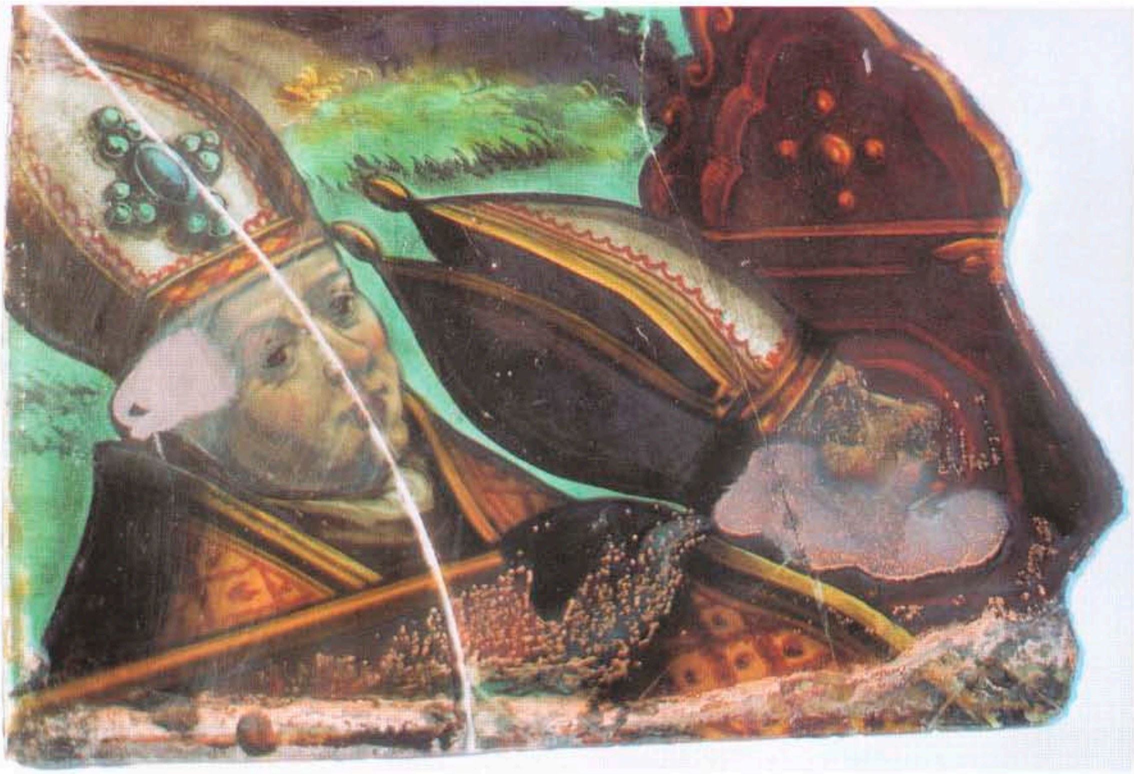
Conservation of two 17th-century windows (pp. 364–6)

COLOUR PLATE 109A *The Transportation of the Remains of Saint Norbertus from Magdebourg to Prague in 1627* (1636–1644) by Jan de Caumont; before conservation

COLOUR PLATE 109B The same after conservation

Conservation of two 17th-century windows (pp. 364–6)

COLOUR PLATE 110 Detail of the glass painting of COLOUR PLATE 109: grisaille paint, various tints of silver stain, blue and purple vitreous enamel, opaque sanguine, translucent sanguine; on slightly greenish glass



COLOUR PLATE 111 Detail of the glass corrosion of COLOUR PLATE 109: corrosion near the lead cames (see border of the glass) and corrosion following paint layers

Conservation of two 17th-century windows (pp. 364–6)

COLOUR PLATE 112 Bisham, All Saints, window sII, panel 1f, before restoration

COLOUR PLATE 113 Bisham, All Saints, window sII, panel 1f, after restoration

COLOUR PLATE 114 Gloucester Cathedral, Great East Window, detail panel E5-2 without front-plate

COLOUR PLATE 115 Gloucester Cathedral, Great East Window, detail panel E5-2 with front-plate

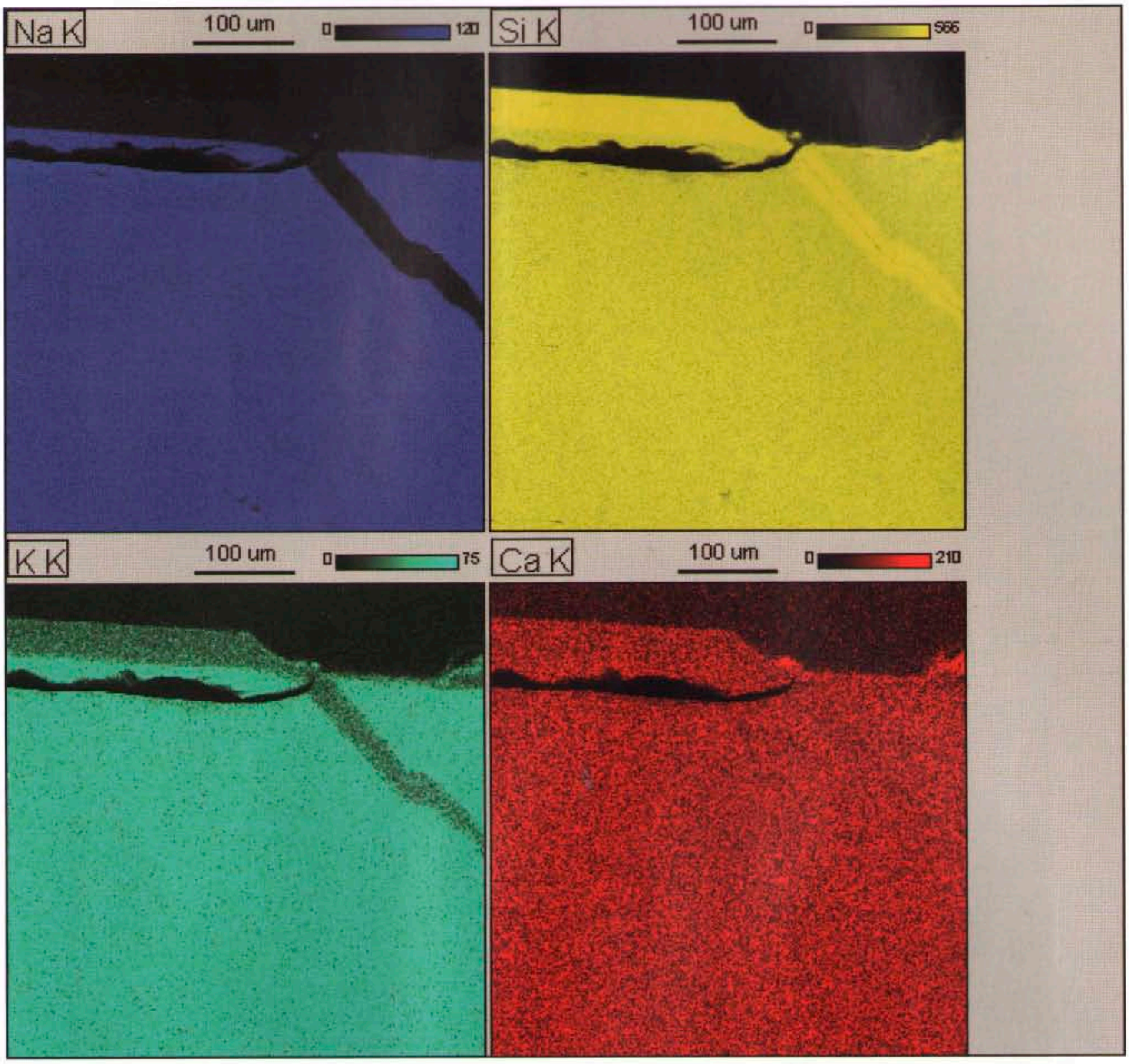
Gain without loss? (pp. 367–9)

COLOUR PLATE 116 The Corning Theatre, probably Nevers, France 1740–1760; ht. 565mm, L. 715mm, depth 586mm; Corning Museum of Glass, 2002.3.22. After cleaning and restoration. The Corning Museum of Glass, Corning, NY, USA

COLOUR PLATE 117 Detail of the top of the left alcove, showing rock crystal pendant, chandelier and putto

COLOUR PLATE 118 Detail of the right side showing levers and pulls (top) and the mechanism under the base (bottom)

The Corning theatre (pp. 371–4)



COLOUR PLATE 119 Elemental maps from the cross-section of FIGURE 1 (p. 383) showing the depletion in sodium and potassium and enrichment in silicon in the altered zone at the surface and along the crack penetrating into the glass

Deteriorating 19th and 20th-century glass (pp. 380–5)

COLOUR PLATE 120 The *ciborium* of *Master Alpais*, (Louvre Museum MRR98) – cliché C2RMF D. Bagault

COLOUR PLATE 121 The cross reliquary (Musée National .... of Cluny CL14793) – cliché C2RMF D. Bagault

COLOUR PLATE 122 Detail of glass cabochons from the Saint Mathieu (Louvre Museum MR2650) – cliché C2RMF D. Bagault

COLOUR PLATE 123 Detail of cabochons from the cross reliquary (Musée National .... of Cluny CL14793) – cliché C2RMF D. Bagault

Identification of false gems (pp. 387–90)

COLOUR PLATE 124 The Bonus Eventus plaque (BM GR 1814.7-4.242 (1958.2-11.1)). © The British Museum

The Bonus Eventus plaque (pp. 391–5)

COLOUR PLATE 125 Basin, probably Europe, late 19th/early 20th-century; enamelled and gilded glass. Museum of Islamic Art, Qatar, not inventoried

COLOUR PLATE 126 Basin, Egypt, mid 14th-century or possibly Europe, late 19th/early 20th-century; enamelled and gilded glass. The Cleveland Museum of Art, inv. no. 1944.235

Understanding Mamluk imitations (pp. 396–400)

COLOUR PLATE 127 Bottle, probably Europe, late 19th/early 20th-century; enamelled and gilded glass. Museum of Islamic Art, Qatar, inv. no. GL.07.97

COLOUR PLATE 128 Mosque lamp, probably Europe, late 19th/early 20th century; enamelled and gilded glass. Museum of Islamic Art, Qatar, inv. no. GL.05.97

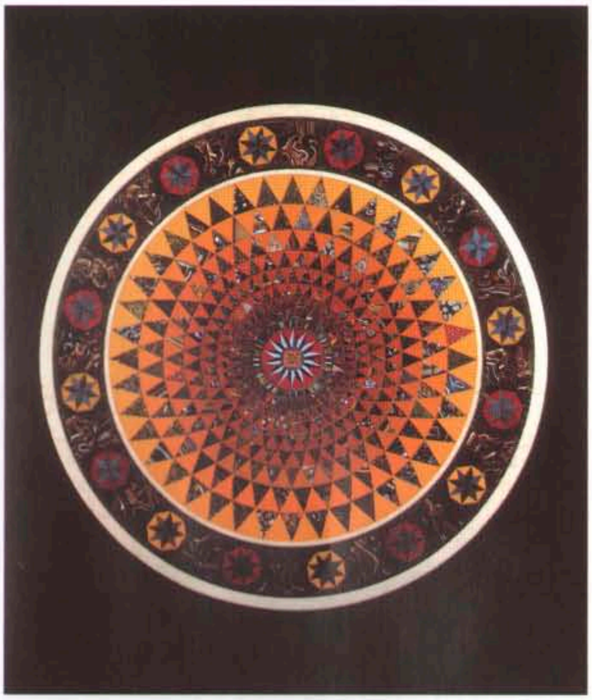
Understanding Mamluk imitations (pp. 396–400)

COLOUR PLATE 129 Marble tabletop inlaid with ancient glass in a star motif (no. 3), attributed to Francesco Sibilio, Rome, *c.* 1825. Diam 850mm. Photo: © Edric Van Vredenburgh, London

COLOUR PLATE 130 *Guéridon* (no. 6) with a top veneered with ancient mosaic glass and set on a South German gilt-wood stand. The top *c.* 1825 and the stand *c.* 1839. Ht 925mm. Photo: © Rainer Zeitz Ltd, London

Francesco Sibilio (pp. 401–4)

COLOUR PLATE 131 *Guéridon* top veneered with ancient mosaic glass (no. 6), attributed to Francescio Sibilio, *c.* 1825; diam 282mm. Photo: © Rainer Zeitz Ltd, London



COLOUR PLATE 132 Marble tabletop inlaid with ancient glass (no. 7) exhibited at the Paris International Exhibition of 1868, by Giovanni Rossignani, Rome; diam 760mm; The Corning Museum of Glass, inv. no. 97.3.10. Photo: © Hadji Baba Ancient Art, London

COLOUR PLATE 133 Gilt metal bracelet inlaid with repolished fragments of ancient mosaic and *reticelli* glass; 19th century; L. 175 mm. Photo: © Bazaart, London

Francesco Sibilio (pp. 401–4)

GLASS FINDS FROM MEDINET MADI, EGYPT

FLORA SILVANO

The known history of Medinet Madi – the Arabic name means 'The City of the Past' – begins in the Middle Kingdom (early 2nd millennium BC) with the foundation of a village named Gia, in the Fayum oasis, 80km south of Cairo. Located on a small hill commanding a strategic position on the south-western edge of the oasis, the city expanded around the temple founded in the Middle Kingdom by Amenemhat III and Amenemhat IV and existed until Ptolemaic and Roman times (Bresciani 2001, 51–4).

During the Ptolemaic period, the town, now called by its new Greek name, Narmuthis (the city of Renenut/Ermuthis), and its temple flourished once again. The town expanded to the south and north of the XII dynasty temple, and a new temple, oriented east–west and dedicated to the cult of two crocodiles, was constructed. Additional structures were also erected during the Roman age, and life in the village appears to have continued until the 9th century. Excavations on this site, directed since 1996 by Edda Bresciani (Pisa University) and Rosario Pintaudi (Messina University), produced a large quantity of glass fragments.

This paper reports on the glass finds from the buildings on the hill south of the temple of the two crocodiles, discovered in 1998 and named temple C. The buildings, buried under an enormous mass of sand and rubble, were explored during the season 2000–2002; they were situated in a panoramic position in relation with the *dromos* of the main temple, discovered by Achille Vogliano between 1935 and 1939, and named temple A. All the materials are to be dated by the find context to between the 1st and the 3rd centuries AD.

The glass from this particular area of the Medinet Madi excavations represents a wide variety of vessels. Most of the fragments come from beakers, bowls, oval and round dishes, flasks and other blown tableware.

The site also yielded many fragments with cut decoration. The group is quite representative and allows us to more accurately define the characteristic of engraved glass from this period in Egypt, recently so well delineated by M. Dominique Nenna (Nenna 2003).

ENGRAVED GLASS

Among the variety of engraved glass found in Medinet Madi, the most complete piece is a beaker of colourless glass (Ht. 150mm; Diam. rim 131mm). It has a rounded rim, straight sides that taper downward and a slightly concave base. On the exterior, on the wall and base, there is a wheel-cut decoration (FIG. 1).

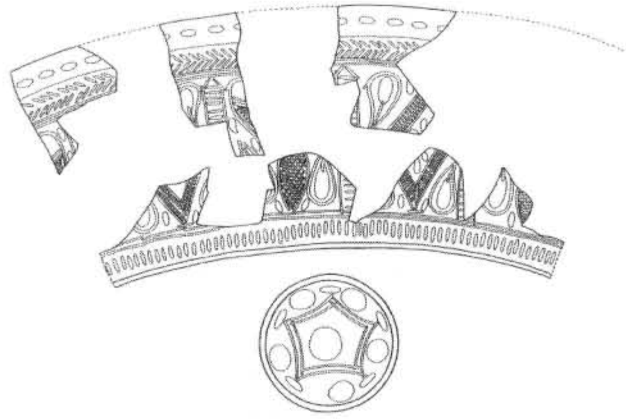


FIG. 1 Unrolled decoration of beaker from Medinet Madi; illustration Lucia Grassi

On the concave base it shows a star-like motif consisting of a double-outlined pentagon with the sides slightly curved inwards. A horizontal oval depression marks each point of the star. There are five circular depressions in each semi-circular space between the points and a single larger one inside the star. On the exterior wall there is a row of narrow oval facets running horizontally just below the rim, and below these a herringbone pattern. The main register, with two horizontal grooves above and below, is composed of four panels divided by four vertical pillars of rice-shaped facets, set one above the another and flanked by grooves. Two of the panels show a diamond pattern with a floral design inside. The edge of the lozenge consists of a double row of slit-like facets, outside of which there are four curving stalks – one against each side – with four rice-shaped facets (COLOUR PLATE 21). The other two panels are very fragmented and are characterized by a cross-hatched pattern with a double incised border. Unfortunately no fragment gives us the upper part of the panel so we do not know its real decoration.

I have not found any parallels for this particular pattern. On the lower part of the panel we have the same curving stalks and on the upper part there had probably once been two other curving stalks with a cross-hatched pattern. The very lower edge of the main register bears a frieze of vertical rice-shaped facets.

A 3D reconstruction of the beaker was also carried out. The pieces of the vessel were digitized by means of a Minolta Vivid 900 3D laser scanner (COLOUR PLATE 22). The software for the acquisition of the parts, the reconstruction of the final object, the representation and interactive visualization of the multi-resolution digital model were developed by the Visual Computing Lab of the ISTI-CNR in Pisa. I am grateful to C. Montani, M. Callieri and P. Pingi for allowing me to present their work.

Some elements of the beaker's decoration may be paralleled among the wheel-cut glasses of the Middle Imperial Period at Dura Europos in Syria. Clairmont illustrated two colourless fragments, dating to the 3rd century, with the same band of rice-shaped facets arranged in a herringbone pattern, and the same vertical pillar and curving stalks (Clairmont 1963, 77–8, n. 298, n. 299). The closest parallel for the diamond pattern with four curving stalks and four oval facets noted on our example is a fragment from Karanis showing the same panel placed horizontally and dating to the 2nd and 3rd century AD (Harden 1936, 86, n. 179, pl. xiii). The same motif, placed horizontally, is also attested in the 2nd–3rd century AD by a hemispherical beaker from the site of Palatiano, a little town in inland Macedonia (Antonaras and Anagnostopoulou 2002, 121, fig. 9). The pattern of the four curving stalks with four oval facets can also be seen in a handled cup from Sedeinga – this too dating to the 3rd century – characterized by two deep wheel-cut designs, each occupying the entire space on the side between the handles (Cool 1996, 207, fig. 4.3). In the centre of each panel there is a cross-hatched circle with double incised border, inside of which there is a diamond-shaped pattern. For the Dura cut glass, Clairmont hypothesized a Syrian or even a local manufacture, but his search for parallels to the Dura vessels in other parts of the Empire was fruitless. Now the Medinet Madi find with the Karanis fragment seem to suggest different possibilities and it is perhaps more likely that the object was made in Egypt.

Three fragmentary bowls belonging to a very homogeneous group (Diam. 190, 178 and 170mm). They are characterized by a very similar decoration quite deeply cut on the exterior, consisting of a row of horizontal oval depressions with a double or single border line above and below, a row of shallow circular depressions and a pattern composed of contiguous diamond-shaped elements with double outlines. Each element contains cross-hatching. One of the Medinet Madi fragments shows the bottom of these bowls (COLOUR PLATE 23). The decoration consists of seven umbonated round shields. The closest parallel for this element of decoration is on a fragmentary bowl from *Augusta Rauricorum*, dating from the 2nd to early 4th century AD (Rütti 1991, 69, n. 1338, Taf. 61). The two upper registers consist of a broad band of vertical flutes and a narrow band of contiguous diamond-shaped panels with cross-hatching inside. In the Medinet Madi bowls, the diamond-shaped decorative pattern is repeated three or four times and makes up a single large register. Parallels for the decorative pattern with the umbonated round shields found in the Medinet Madi sample include a faceted bowl, dating to the second half of the 2nd century AD, discovered in a grave at Leuna, Germany (Harden *et al.* 1987, 196, n. 106), and one fragment bearing a geometric wheel-cut decoration, found in Aquileia and probably coming from a bowl (Paolucci 1997, 120–1). In both cases, the motif is arranged on one of the horizontal registers of the decoration and not on the base.

Three fragments of thin transparent glass show a faceted decoration and belong to bowls with an everted rim and round bases. Two have a row of rice-shaped facets running horizontally, below which there are two rows of alternating vertical rice-shaped facets. The decoration of Medinet Madi vessels may be compared with that of similar facet-cut bowls from *Augusta Rauricorum* (Rütti 1991, 68, n. 1327–32, Taf.59) and Dura Europos (Clairmont 1963, n. 337, Taf. ix) belonging to the second half of the 2nd century–second half of the 3rd century AD. Many vessels of the same shape, but decorated only with fine-cut lines were found at Medinet Madi. The bowls with everted rims and round bases are reported in Egypt from Karanis (Harden 1936, 122–3, pl. 15) and Quseir al-Qadim (Meyer 1992, 27 n. 131–40, pl. 7) but also in the Eastern Mediterranean from Jalame (Weinberg and Goldstein 1988, 96–7, fig. 4.49) and Dura Europos (Clairmont 1963, 96, pl. 10).

APPLIED DECORATION

Three fragments show a snake-thread decoration. The vessels were blown from gathers of colourless glass with trails of the same colour as the base glass. On one of the fragments the snake-threads are narrower and smooth, while on the other two they are broad and decorated with small rounded corrugations. Unfortunately the Medinet Madi pieces coming from glassware worked with this particular technique are too small to determine the original shape of the vessel. Fragments with snake-thread decoration, whose invention in the Near East dates perhaps from the first half of the 2nd century (Clairmont 1963, 42; Whitehouse 2001, 217, n.786), were discovered also in Karanis (Harden 1936, 173, n.420, n.492) and Dura Europos (Clairmont 1963, 42–6, n.161–78).

Three fragments show a pinched thread decoration running horizontally in a single frieze. It is characterized by the formation of the arches and the short sections where the two threads merge, forming a 'google' pattern. Two of them also have a vertical rib above the horizontal frieze. This decoration resembles that of some fragments from Dura dating to the 2nd century (Clairmont 1963, 48). Likewise in this case the extremely fragmentary state of the three fragments has made it difficult to ascertain the shape of the vessels.

MOSAIC GLASS

Among the glass material from Medinet Madi we also have two pieces of mosaic glass, the first is part of the rim of a very shallow hemisperichal bowl, the other is a fragment of a cylindrical bead. The hemispherical bowl (diam. 200mm) with external groove and a convex bottom, is made of canes with a floral motif (COLOUR PLATE 24). The combination includes black canes bearing a green-centred flower with white petals surrounded by a circle of white points. For this mosaic glass from Medinet Madi, the chronology suggested by the find context is from the late 2nd to the 3rd century AD.

The fragment is important as it represents yet further proof of the continuous use of mosaic glass in Egypt from the 3rd century BC to the late Roman period, when it is much less widespread but still present (Rutti 1991, 126–34; Nenna 2002). In the Kharga oasis, the same shape of the vessel is unknown before the 4th century (Hill and Nenna 2001) but in Medinet Madi the find context placed it a century earlier.

The fragment of the bead (COLOUR PLATE 25) shows monochrome canes arranged in a chequerboard pattern composed of tiny square roads of opaque white, opaque yellow, opaque red, opaque turquoise blue, and opaque black – each colour symmetrically arranged within the mosaic cane to form a lozenge pattern (for a similar pattern compare Gudenrath and Tatton-Brown 2003, fig. 4).

PAINTED GLASS

Finally also one example of painted glass was among the finds at Medinet Madi. The fragment is made of thin colourless glass but the size is too small to determine if it represents a human, animal or plant motif. The green paint and gilded decoration are applied in a black outline.

In summary, the presence in Medinet Madi of a wide variety of engraved and other luxury vessels is very important for understanding the history of glass and its chronological development in this particular Egyptian area. Continued excavations and documentation of glass finds from this site surely will produce further interesting data which should help to provide a more complete picture about sources, function and social context of the glass vessels.

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LA CIRCULATION DU VERRE EN MÉDITERRANÉE AU DÉBUT DU III^{E} SIÈCLE: LE TÉMOIGNAGE DE *L'ÉPAVE OUEST EMBIEZ 1* DANS LE SUD DE LA FRANCE (FOUILLES 2001–2003)

DANIÈLE FOY, MARIE-PIERRE JÉZÉGOU ET SOUEN FONTAINE

Au large de la côte provençale, une épave antique, datée de la fin du IIe siècle ou du début du siècle suivant, fait l'objet d'une fouille conduite par le *Département des Recherches Subaquatiques et Sous-Marines* (DRASSM, Ministère de la Culture) et par l'*UMR 6572* du CNRS. Ce bateau, essentiellement chargé de produits verriers diversifiés (vaisselle, vitre et matière brute), met en évidence une chaîne de production segmentée impliquant des liens économiques et techniques entre diverses provinces de l'Empire romain (Foy et Jézégou 1998).

On connaît, dans cette partie de la Méditerranée, d'autres cargaisons de verre immergées, parfois beaucoup plus anciennes, mais ces artefacts, moins variés, ne constituent pas le chargement principal des bateaux. On signalera plus particulièrement, en Corse à Porticcio, la fouille en cours d'une épave datée de la seconde moitié du IIIe siècle par la céramique et les amphores africaines et orientales. Cette épave contient du verre à vitre et des formes de vaisselle de verre différentes de celles de l'épave des Embiez, en particulier des assiettes de verre moulées, des gobelets à fond épais, décorés de dépressions et des bols à décor gravé de facettes (fouille et communication de H. Alfonsi aux journées du DRASSM 2003).

LA CARGAISON

Le verre brut

Le verre brut apparaît comme la part la plus importante du chargement. Jetés en vrac et empilés jusqu'à plus d'un mètre d'épaisseur, ces blocs forment une masse imposante dont on essaye de cerner les limites. À la fin de la campagne de fouilles de 2003, nous sommes assurées que ce verre brut, qui occupe l'avant et sans doute le centre du bateau, représente au moins un volume de 3 à 4 m^3, soit environ 8 à 10 tonnes de verre. Mais cette estimation sera sans doute revue à la hausse lorsque nous aurons complètement défini l'emprise de ces produits semi-finis.

De gabarit et de forme irréguliers, ces blocs incolores proviennent du concassage de la dalle de verre d'un four primaire, tels ceux que l'on connaît à une époque plus tardive en Palestine, (Gorin-Rosen 1995). Les pièces les plus importantes peuvent atteindre jusqu'à 25kg, mais les plus nombreuses ont un poids compris entre 5 et 10kg (COLOUR PLATE 26).

La vaisselle

Des centaines de verre incolores ont déjà été remontés et les analyses confirment qu'ils sont fabriqués avec les mêmes matières premières que le verre brut.

Fragile, cette cargaison n'est pas restée intacte. Nous retrouvons aujourd'hui des centaines de fragments, plus particulièrement des fonds qui sont sans doute les parties les plus résistantes de cette vaisselle. Cette accumulation évoque les pratiques de récupération et de recyclage du verre connues dans l'Antiquité, mais nous n'avons pour l'instant aucun argument archéologique pour assurer que du groisil composait aussi le fret du bateau. Conservées depuis plus de 1800 ans dans l'eau, ces verreries ont subi une altération et les rebords et parois, à l'origine très fins, ont pu se dissoudre presque complètement.

Gobelets cylindriques

Les gobelets cylindriques, les plus nombreux, voyageaient emboîtés et protégés par un emballage végétal, copeaux de bois dont quelques débris restaient encore coincés entre deux fonds. De forme simple, ces pièces offrent deux variantes déjà mises en évidence dans des fouilles terrestres (Rütti 1991, AR 98.1, 98.2). Toutes ont des parois rectilignes, mais se différencient par leur rebord vertical ou évasé et la présence ou non de filets de verre décoratifs, déposés sous l'embouchure et à la base des parois (FIG. 1.1–2). Ces deux gobelets ont en commun le façonnement de leur base qu'ils partagent d'ailleurs avec d'autres verreries, et qui constitue l'originalité d'une grande partie de la vaisselle transportée. Le pied est fait d'un cordon de verre rapporté sous la pièce. Un second cercle plus réduit marque le centre du fond. Les deux cercles concentriques sont parfois faits dans un même cordon et le geste du verrier est clairement visible dans le filet de verre qui unit le pied annulaire et le cercle central. Cette façon de faire constitue une sorte de tour de main et donne à la vaisselle une unité sans doute révélatrice d'une origine commune. Ce gobelet passe, à juste titre, pour le verre à boire le plus communément utilisé à la fin du IIe siècle et surtout au début du IIIe siècle. Les découvertes du Portugal et du sud-ouest de la Gaule (Boissavit-Camus 1993 *et al.*, 66) ont bien montré qu'il n'était pas spécifique de l'Europe du Nord-Ouest. Leur présence dans cette épave, mais aussi dans de nombreux sites du Midi méditerranéen (Nice, Olbia, Toulon, Marseille, Ambrussum entre Nîmes et Montpellier) et de la vallée du Rhône (Arles, Orange, Lyon) prouve que leur aire d'utilisation est plus ample et leur origine certainement pas unique, comme le suggèrent aussi les multiples variantes. L'aspect du verre incolore ou bleu-vert, le profil des parois et la présence ou non de filets

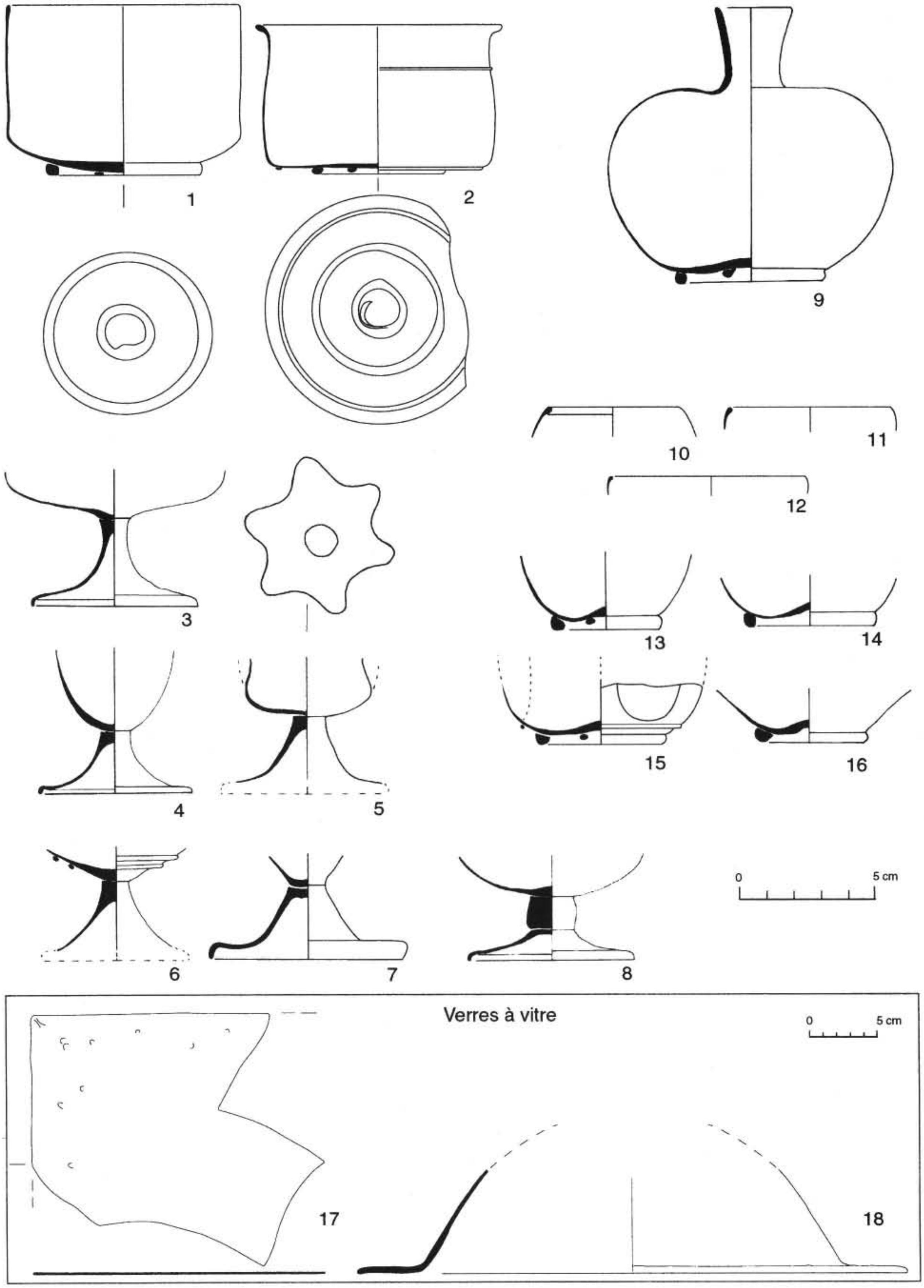

FIG. 1 Principales verreries de l'épave. 1, 2: gobelets cylindriques (nos 0106, 0107) ; 3 à 7: verres à pied tronconique (nos 0078, 0082, 0077, 0083, 0045); 8: verre à balustre (no. 0075); 9: flacon pansu (no. 0105); 10 à 16: autres verreries (nos 0064, 0029, 0052, 0086, 0102, 0014, 0088); 17 et 18: vitres étirées de forme rectangulaire et circulaire (no. 0006 et 0292)

permettent de distinguer divers types, mais l'on doit aussi tenir compte du façonnement des fonds. Dans la plupart des découvertes signalées en Europe, le pied annulaire est pris dans l'épaisseur de la paraison; dans la cargaison de l'épave, les fonds incolores, larges et plats ont toujours le pied rapporté. La distinction entre pied replié et anneau rapporté a été quelquefois observée: à Augst, Colchester et Castelford par exemple, se trouvent des pièces semblables au mobilier de l'épave (Rütti 1991, no. 1839; Cool and Price 1995, no. 529; Price and Cottam 1998, fig. 38.b), mais les exemplaires à pied annulaire replié semblent dominer largement. La situation est différente dans le midi de la Gaule où nous connaissons de nombreuses trouvailles comparables aux pièces transportées par le bateau.

Verres à pied

Les verreries portées par des pieds tronconiques et à balustre sont, dans l'état actuel de l'avancement de la fouille, moins nombreuses. Ce constat ne reflète pas forcément la cargaison d'origine. On peut imaginer que la verrerie a été chargée de manière rationnelle sur le bateau, catégorie par catégorie, chacune ne nécessitant pas le même mode de conditionnement et ne permettant pas le même rangement. Il faut donc attendre une exploration plus ample du bateau pour avoir une vision claire de la diversité de la cargaison et de la part de chacun des produits.

Les verreries qui reposent sur un pied rapporté et soudé à la panse par l'intermédiaire ou non d'une boule pleine sont des verres à boire ou des fioles ovoïdes (Isings 86, 93; Rütti 1991, no. 99). Aucune pièce issue du bateau n'a pu être reconstituée, mais les profils des coupes et la présence ou non de filets de verre rapportés montrent déjà une grande diversité (FIG. 1.3–8). Nous ignorons cependant si ces verres étaient luxueusement décorés à l'instar de nombreuses découvertes terrestres: seuls apparaissent des simples filets rapportés et des décors originaux de dépressions. Des verreries complètes ou à l'état de débris ont été découvertes tant en Occident qu'en Orient. Les ateliers rhénans en ont fabriqué beaucoup ce qui n'est pas une raison pour leur attribuer toutes les trouvailles occidentales. D'autres ateliers en Occident ont pu produire ces formes, mais certaines d'entre elles, mises au jour sur les côtes italiennes, provençales et dans la vallée du Rhône, sont vraisemblablement de provenance orientale.

Flacons, bouteilles et autres vaisselles

Un seul flacon pansu a été découvert intact; sa base à double cordon concentrique rappelle celle des gobelets (FIG. 1.9). Ce n'est pas un *unicum* car d'autres fragments renvoient probablement à la même forme. Nous ne lui avons pas trouvé de parallèle parfait, mais beaucoup d'autres flacons, en verre fin et incolore et à pied annulaire, mais de profils très divers, parfois éloignés de notre trouvaille, nous semblent appartenir à la même famille. C'est le cas pour de très nombreux vases à panse sphérique ou bulbeuse, décorées ou non de fils rapportés et au col plus long, parfois avec anse en chaînette ; ces pièces découvertes en Grande-Bretagne (Price 2003; Price and Cottam 1998, fig. 70), en Normandie (Sennequier 1985, nos 195, 296), dans le nord de la Gaule (Dilly et Mahéo 1997, nos 143–5) ou en Rhénanie (à titre d'exemple Boeselager 1989, fig. 9), sont aussi connues dans des régions plus méditerranéennes, par exemple en Algérie dans les nécropoles de Tipasa (Lancel 1967, nos 68–9) et en Tunisie dans la nécropole de Pupput (Hamammet) ou à Uzita (Van der Werff 1982, pl. 41.2). Sans contester l'origine rhénane souvent avancée, nous pensons que les lieux de production sont beaucoup plus diversifiés.

Bien d'autres fonds, de profils divers mais toujours renforcés par un ou deux anneaux de verre rapportés, prouvent qu'il existe dans le bateau un répertoire de formes infiniment plus large que celui que l'on peut entrevoir à partir des centaines de débris. On observe des fonds de gabarits divers; un verre décoré de dépressions et des contenants, verres à boire ou fioles, à panse ovoïde ou tronconique (FIG. 1.13–16). Les rares rebords retrouvés, n'appartiennent pas tous aux formes déjà identifiées (FIG. 1.10–12). Se trouve aussi, en un seul exemplaire, une bouteille carrée à une anse.

Le verre à vitre

Deux types de vitrages faisaient partie de la cargaison. Au-dessus du verre brut, des vitres rectangulaires étaient sans doute entreposées car l'essentiel de ce mobilier se concentre dans la partie supérieure des blocs. Aucune vitre n'a encore été retrouvée complète, mais les fragments importants (jusqu'à 300mm de long) ne peuvent laisser penser qu'il s'agit de verre à recycler car, dans ce cas, les feuilles de verre auraient été réduites en débris pour un encombrement minimum.

Un seul fragment de vitre circulaire a été extrait de la cargaison, mais l'empilement de 3 ou 4 pièces au-dessus de la vaisselle de verre a été observé lors de la dernière campagne d'octobre 2003. La fonction de ces objets semblables à des coupes profondes n'a été que récemment reconnue et c'est la première fois que leur présence est attestée dans un bateau de commerce. D'un diamètre de 43cm en moyenne, ces vitres bombées et à rebord plat, en forme de chapeau, sont apparemment fabriquées dans la même matière (claire, légèrement verdâtre) que les pièces rectangulaires. Ces fermetures, réservées essentiellement aux *oculi* des murs et des voûtes des thermes n'ont pas toujours été identifiées en tant que telles (Taborelli 1980, 151, fig. 6.1–2). Elles sont pourtant repérées sur plusieurs sites. En Provence, un seul fragment a été noté sur le site d'Olbia (Fontaine 2002, no. 164), mais en attirant l'attention sur ce type de verre architectural nul doute que l'on en signalera d'autres; en Grande-Bretagne un fragment de grand diamètre provient du forum de Caerwent (Allen 2002, fig. 8.8). En Espagne, et plus particulièrement en Aragon, plusieurs vitres circulaires et bombées ont été découvertes: d'abord sur le site de Labitolosa (Huesca) où trois pièces sont maintenant identifiées dans les thermes et dans un édifice public (Ortiz Palomar et Paz Peralta 1997, fig. 1A; Magallon Botaya et Sillières 1998, fig. 13; Ortiz Palomar 2001, fig. 6); d'autres ont été exhumées à Zaragoza (*Los Bañales*) et Astorga (Fuentes Dominguez *et al.* 2001, 161). Ces vitres, datées en Espagne de la fin du Ier siècle, et des IIe-IIIe siècles, sont tout aussi communes en Italie. Il ne reste pratiquement rien de celles qui étaient dans les ouvertures des thermes d'Herculanum, mais le musée du Louvre conserve trois pièces complètes de la collection Campana qui permettent de voir que ces vitrages existent dans des gabarits plus petits, de l'ordre de 250mm de diamètre (Arveiller et Nenna 2000, nos 275–7).

Ces vitres coulées sur une plaque, présentent une surface lisse et une autre d'aspect granité dû au support sur lequel le verre a été étiré. Près des rebords irréguliers, les marques d'outils, petits creux ronds et traces de chevrons, sont visibles. Les vitres rectangulaires ont été façonnées à l'intérieur d'un cadre rectangulaire ou carré. Les vitres circulaires ont sans doute été modelées sur une forme convexe, après avoir été étirées comme des galettes.

L'itinéraire du bateau

L'examen de la vaisselle de verre et des amphores (Bernard et Bonifay 2003) autorise à situer le naufrage à la charnière des IIe et IIIe siècles. La multiplication des trouvailles permettra sans doute d'affiner la datation, mais la restitution de l'itinéraire du bateau est un problème plus difficile à résoudre.

Les amphores constituent généralement la documentation principale pour comprendre l'organisation du grand commerce. Une trentaine de pièces intactes ou fragmentées, d'origine diverse, ont été découvertes dans l'épave et il en reste certainement d'autres. Cette hétérogénéité laisserait penser à des contenants pour les réserves alimentaires de l'équipage, mais le nombre d'individus ne permet pas d'exclure la présence d'une cargaison marchande complémentaire.

Les analyses chimiques révèlent aussi que tout le verre n'est pas homogène (TABLE 1; FIG. 2):

• Le verre brut et la vaisselle incolores, qui appartiennent à un même groupe de composition chimique, proviennent certainement du même atelier ou de la même aire géographique. On peut penser que les blocs de verre brut, très homogènes, sont issus du même four.

• La composition du verre à vitre, en revanche, s'apparente à celle des ateliers syro-palestiniens. Ce groupe de composition est celui que l'on retrouve le plus souvent et que l'on présente comme caractéristique des verres romains (Thirion-Merle 2003).

Les gisements de sables à l'origine de la vaisselle et du verre brut ne sont malheureusement pas localisés; ils ont été pourtant massivement exploités à partir de la fin du Ier siècle et surtout aux IIe et IIIe siècles et se distinguent nettement des sables que l'on sait utilisés par l'artisanat verrier de Syro-Palestine et d'Égypte. La composition de ce verre, dit groupe 4 (Foy *et al.* 2000) se distingue principalement des sables syro-palestiniens par des pourcentages de chaux et d'aluminium plus faibles. Les

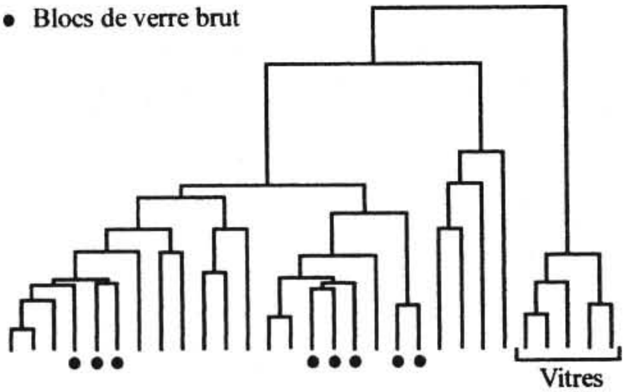

FIG. 2 Classification par analyse de grappe, en affinité moyenne non pondérée, sur variables centrées réduites relatives aux 8 constituants suivants: Na, K, Mg, Ca, Al, Fe, Si, Ti

deux groupes se caractérisent par des teneurs très faibles en fer, ce qui montre que, dans les deux cas, on a pris soin de choisir un sable assez pur pour obtenir un verre clair. Un agent décolorant était cependant indispensable pour l'obtention d'un verre parfaitement incolore: l'antimoine a été utilisé pour la vaisselle et le verre brut; le manganèse pour les vitres.

L'origine diversifiée des amphores fabriquées en Méditerranée orientale (région d'Éphèse, Cilicie, mer Noire?) et occidentale (Italie en très grande partie, mais aussi Espagne et Afrique du Nord), et les deux catégories de verre ne plaident pas en faveur d'un itinéraire direct depuis la Méditerranée orientale. On sait que les trajets sur longues distances sont assez rares et l'archéologie sous-marine met de plus en plus en évidence le rôle des grands ports de redistribution du monde antique et la fréquence des ruptures de charges. Dans l'état actuel des recherches, plusieurs hypothèses sont recevables. La multiplication des trouvailles, leur position dans le bateau, l'identification de l'origine et de la fonction des céramiques et des amphores, (distinction entre amphores de bord et amphores constituant une cargaison marchande; réutilisation ou non d'amphores à des fins diverses) et bien d'autres données encore peuvent considérablement modifier notre point de vue, après seulement trois campagnes de fouilles.

Dans le premier cas, le bateau serait originaire de Méditerranée orientale comme pourrait le faire penser la céramique de bord (deux cruches) et la présence de verre brut; il serait parti chargé de verre brut, de vaisselle de verre et d'autres produits contenus dans des amphores ; il a pu faire escale dans un port de redistribution – en Italie probablement – pour embarquer une cargaison

TABLE 1 Les analyses chimiques des blocs, vaisselle et vitres

	CaO	Fe_2O_3	TiO_2	K_2O	SiO_2	Al_2O_3	MgO	MnO	Na_2O	P_2O_5	Sb
Blocs											
moyenne	5.31	0.25	0.053	0.35	72.04	1.82	0.39	0.0000	19.43	0.01	5523
écart type	0.12	0.09	0.004	0.02	0.89	0.05	0.03	0.0000	0.50	0.02	1304
Vaisselle											
moyenne	5.37	0.33	0.051	0.42	70.05	1.99	0.42	0.0305	19.27	0.01	5445
écart-type	0.34	0.06	0.021	0.06	1.82	0.20	0.07	0.0649	0.78	0.02	1065
Vitres											
moyenne	8.41	0.33	0.030	0.44	68.51	2.64	0.50	1.8332	17.08	0.11	6
écart-type	0.06	0.04	0.024	0.01	0.06	0.07	0.04	0.1268	0.19	0.03	5

complémentaire et diversifiée comprenant entre autres des amphores vinaires de la côte tyrrhénienne d'Italie, mais aussi d'Afrique et de Bétique et du verre à vitre. La position de celui-ci, qu'il s'agisse de plaques rectangulaires ou de vitres circulaires et bombées, va dans le sens de cette hypothèse puisque ces vitrages se trouvaient respectivement, on le rappelle, au-dessus du verre brut et par-dessus la vaisselle de verre. On observera aussi que les vitres circulaires non soufflées ne semblent pas utilisées en Orient, alors que plusieurs pièces connues sont originaires d'Italie.

Tout aussi plausible serait l'hypothèse d'un commerce de redistribution. Le bateau serait allé chercher l'ensemble de sa cargaison dans un port de Méditerranée centrale, à Ostie par exemple où se trouvaient déjà réunies des marchandises venues de toutes parts. On ne peut totalement exclure un trajet direct des côtes orientales.

Ce verre n'était pas seulement réservé à une clientèle établie sur les bords de la Méditerranée. Les ports du Midi, Marseille et surtout le double port fluvial et maritime d'Arles, choisi par l'Administration impériale comme le port officiel du Service de l'Annone, commandaient l'accès du sillon rhodanien, la voie majeure pour diffuser les importations, au-delà des zones côtières. Arles a pu être, sinon la destination finale du bateau, du moins une place de transit importante.

Produit semi-fini et objets manufacturés empruntaient sans doute les mêmes itinéraires pour fournir les marchés et les ateliers installés dans des terres plus continentales. Dans l'officine de Besançon par exemple, et dans de nombreux sites d'habitats en Gaule, en Rhénanie comme en Grande-Bretagne, mais aussi en Espagne et en Afrique se retrouvent du verre brut et/ou des produits manufacturés de qualité comparable à ceux qui composent la cargaison. Ainsi, sans pouvoir encore retracer l'itinéraire du navire, peut-on assurer que le bateau des Embiez participait au commerce inter provincial de l'Empire.

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CUPS FOR GENTLEMEN

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INTRODUCTION

It is becoming apparent that social custom, rather than mere availability, probably governed the use of many glass vessels in Roman Britain. Study of site assemblages has shown a recurrent difference between urban and rural patterns of use; as well as differences between those used by civilians and the military (Cool and Baxter 1999; Cool 2003). Site assemblages, though, are coarse tools to work with, as they relate to groups rather than individuals. More detailed insights can be gathered by studying what items were thought appropriate to place in the graves of people of known age and sex. Developments in the study of human bone mean that increasingly there is very detailed information about the person buried. Our work in this area is at an early stage; but we feel that the methodology we have developed may be of use to others working with cemetery assemblages, and those who wish to explore what vessels were thought appropriate for different parts of the community.

The paper outlines the methodology with special reference to a cremation cemetery excavated outside the fort and *vicus* at Brougham, Cumbria. The site was excavated in 1966 and 1967 in very difficult circumstances as it was being destroyed by the building of a new road. The archive from the excavations has recently been re-assessed and all the material, including the cremated human bone, re-analysed. This has shown a very complex pattern of behaviour surrounding the funerals of the dead, and the way in which glass vessels were used is just one part of these (Cool 2004).

THE CEMETERY

Brougham is located in the military northern zone of Roman Britain. There has been very little excavation in the fort and the *vicus*, and so the history of occupation is unknown. The cemetery being considered was in use for a relatively short period of time. The widest date range possible is AD 200–310, but the most likely period is AD 220–300. Many of the formal urned burials were accompanied by jars made in Black Burnished Ware (BB1). The 3rd century was a period when the types of decoration on these changed (Bidwell 1985, 175; Holbrook and Bidwell 1991, 95), and this can be used to assign many of the burials to one of three separate phases. Phase 1 is AD 220–240, Phase 2 is AD 240–270, and Phase 3 is AD 270–300/10.

All ages were buried in the cemetery. In the formal urned burials it has been possible to identify 13 infants (0–5 years), 20 immature individuals (6–18 years), 14 adult males, 17 adult females and 32 adults which it has not been possible to sex. There are also eight double burials, generally of an adult and small child. During the 3rd century a cavalry unit, the *Numerus Equitum Stratonicianorum*, was in garrison in the fort (RIB 1, no. 780; Jarrett 1994, 69, no. 10). It is likely that this cemetery was the burial place of the soldiers and their families. This supposition is strengthened by the remains of horses and military equipment in the pyre goods.

It is clear that the majority of the wealth expended on the funerals was consumed on the pyre. Adults were taken to their pyres on biers decorated by elaborate bone veneers which were burnt with them, together with many other items including metal vessels, gold jewellery and objects of ivory. After the body had been burnt, the cremated bone was normally placed in a pottery urn. The urn was then placed in a grave, and was frequently accompanied by other pottery vessels. In some graves the urn was also accompanied by a glass vessel but this was far less common.

Melted glass is a regular feature of the pyre debris, indicating that glass vessels were placed on the pyre. All the melted glass was blue green and, where the vessel type could be identified, it was either a flask or a bottle. The vessels were clearly there as containers for liquids. In one case the vessel could be recognized as a bath-flask, suggesting perfumed oil may have been poured on the pyre. There were also the remains of square bottles of Isings (1957) form 50. This is of particular interest as it shows these were still being used in the mid 3rd century. The vessels placed entire in the graves were predominantly colourless drinking cups (FIG. 1). Closed forms were rare. The cups have been the subject of a previous paper in the *Annales* (Cool 1990). The recent analysis has allowed more precise dating to be assigned to them than was possible in that paper, and the results of this are noted in the caption to the figure.

THE DISTRIBUTION OF THE VESSELS

The associations of the glass vessels where the age and sex of the person in the grave is known are shown in TABLE 1. Glass flasks and their contents were clearly used on the pyres of people of all ages and sexes. Drinking vessels, though, appear to have only been placed in the graves of

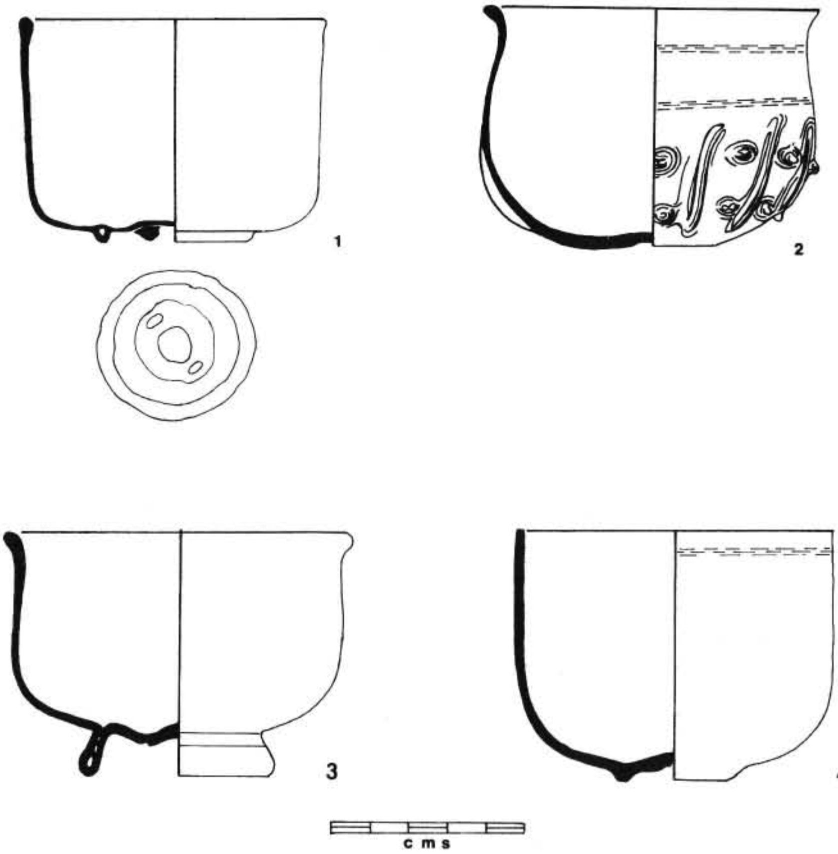

FIG. 1 Examples of the drinking vessels from Brougham. The cylindrical cups (FIG. 1.1) came from Phase 1 and Phase 2 graves. The hemispherical cups (FIG. 1.2) came from Phase 2 and Phase 3 contexts. FIG. 1.3 came from a Phase 2 burial and FIG. 1.4 from one of Phase 3; scale 1:2

adults, and apparently only in those of men. It was of some interest to establish whether glass cups were the preserve of grown men only.

This was explored by looking not only at the graves that did have glass vessels; but also those that did not. TABLE 2 shows the occurrence of glass drinking vessels in adult graves from Brougham where a determination of sex has been possible. Inspection suggests an association between the presence of a glass drinking vessel and sex, with male graves more likely to contain such vessels.

Statistical tests can be used to address the question of whether the apparent association came about by chance. The chi-squared test is that which archaeologists are most likely to be familiar with (Shennan 1997, 104). Application here suggests a significant association between sex and vessel presence at about the 1% level or better (the precise value depending on which version of the test is used). Unfortunately the validity of the test is questionable because of the low values of some of the row and column totals, leading to low expected values (less than 5) in the chi-squared test.

Fisher's exact test avoids such problems, and was used to confirm our intuition that apparent associations were indeed statistically significant. The idea behind the test is to construct all possible tables that have the same row and column totals; determine the probability of getting each table by chance; and calculate the probability of getting a table at least as 'extreme' (or unusual) as the one observed. For example, TABLE 3 preserves the row and column totals of TABLE 2 but is less 'extreme' than that actually observed. Applying the test to the data in TABLE 2 gave a p-value of 0.004, significant at better than the 1% level and confirming that the association suggested is unlikely to have arisen by chance.

Fisher's test is a useful alternative to the chi-squared test when sample sizes are small. We have illustrated it for a 2×2 table, but a generalization to $r \times c$ tables, sometimes called the Fisher-Freeman-Halton test, exists that we have also used. These tests have had limited use in archaeology, possibly because of their past lack of availability in commonly used software. On a technical note, we used

TABLE 1 THE ASSOCIATIONS OF THE GLASS VESSELS PLACED UNBURNT IN GRAVES AND ON THE PYRE

Age Band	Cup/ beaker	Grave-flask	Jar	Pyre
Adult	4	1	–	5
Female	–	–	1	3
Male	6	–	–	3
Double	–	–	–	1
Infant	–	1	–	3
Immature	–	–	–	1

Table 2 The occurrence of glass drinking cups in the graves of men and women

Sex	With	Without	Total
Male	6	8	14
Female	0	17	17
Total	6	25	31

Table 3 A less 'extreme' version of table 2 retaining row and column totals

Sex	With	Without	Total
Male	5	9	14
Female	1	16	17
Total	6	25	31

the R package (Dalgaard 2002), which is free, S-Plus (Venables and Ripley 2002), and two-sided alternative hypotheses.

Cups as a mark of status?

With results such as these it seems very reasonable to conclude that, in the community that was burying its dead in the cemetery at Brougham, glass cups were seen as the exclusive preserve of adult males. This fits a pattern where the types of things used in the funeral ritual varied according to the age and sex of the deceased. It is likely, for example, that only adult females had large copper-alloy vessels like Hemmoor buckets placed on their pyres; while small samian cups of Dr. 33 were only placed in the graves of babies and very young children.

In the case of the males buried with glasses it is possible to suggest that they were part of the upper echelons of society. In the cemetery the number of vessels deposited with the deceased ranged from one to eight, with just under 80% of the graves having between one and three vessels. The burials with four or more vessels tended either to be double burials of two individuals; or to have indications in the pyre goods that this may have been the burial of a person of high status. It is noticeable that glass vessels were only being deposited in the graves which contained four or more vessels.

At present we do not know whether glass cups were held in a similarly special regard elsewhere in Roman Britain. There are grounds for thinking that the unit stationed at Brougham during the 3rd century, and which buried its dead in the cemetery, had originated in the Danubian area, possibly from Pannonia. This is suggested by finds in the cemetery that find their best parallels there, and in the lands of the *Barbaricum*; by epigraphic evidence on a gravestone and in the form of a graffito; and by some of the burial rituals. It is possible that the unit had spent time in the Rhineland before coming to Britain, as the site has an unusually high proportion of East Gaulish items at a time when the neighbouring sites were more likely to have Central Gaulish material. At Brougham there are, for example, many colour-coated beakers from Trier, a vessel type thought particularly appropriate for children and young people.

This way of using glass vessels may, therefore, have been more typical of continental Europe than of Britain. Currently we are starting to look at other Romano-British cemeteries where there is good human bone evidence to see if similar patterns start to emerge.

Conclusions

Whilst it has long been accepted that items such as jewellery and weapons might be gender-specific, other types of material culture such as vessels have traditionally been regarded as gender-neutral. The work at Brougham indicates that this may be far from the case.

The approach we have outlined here of tabulating the occurrence of a type of grave or pyre good according to the age and sex of the individual, and then using a statistical significance test to explore whether the observed patterns could have come about by chance, is a simple one to implement. We feel that the analysis of many other cemeteries could benefit from adopting it.

Acknowledgements

The analysis of the Brougham cemetery was funded by English Heritage. It was carried out by a large team of whom we were only a part. We would like to thank especially here Jacqueline McKinley of Wessex Archaeology who reported on the human bone, and Jerry Evans of Barbican Research Associates who dealt with the pottery and provided the phasing. The drawings are by Peter Dunn.

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Abbreviation

RIB 1. Collingwood, R.G., and Wright, R.P. 1995. *The Roman Inscriptions of Britain. I: Inscriptions on Stone*. Stroud, Alan Sutton Publishing (New edition).

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A FOURTH-CENTURY ASSEMBLAGE OF GLASS FROM THE ROMAN VILLA OF CAN PALAU, BARCELONA, SPAIN

JOAN-MANUEL COLL RIERA

INTRODUCTION

In 1999 the archaeological site of Can Palau (Sentmenat), 24km from Barcelona, was found. This site consists of a mausoleum with a necropolis annexe (4th century) and a collection of domestic rubbish pits belonging to a Roman villa found beneath the nearby country house of Can Palau, situated about 100m from the excavated site.

The material originating from the rubbish pits is made up of ceramics of general use, and plates and dishes, amongst which stand out some fine ceramics of African (ARS – African red slip: Hayes 1972) and Gaulish origin (*Lucente*: Lamboglia 1963). Related to these contexts, 72 Roman coins were recovered, which, together with the ceramics, permit the dating of the rubbish pits to two exact periods, the first datable between AD 330 and 360 and the second between AD 360 and 390–400.

In this paper we present the results of the study of the glass associated with these contexts, and detail the forms and minimum numbers of identified pieces using the Clasina Isings catalogue as a reference (Isings 1957).

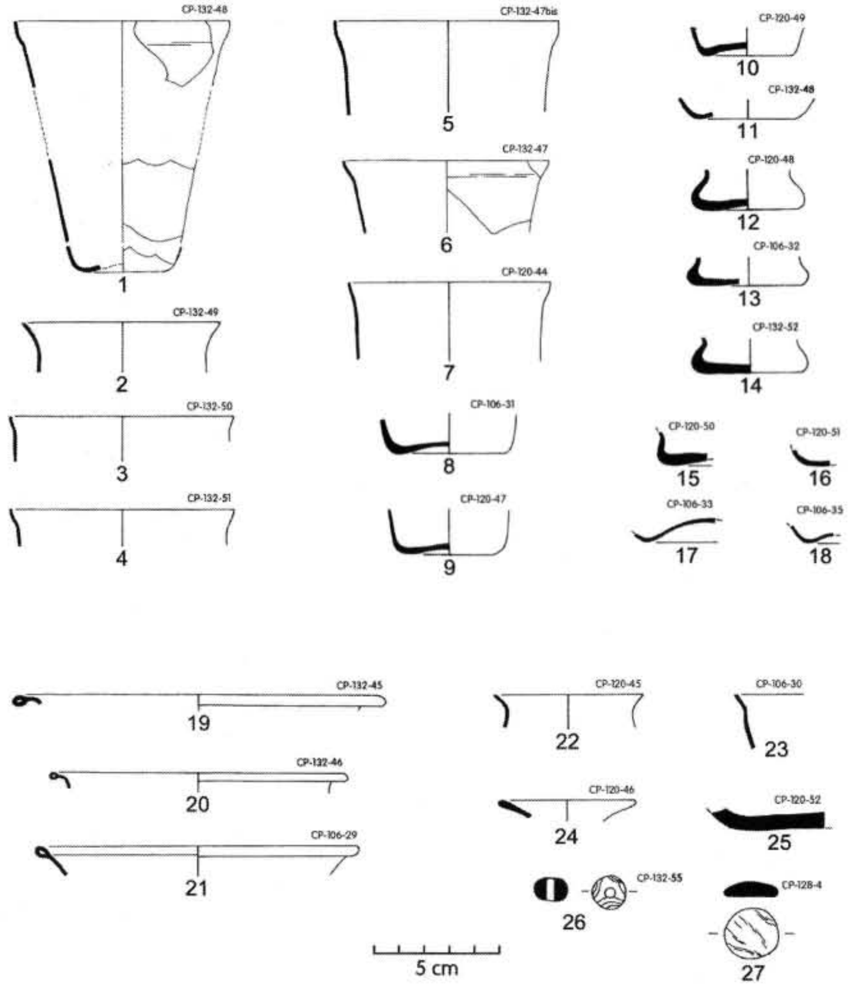

FIG. 1 Glass vessels from contexts dated between AD 330 and 360; scale 1:3

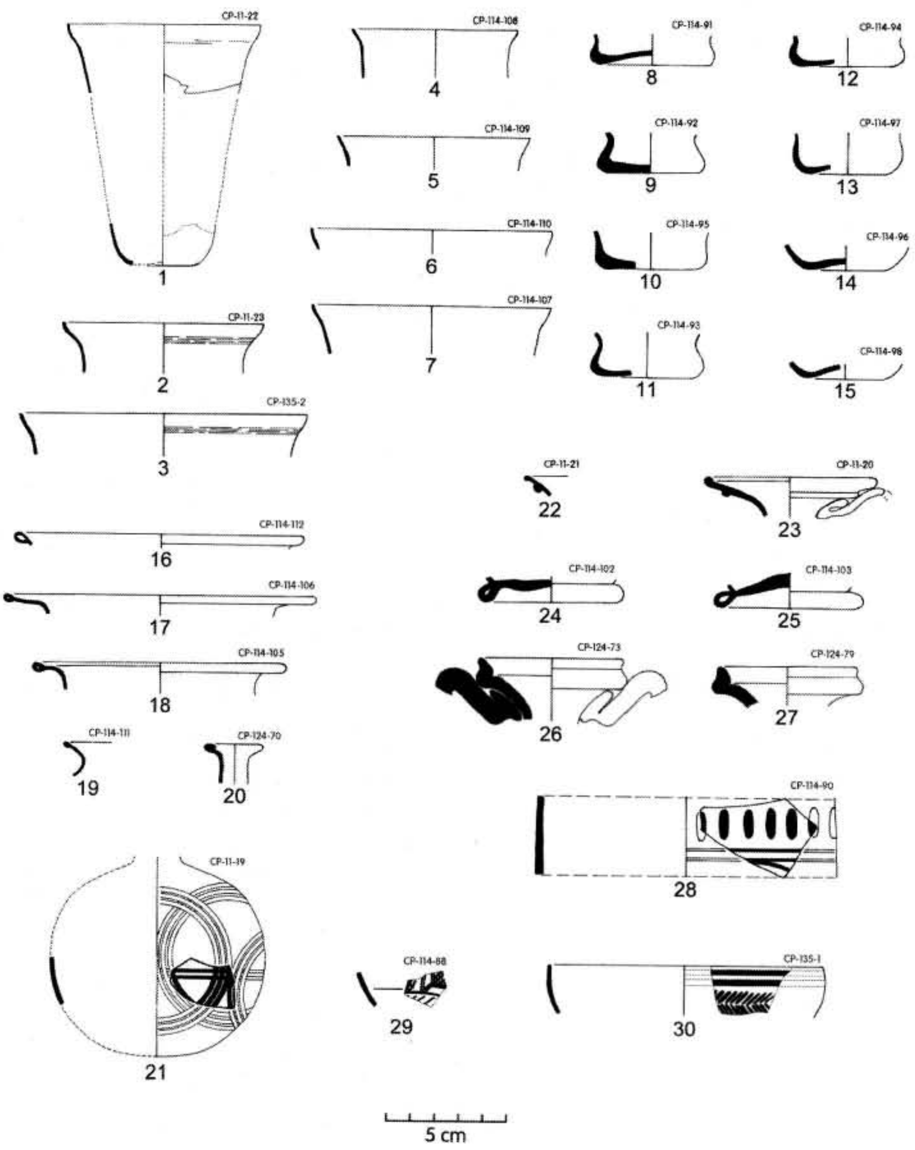

FIG. 2 Glass vessels from contexts dated between AD 360 and 390; scale 1:3

CONTEXTS DATED BETWEEN 330 AND 360

The archaeological contexts attributed to this period are formed by eleven rubbish pits with similar vessel glass dated from fine wares (forms Hayes 58B, 59 and 61A) and coins, among which the latest are those of the Constantinian dynasty. In these rubbish pits there is no evidence of any material earlier than AD 330 or later than 360. In total a minimum of 35 vessels (143 fragments) have been documented, all of colourless blown glass, with light tones of green or very diluted blue. The predominant shape is form 106, with a minimum of 26 vases identified, with conical body, bevelled edge and flat base, lightly concave, without any identified decoration. Some of them present an open base-ring where the body and the base are joined (FIG. 1.1–16).

There are a few other types of vessels, identified generally from one or two fragments – three bowls with a tubular rim (FIG. 1.19–21) and one rim from a form 120 bottle (FIG. 1.24). There is also a gaming piece in opaque dark glass (FIG. 1. 27) and a black bead with a yellow wavey line and blue drops (FIG. 1.26).

CONTEXTS DATED BETWEEN 360 AND 390–400

These contexts are dated by the fine pottery of African origin, specifically the Hayes (1972) forms 53A, 53B, 58B, 59, 61A, and 70, and by the presence of coin types AE3 and AE4. The absence of fine pottery of Gaulish origin (*Derives des sigillees paleochretienes*), generally present in the archaeological sites of Catalonia from the beginning of the 5th century, permits the dating of the later contexts from Can Palau to before the beginning of that century, dating back to Theodosian times.

In total a minimum of 48 vessels (137 fragments) have been documented. The colourless form 106 glass vessels are still the ones most found and are identical to those from the earlier period, with a minimum of 26 pieces (FIG. 2.1–15). We have documented for the first time the presence of some olive green pieces – there are a pair of two-handled form 127 bottles (FIG. 2.26–7), and three globular form 120 bottles (FIG. 2.23–5). Also present are some fragments of engraved glass, all colourless, with a minimum of five receptacles – a cylindrical form 126 bottle, decorated with abraded ovals and engraved lines (FIG. 2.28), a shapeless fragment of wheel-cut glass, with a grille decoration (FIG. 2.29), a form 96b bowl with wheel-cut decoration in the motif of a palm leaf (FIG. 2.30) and a fragment of a form 103 bottle with wheel-cut concentric circles (FIG. 2.21).

ENGRAVED FRAGMENT WITH APPLIED GOLD LEAF

We have left to the end the study of the cut fragment CP-114-87 (FIG. 3.1–3). This is a fragment of colourless glass, with the outside surface decorated by a wheel-cut engraving. This represents a male bust, freehand engraved, looking to the left, with the hair styled *a calotta*, beardless, dressed in a *tunica* and *pallium* with *clavi,* framed in an octagonal wheel-cut line. Originally this bowl had an applied gold-leaf finish, possible with painted details most clearly visible on the *clavi* of the *tunica.* These had been abraded with less care than the rest of the figure, very probably to receive a glaze, possibly red.

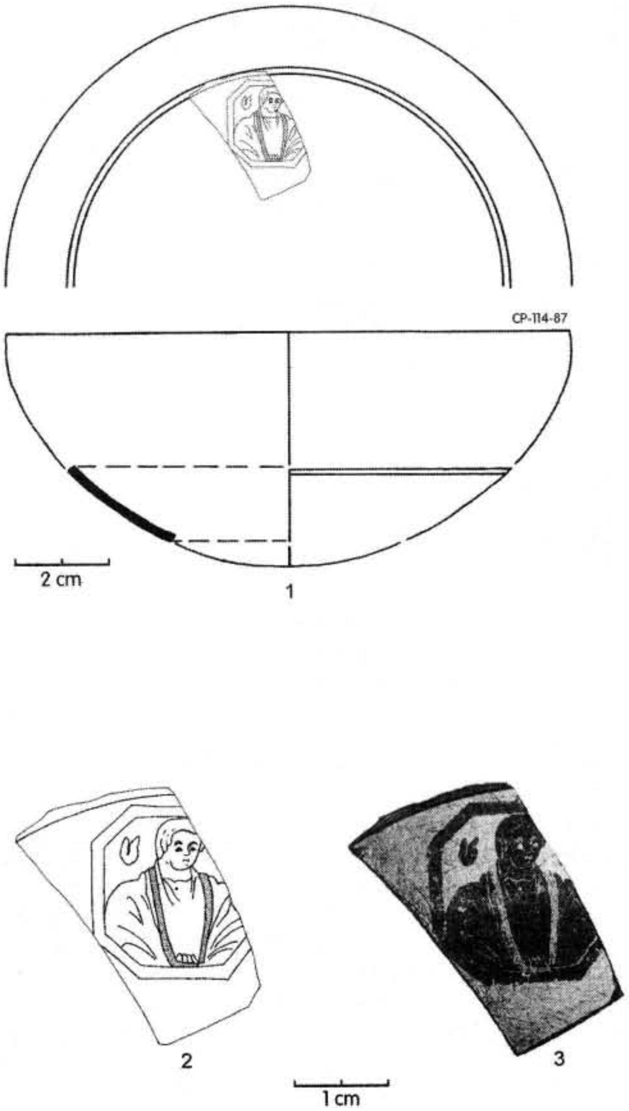

FIG. 3 Cut and engraved glass vessel; scales as shown

Iconographically, this bust, engraved with a very similar technique to the glyptic, represents a Christian character very probably an apostle or saint, stylistically close to some vases decorated by *fondi d'oro* originating from Rome (Morey 1959; Zanchi Roppo 1969), though the fragment described here is technically very close to other types of vase with applied gold leaf, like the cup of Köln-Braunsfeld (Harden *et al.* 1987, 25–7). It is necessary to mention here the recent publication of two fragments of engraved vases with an applied gold leaf, originating from Zaragoza, one of them with zoomorphic motives, engraved freehand, geographically very close to our fragment (Ortiz 2001, 174–5, pl. 34.1).

From the dimensions and the direction of the wheel-cut line, this fragment seems to be attributable to form 96b bowls in which the cut lines, and other framed images with the busts of characters, would frame a central figure motif. Parallels to these radial compositions, generally some apostles surrounding Jesus, Saint Peter or Saint Paul are documented in some *fondi d'oro* published by Morey (1951, particularly nos 36, 52, 104 and 105 from the collections of The Vatican Library and Museo Sacro). At the same time the use of octagonal frames with figured compositions is well documented in diverse fragments conserved in different collections (Morey 1959; Zanchi Roppo 1969). All these elements permit us to attribute the fragment, without too much risk of error, to a workshop linked to the city of Rome, probably active during the second half of the 4th century AD.

Some slightly later villas have also provided examples of cut glass, all datable to the second half of the 4th century AD. Among these may be noted: the bottom of a form 116b plate from the Villa de l'Aiguacuit in Terrassa (Barcelona), with an engraved tree (FIG. 4.1); a form 116b bowl from Poble-Sec (Sant Quirze), attributable to the *grupo Sagui* (Sagui 1997) with the iconographic motif of a hunting scene (FIG. 4.2); and a form 116 bowl from Can Tarres (La Garriga), decorated with lined motifs. An exceptional form 96b bowl (FIG. 4.3) and a form 116b plate (FIG. 4.4) originating from the urban villa of l'Arxiu Administratiu in the city of Barcelona (Beltrán de Heredia 2001, 156-7) may also be mentioned; both pieces have hunting scene motifs and are attributable to the workshop of maestro Daniel in the city of Rome (Paolucci 2002). All these bowls, chronologically placed during the second half of the 4th century AD, are associated stratigraphically with the construction and reconstruction phases of important villas of rural and urban character. They constitute at present one of the rare archaeological elements to indicate the location and distribution of rural and urban aristocracies of the 4th century AD in the *territorium* of Barcino.

CONCLUSION

The glass vessels of Can Palau, despite their extreme fragmentation, originate from some well-dated

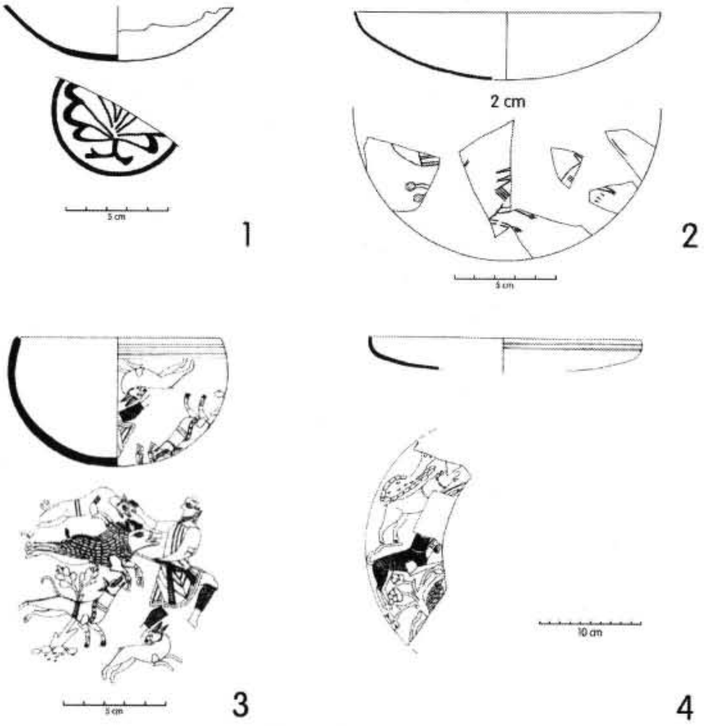

FIG. 4 Some engraved vessels from the *territorium* of Barcino; scales as shown

archaeological contexts permitting the identification of different types of glass receptacles of everyday use in an aristocratic villa around Barcino, between the post-Constantinian and Theodosian periods. Thus Isings forms 106, 120 and 127 are the most usual together with some engraved glass vases of a more luxurious style. The fragment of a form 96b bowl with an iconographic motif of Christian character, a product of a workshop in Rome, can be interpreted as a present or a purchase of a religious object, linked to the personality and culture of the owners of the villa, members of the small rural aristocracy.

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GLASS VESSEL FINDS FROM A POSSIBLE EARLY FOURTH-CENTURY CE CHURCH AT AILA (AQABA), JORDAN

JANET DUNCAN JONES

Excavations at Roman Aila (Aqaba) under the direction of Professor S. Thomas Parker have uncovered the remains of a monumental mud-brick structure dating to the end of the 3rd century or to the beginning of the 4th century CE. Based on the eastward orientation of the building, its monumentality, plan, details of construction, and the associated artefactual finds, the excavators propose that this structure was a purpose-built Christian church, possibly the earliest such structure yet identified (Parker 2000, 390). A bishop of Aila is attested at the Council of Nicea in 325 CE, indicating a sizeable Christian community at Aila by early in the 4th century (*ibid.* 2000, 386).

This structure has produced over 650 diagnostic glass vessel fragments (of 1650 total fragments), attributable largely to vessel types dated to the 4th century CE. The rare fragments of much earlier date, such as a cast plate with an overhung rim and a ribbed bowl, appear to be heirlooms. Some fragments, such as stemmed lamp fragments, represent types with a long period of production. The corpus includes a significant number of fragments from cut and cast glass vessels including four fragments from a cage cup. At least 166 fragments can be attributed to open shapes (bowls, beakers, lamps and plates) and at least 30 to closed shapes (bottles and jars). The rest are decorated body fragments or handles and bases that are not attributable with certainty. In addition to vessel fragments, the structure produced *c.* 15 fragments of bracelets, one bead or counter, one pendant, and eight window pane fragments.

CAST OR MOULDED VESSELS (FIG. 1.1 and 2)

The structure produced 13 of a site total of 49 fragments of heavy cast or moulded colourless beakers, bowls, and plates including six of a site total of 18 fragments of colourless base-rings (FIG. 1.2) that were either cast of one piece with the vessel or applied to blown vessels. The most exceptional of the cast fragments from the structure were three fragments of an elegant cast and lathe-cut colourless plate or bowl (FIG. 1.1) with an overhung rim similar to examples from Quseir al-Qadim (Meyer 1992, 19–20, nos 28–51).

Glass luxury tablewares such as these are known from throughout the Roman world in the early empire and were manufactured in various workshops in the late 1st and early

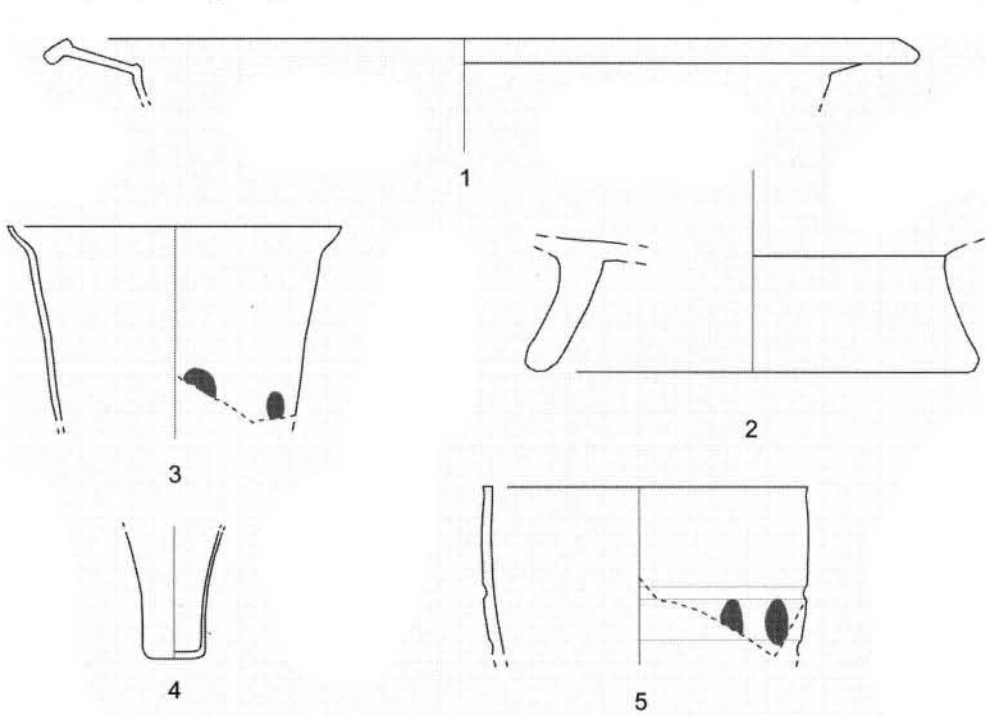

FIG. 1 Fragments from cast vessels and lamps; scale 1:2

2nd century CE. The Aila examples were most likely of Egyptian manufacture. Such vessels were clearly exported from the more southerly Red Sea port of Quseir al-Qadim in the 1st and 2nd centuries CE (Meyer 1992, 11–13), but were never present at Aila in quantity. It is probable that the vessels at Aila were imported from Egypt for local consumption. These vessels were heavy, durable luxury goods and, thus, the plate from this structure is likely to be an heirloom.

Blown vessels

The vast majority of fragments found in the structure, and from Aila as a whole, come from blown vessels with cut, moulded, tooled or no decoration. There is a significant number of fragments from carefully crafted luxury vessels or lamps, but a majority are rims and bases from utilitarian types of tablewares (63 simple straight or folded rims from open shapes, 28 simple straight or folded rims from closed shapes, 8 neck fragments from closed shapes, 27 concave or kicked bases, 23 pushed-in bases or tubular base-rings, 6 coil bases, 7 coil handles, and 4 ribbon handles). There are no waste fragments, as yet, or any other evidence of glassworking at Roman Aila.

Lamps/Bowls (FIG. 1.3–5)

The largest group of glass fragments recovered comes from lamp or beaker (bowl) types most commonly dated to the 4th century CE. These finds include 38 cracked-off rims (several with signs of burning), 13 conical bases, and 15 fragments decorated with blue blob decoration. These fragments constitute a majority of the total of 65 cracked-off rims, 15 conical bases, and 23 blue blob decorated fragments unearthed by the project as a whole.

These lamps or beakers – there is evidence for use as both (Weinberg and Goldstein 1988, 89–91) – are distinctive in shape and decoration. They are commonly thick-walled, conical or hemispherical, and decorated with wheel-cut grooves and applied blue blobs. The wheel-cut decoration ranges from well defined polished grooves to simple unpolished incised or abraded lines. The blobs are usually elongate ovals ranging in length from less than 5mm to greater than 20mm; the smaller blobs are often arranged in triangular or diamond-shaped patterns. Examples without blue blob decoration are common.

Lamps and beakers of this sort were widely distributed throughout the Roman world. Examples from the eastern empire, like those at Aila, tend to be thick-walled and light green or colourless. They are well attested in Egypt, particularly at Karanis (Harden 1936, 155–66), and in Syro-Palestine where colourless or pale green conical examples with blue blobs are known to have been manufactured at Jalame for a generation from 351–383 CE (Weinberg and Goldstein 1988, 89–91).

Finds from the Aila structure include both straight and everted cracked-off rim fragments in addition to the conical bases and body fragments with blue blob and cut decoration. Eleven of the cracked-off rims from the structure are thinner-walled everted rims. Such rims are known on lamps (Whitehouse 1997, 250, no. 427), globular bowls (*ibid.*, 258, no. 449), and goblets (*ibid.*, 216–17, no. 373) of similar date to the heavier lamps.

In addition to the lamps with cracked-off rims, the structure also produced three small fragments from stemmed lamps out of a site total of five. Such lamps were made for use in *polycandela* and range in date from the 3rd century to early Islamic (Hadad 1998, 69, type 3). There are examples similar to the Aila fragments from church contexts at Jerash dated from the 4th to 5th century CE (Baur 1938, 534, no. 237) and the 7th century (Meyer 1987, 203, fig. 11, h–l).

The type of lamp that dominates the corpus, the heavy conical or bowl-shaped type with cracked-off rim, is the predominant lamp type of the 4th century. It is superseded in the region by the tumbler lamp, a beaker-shaped vessel with heavy out-folded rim and three handles common to the many slightly later late Byzantine churches of the late 5th to 6th century CE in the region, and found in distinctively thick deposits at el-Lejjun (Jones 1987, 627–8, no. 73), Jerash (Meyer 1987, 184, 210, fig. 12 P, 212), Khirbet al-Karak (Delougaz and Haines 1960, 49), and Humeima (currently under study by the author). No tumbler-type lamp fragments were found in the structure. The stemmed lamp, of which two possible fragments were recovered from the structure, is a long-lived type. Thus the lamp fragments from the Aila structure and from the slightly later churches nearby fall on opposite sides of a significant shift in lamp types.

Vessels with cut decoration (FIG. 2.1–8)

The structure produced 30 fragments with engraved decoration ranging from the few abraded lines or wheel-cut grooves often seen on lamps, to facet-cut and complex geometric cut designs. The majority of the fragments from the structure with cut decoration have the simple linear cut decoration typical of nicer bowls, beakers, lamps and bottles. The examples illustrated here are the more complex examples with geometric patterns and facet-cut designs. These fragments are, as a rule, too small to allow reconstruction of the entire vessel profile.

A thin, flat fragment (FIG. 2.1) exhibits a simple pattern of abraded criss-crossed lines that is common in cut designs of the 4th century, for example on a series of globular bottles with Greek letters (Whitehouse 1997, 266, no. 454) and on fragments of similar date from Jalame (Weinberg and Goldstein 1988, 101–2, no. 518) and Dura-Europos (Clairmont 1963, 72–4, no. 273).

A larger fragment with lightly abraded decoration (FIG. 2.2) consists of a pair of lines following the rounded contour of the vessel, a series of elongate abraded ovals on either side of the lines, two larger ovals above, at an interval of five of the smaller ovals, and linear elements extending from these larger ovals toward the break. This design can be compared to a similar section of decoration on a bowl from a tomb group at Al Bassa dated by Harden to the second half of the 4th century CE (Harden 1949, 156–8; Weinberg and Goldstein 1988, 101–2, and note 223).

A more complicated design occurs on a thick fragment (FIG. 2.3) on which four pairs of lines intersect each other to create a star or cross-shaped pattern; ovals are cut into the angles between pairs of lines. The orientation of this

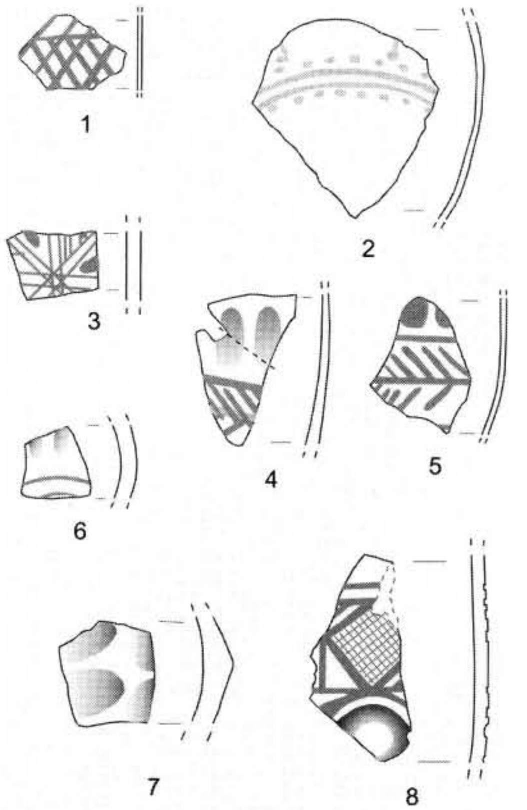

FIG. 2 Fragments from vessels with cut decoration; scale 1:2

fragment is unclear. The pattern seems closely related to the central abraded star pattern in the decoration of a bowl with Greek letters in the Römische-Germanisches Museum of Cologne (Harden *et al.* 1987, 203–4, no. 112). The Cologne example is a rare bowl in a group of vessels (primarily bottles like the Corning example mentioned above) identified and dated by Harden to the first half of the 4th century CE (Harden 1967/1968, 50–1).

Two fragments (FIG. 2.4, 5) have wheel-cut designs similar to each other consisting of three horizontal lines with short diagonal elements branching off the middle line and a row of contiguous facet-cut lozenges above. Number 4 has a thicker fabric, and the patterns of the two fragments are at a slightly different scale. Exact parallels are elusive, but these fragments belong to a large group of cut vessels, possibly of Egyptian or Syrian manufacture and dated to the 4th century CE (Harden 1936, 141; 1949, 159).

Facet cutting is also represented among the finds from the structure. A thick fragment (FIG. 2.6) from a cup with linear and facet-cut decoration is similar to a cup at Corning (Whitehouse 1997, 258–9, no. 442). The Aila fragment preserves a pair of horizontal cut lines that follow the contour of the vessel with portions of two vertical, elongated oval facets above.

A second, very thick fragment (FIG. 2.7) preserves traces of four large oval facets in two rows, one with vertically aligned facets and one with horizontally aligned facets. A colourless shallow bowl at Corning, dated to the 4th century CE, has rows of facets with a similar relationship to one another (Whitehouse 1997, 263, no. 450).

The most deeply cut and most carefully worked of the cut fragments from the Aila structure is a nearly flat fragment (FIG. 2.8) with an elaborate design around two major elements: 1) a large, deeply incised circle with a raised centre, and 2) a cross-hatched diamond within a rectilinear frame. Again, exact parallels are elusive. There are many examples of vessels with a continuous motif of cross-hatched diamonds or squares that date to around the beginning of the 3rd century CE (Clairmont 1963, 73, n. 187) and Corning has two examples of a cup with a frieze consisting of cross-hatched diamonds alternating with diamonds with an abraded circle in the centre dating to the 3rd to 4th century CE (Whitehouse 1997, 262–4, nos 447, 451). The design on these cups, although related in conception to that on the Aila fragments, does not match it for depth of carving or quality of workmanship.

Sprinkler bottles (FIG. 3.1)

The structure produced diaphragms from two sprinkler bottles. Sprinklers, distinguished by a narrow diaphragm at the neck that was probably intended to slow evaporation, are thought to have functioned as storage and dispensing vessels for unguents and perfumes. These vessels came in various shapes and decorations, but the Aila examples are known only by their diaphragms. Sprinklers are generally dated to the 3rd–4th century CE, but later examples are known (Stern 1995, 187).

Vessels with mould-blown decoration (FIG. 3.2)

Two mould-blown fragments from the structure are decorated with a sunken relief pattern of dots or, possibly, expanded mould-blown hexagons. Production of vessels with sunken relief seems to have begun in the 4th century CE and lasted into the 7th century CE (Stern 1995, 247–8, 251). The vessels that have decoration most similar to the Aila fragments are two inverted conical jugs in Toledo with patterns of slightly expanded mould-blown hexagons (*ibid.*, 264–5, nos 187–8).

Bowl with scalloped edge

The structure produced one small fragment from a distinctive deep bowl with a rim that has been pulled with pincers to create a scalloped effect. Excavated examples are known from Karanis (Harden 1936, 97, 111–12, nos 257, 259) dated to the 4th to 5th century CE.

Vessel with pinched decoration

One fragment of a vessel with pinched decoration in the wall was found. This decorative scheme is common on small jars such as the intact example from a church context at Jerash (Baur 1938, 536, no. 244) dated to the 4th to 5th century CE and on fragments from Jalame (Weinberg and Goldstein 1988, 82 , nos 178, 370, 371) dated to the second half of the 4th century CE.

Handles

Two curving fragments of a spiral handle or bracelet were found in the structure. As a bracelet, it is paralleled by an unstratified find at Sardis (von Saldern 1980, 33–4, no.

233); as a handle, it is paralleled by a cup in the Newark Museum dated to the 1st century CE (Auth 1976, 87, no. 105). Glass bracelets from the Roman period are rare, but spiral rods are well known throughout the Roman empire (Harden 1936, 286) and generally dated to the 1st through 3rd century CE (Meyer 1987, 188).

Also found was part of a crimped handle such as ones seen on jugs of 4th-century date at Newark (Auth 1976, 109, no. 127) and Berlin (Platz-Horster 1976, 48, no. 179), on a flask from Kerak dated to the second half of the 4th century (Dussart 1998, 155, no. BX632), or on a lentoid flask of similar date in Toronto (Hayes 1975, 81–2, 96, no. 333).

Coil bases

The structure produced eight coil bases, seven of these have a single coil and are small and carefully worked. These are paralleled at Karanis (Harden 1936, 256, 263, no. 792), at Mezad Tamar (Erdmann 1977, 115, no. 52) a site of the 3rd to the 7th century CE, and from 3rd to 4th-century contexts at el-Lejjun (Jones forthcoming, nos 5–7). There is one example of a complex coil base with three revolutions that is paralleled at Karanis (Harden 1936, 217, no. 658) and at Jalame (Weinberg and Goldstein 1988, 58–9, nos 152–5).

Bowls with a double fold in wall (FIG. 3.3)

The structure produced four of the site total of five examples of a rim from a bowl with a double fold below the rim. These are attested at Jalame (Weinberg and Goldstein 1988, 53–4, nos 108–17) and appear to be most common as the rims of deep bowls (*cf.* Hayes 1975, 120, no. 472; Whitehouse 1997, 79, nos 102–3). They are typically dated to the 3rd to 4th century CE.

Triangular rims (FIG. 3.4)

The structure produced three examples of a distinctive triangular plate or bowl rim that is not readily paralleled. The rim is solid and triangular in section. Its closest cousin appears to be a more upright triangular rim from a small bowl known at Jalame (Weinberg and Goldstein 1988, 50–1, nos 83–7). One of the Aila examples displays the wheel polishing that is noted on the Jalame examples.

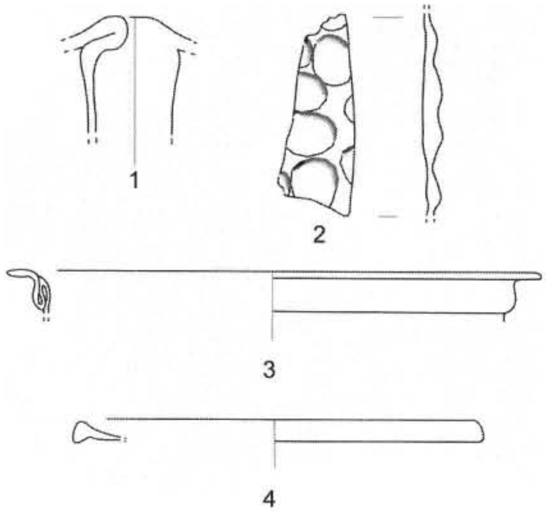

Fig. 3 Fragments from moulded and tooled vessels; triangular rim fragment; scale 1:2

CAGE CUP (FIG. 4)

The most notable glass vessel find from the mud-brick structure is a fragmentary cage cup comprising three joining fragments from the rim and upper body of the vessel in colourless glass with blue, green and amber overlays, and one body fragment that appears to preserve part of a strut in colourless glass with a green overlay (Jones 2003). The vessel is unique among known cage cups in having several colours in one horizontal band. The fragments appear to come from a *situla* or bucket-shaped vessel, most likely from Harden and Toynbee's Group B (without figured decoration) (Harden and Toynbee 1959, 203). The closest parallel is a bucket cage cup from Soria in the Museo Arqueologico Nacional, Madrid (Harden and Toynbee 1959, 210–11, n. 6, pl. lxxi.d).

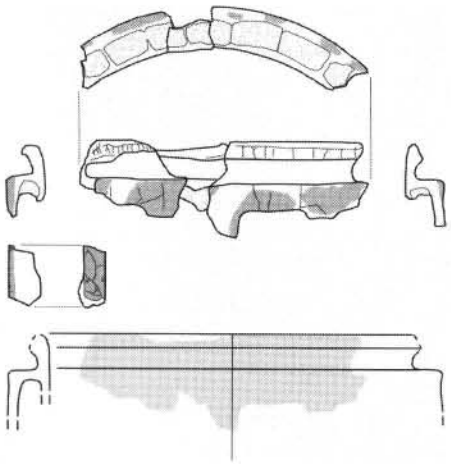

FIG. 4 Fragments from cage cup (after Jones 2003, 181, fig. 1); scale 1:2

Cage cups are presumed to have functioned primarily as suspended lamps (Whitehouse 1997, 285). The *situla* shape, however, was long associated with religious rites and formed part of the liturgical equipment of an early Christian church, functioning as a ceremonial container for holy water (Michelli 1996). In this context it is interesting to note that the cage cup fragments from the Aila mud-brick structure were found in a part of the building tentatively identified by the excavators as the *pastophorion*, a chamber used by clergy to store vestments and objects associated with worship in the adjacent chancel. Other vessels from this room include one sprinkler vessel and several fragments of vessels with cut decoration.

CONCLUSION

The corpus of glass from the monumental mud-brick structure is of particular interest to the excavators for its bearing on the interpretation of the structure. The concentration of fragments from glass vessels of high quality in this structure is distinctive at Aila and underscores the prestigious character of a building already set apart by its plan and construction. The relatively large number of fragments with deeply engraved complex patterns or facet-cut decoration would have been appropriate to the formal tablewares of an elite establishment or household. Stemmed glass lamps in chandeliers and windows would have supplied ample lighting for a venue accustomed to sizeable gatherings. Heirloom cast plates and elegant lighting fixtures such as the cage cup would also be appropriate to such a high-status setting. The glass finds alone place the structure out of the run of common buildings.

The glass finds from the mud-brick structure are not inconsistent with an identification of the building as an early Christian church. No securely identified church of this early date has yet been discovered, therefore there is little in the way of material that is directly comparable. However, concentrations of glass lamps have long been a hallmark in the excavation of Byzantine churches. In addition, two vessel types with the potential to serve as liturgical equipment – the *situla* (cage cup) and the sprinkler bottle – add support to evidence already gleaned from other aspects of the building for its interpretation as an early church. The seat of a Christian bishop seems likely to have had the need for high-quality tablewares, lamps, and liturgical furnishings such as those unearthed in the excavation of this monumental mud-brick structure at Aila.

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THE PARTHIAN AND SASANIAN WORLDS

MESOPOTAMIAN GLASSWARE OF THE PARTHIAN AND SASANIAN PERIOD: SOME NOTES

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For a long time studies on Mesopotamian glassware of the Parthian period have been based mainly on the finds from Dura Europos (Clairmont 1963) and on the scanty published evidence from Parthian sites. For the Sasanian period they have been based mainly on items in private collection and short excavation notes. In recent years, however, several studies have reconsidered the finds from old excavations, and new material has come to light in both planned and salvage excavations in the old Mesopotamian area. Even if glass fragments have not always been taken into account and/or published in detail, glassware with reliable provenance from Parthian and Sasanian contexts is now known from several Mesopotamian sites.

PARTHIAN GLASS

In Mesopotamia the range of Parthian glassware consisted mainly of small closed containers, flasks, jars and *aryballoi* with spherical bodies, both imported and locally produced; and a smaller percentage of tablewares, in particular plain and decorated vessels in coloured glass and plain or ribbed cast bowls. These were produced in the eastern Mediterranean until the second half of the 1st century AD, but were still scattered in Seleucian and Hatran levels of the first half of the 3rd century AD (Negro Ponzi 2002; Dorna Metzger 2003).

Glass vessels found in Seleucia (central Mesopotamia) came both from settlement layers and graves, dating from the end of the 1st century BC/beginning of the 1st century AD to the end of the 2nd/first half of the 3rd century AD (FIG. 1). The commonest types were plain bottles for balms. These can be classed into four groups according to the body shape and the body to neck height proportions (Negro Ponzi 2002). These bottles had close parallels among the contemporary funerary furnishings of two late-Parthian graves found by German excavators in the nearby Al Mada'in area (Hauser 1993). However, glassware was scarce in the Seleucian graves, as it was in the contemporary Dura Europos graves (Clairmont 1963).

Glassware from a Parthian settlement has also been excavated at Hatra, in North Mesopotamia, and a recently published group of glass fragments from a 3rd-century AD house shows both affinities and differences with the glass production of the Seleucia/Al Mada'in area (Dorna Metzger 2003). The balm bottles have a tall cylindrical neck associated with a low conical body made in very thick glass, corresponding to Seleucia type III as in Nippur (McCown and Haines 1967) and Uruk (Van Ess 1992), as well as in Iranian sites (Fukai 1977), but they only formed a small percentage of the total fragments. Moreover, the eastern Roman component appears generally stronger in Hatra, as it was in other north Mesopotamian sites (Simpson 1996; 2000); and a type of oval bowl on high foot-ring, widespread in the area, is entirely missing in central Mesopotamia and finds some parallels only in glass vessels from the Syrian area.

SASANIAN GLASS

The transition between the late Parthian and the early Sasanian period is marked in Mesopotamia by an abrupt change of the glassware range. The earliest settlement layers of Veh-Ardashir, a new town in the al Mada'in area founded by Ardashir I in the second third of the 3rd century AD, already show a different range of mass-produced glassware (Negro Ponzi Mancini 1984).

The new types included high beakers with solid stems (FIG. 2.5), cylindrical goblets with applied bases (FIG. 2.4), very similar to a well-known Roman type, and goblets with a hollow stem, supporting a spherical cup with vertical or out-turned rim, or a tall cylindrical cup with flaring sides (FIG. 2.3 and 1), the latter derived from the Roman imperial type, the *carchesium*. The stemmed goblets had mould-blown reblown decorated variants, with vertical ribs for the spherical cup and twisted ribs for the tall cup. Mould-blown patterns were, on the contrary, never used for the high beakers with a solid stem; while a parallel series of heavy deep bowls was decorated both with vertical and twisted ribs (FIG. 2.8–9), as well as with ribs pinched in groups of two or three, a pattern that is never used on the goblets. This new range was already dominant in the mid 3rd century glassware of Veh-Ardashir, and continued

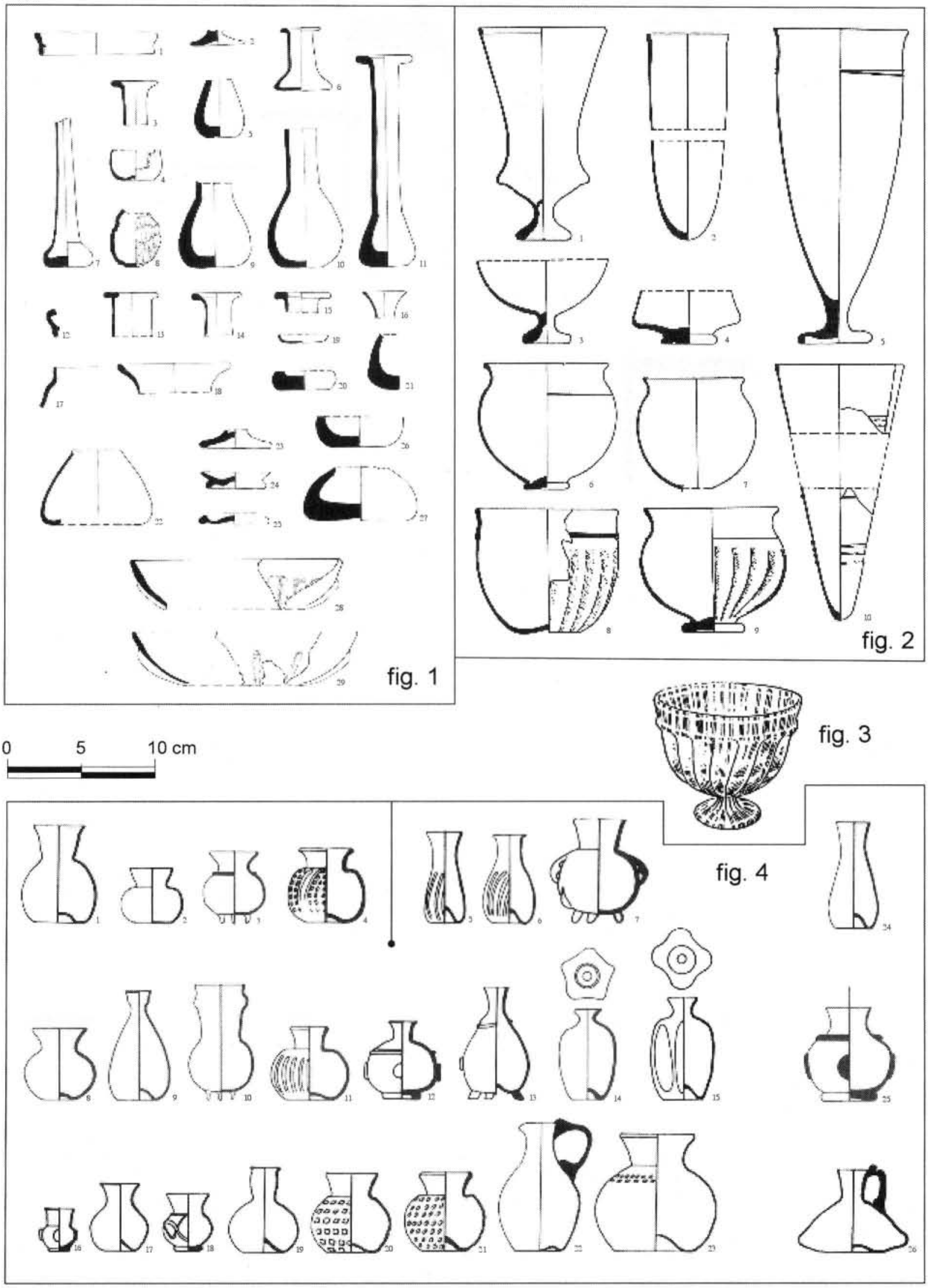

FIG. 1 Seleucia, glassware, C1st–2nd, 1–11 vessels from graves, 12–27 fragments from the Archives area; FIG. 2 Veh-Ardashir, glassware, 1, 4–9 C4th, 3 second half of C4th, 2, 10 C5th; FIG. 3 Khynysly (Caucasian Albany), glass bowl, C5th; FIG. 4 Umm Kheshm, glassware, 1–4 grave 1 sounding 29, 5–7 grave 1 sounding 32, 8–15 grave 8 sounding 24, 16–23 ?grave 20 sounding 21, 24–6 glassware from graves 3, 5 and ?73 of sounding 21

without major changes till the 5th–6th century AD levels. Deep bowls decorated with reworked mould-blown ribs were common in other areas of the Sasanian Empire too, as possibly also were some heavy variants of the stemmed goblet. Examples include that found in Caucasian Albany (FIG. 3), in a 5th-century AD grave belonging to a cultural phase in which the local aristocracy was under early Sasanian influence (Khalilov 1962, 217, fig. 6.4); and a stemmed goblet of Iranian provenance in the Victoria and Albert Museum, London (Accession no. C 47-1069) decorated with pinched ribs as on the Veh-Ardashir bowls. This also finds parallels among other pieces from Amlash and Gilan in Iran.

The same range of glassware was also widespread in northern Mesopotamia in the middle of the 3rd century, as it was found in early Sasanian graves at Yorgan Tepa near Nuzi. Here the surface of the mound was occupied by a cemetery cutting a late Parthian level with a large building associated with coins of Volagases III (*c.* AD 152) (Erich 1939, 569, pl. 140.J, K, M, N, O, P). One of the graves contained a plain deep bowl with vertical sides, associated with a coin of Shapur I, very similar to a fragmentary bowl also associated with a silver coin of Shapur I in Tell Mahuz. There, a large cemetery with Sasanian coins from the 3rd to the 4th century AD produced rich funerary furnishings including a high percentage of early Sasanian glassware (Negro Ponzi 1968/69). The Tell Mahuz series exactly corresponds to the earliest stage of Veh-Ardashir glassware, with which it shares both typological and production characteristics.

A change in the production range occurred again in Mesopotamia between the late 5th and the 6th century AD. The new types, which were to become peculiar to the late Sasanian period, such as the hemispherical bowls with deep-cut facets well known both in Mesopotamian and Iranian glassware collections, appear in Veh-Ardashir in 5th to early 6th-century levels and continue until the early Islamic period.

There also existed another glassware range in Mesopotamia between the late Parthian and the early to middle Sasanian periods, of which no fragment has been found in Seleucia or Veh-Ardashir layers. Two sites not far from each other, Abu Skheir and Umm Khesham in the south-eastern area of Hira, in central Mesopotamia, have on the contrary revealed cemeteries rich in this peculiar glassware. Hira, the capital of the Arab dynasty of the Lakhmids, was founded in the 2nd–3rd century AD and was abandoned in the 7th century. This was partly due to political troubles; and partly due to the shifting of the branch of the Euphrates on which its harbour had been constructed to which, from the 4th to the 6th centuries, ships from China and India had come. The settlements to which the Abu Skhair and the Umm Khesham graves belonged have not been identified, and their ancient names are unknown. However, the latter might have been a village quoted in the Arab sources as having been destroyed during the Arab conquest because its inhabitants were settled Christian Arabs – the position of which had already been forgotten at Tabari's time (end of 9th–10th century AD).

Many years ago I proposed a Parthian date for the Abu Skhair glassware on the grounds of its assumed association in the Directorate General's Report with the furnishings of a single grave group, among which were typically Parthian glazed and unglazed pottery vessels (Negro Ponzi 1972). However, later excavations have demonstrated that both the Abu Skheir and the Umm Khesham cemeteries consisted of separate grave groups, each one with a single or prevailing grave type. The pottery came from glazed coffins of Parthian type or simple ditch graves with a side chamber, where it was never associated with the glassware by then dated to the Sasanian period (Al-Shams 1996, 45, n. 18–19; Abdul-Khaliq 1976, 117, n. 3). The graves belonged in general to long-lived types found both in Parthian and early Sasanian sites, but those with richer furnishings of glassware were always ditch graves sealed by a row of large 'torpedo' jars laid flat over the burial or by two-part pottery covers similar to up-turned coffins. The first type has been found in Seleucia and Hatra in Parthian levels, but it was also used in the later Arab cemeteries; while the second one has no published parallels in other Mesopotamian sites, and the main chronological references are its furnishings. At both sites, most of the glass vessels were small plain or ribbed jars, which were often associated in the graves with arm-rings and anklets in iron or copper, beads, wood sticks for kohl and small painted plaster-set round mirrors (Al-Haditti 1995; Al-Shams 1996). Some Umm Khesham graves also contained jars with applied round pellets or interlaced trailed coils, which were absent among the Abu Skhair furnishings.

A similar range of small glass containers associated with personal jewellery and plaster-set mirror plaques has been also found in funerary contexts at another Mesopotamian site, Tell Mohammed 'Arab in northern Mesopotamia (Roaf 1984). Its cemetery consisted of 71 graves of the ditch type with side chamber. This is a very unusual burial type in northern Mesopotamia, but similar to one of the types of Umm Khesham, which at least in part dated to the Parthian period from associated pottery. The graves of Tell Mohammed 'Arab did not offer precise dating elements, but a silver coin of Shapur I was found on the surface of the mound and three Sasanian seals were deposited in the graves, one of them with a *pahlavi* inscription. This suggested to the excavators a chronological horizon in the 4th century AD, possibly lasting to the 6th century AD; belonging therefore in the same period of the Umm Khesham settlement.

Chronological horizons

The late Dr Majid al-Haditti, director of the Umm Khesham excavations, published the glassware in his preliminary report as a typological catalogue, with a single example for each type. However, as the plates maintained the original provenance label in Arabic for each vessel, I have tried to reconstruct the grave associations of the published vessels and set up an initial chronological framework by means of cross-referencing the provenance areas, the grave groups and the dated parallels of the glassware types in other Mesopotamian sites. The results are as follows.

- A chronological horizon of 1st–2nd century AD for the glazed coffins and ditch graves with side chamber, which contained Parthian pottery, but no glassware both in Abu Skhair and Umm Khesham.

• A chronological horizon of late 2nd–3rd century AD, i.e. from the late Parthian to the early Sasanian period without a significant division between the two phases, for saddle-roofed graves in baked bricks and simple ditch graves, with furnishings of small plain jars. The same horizon has ditch graves with 'torpedo' jars over the burial. In both cemeteries these had rich furnishings of plain and ribbed small jars with squat bodies.

• A chronological horizon in the 3rd–4th century AD, from the early Sasanian to the middle Sasanian period, for the graves with two-part pottery covers, which contained rich furnishings on both sites, some of which including several glass vessels. One of the commonest types (FIG. 4. 11) were small jars with a ribbed expanded body and rounded or horizontal shoulder (Negro Ponzi 1972; Al-Shams 1994). These find parallels in Mesopotamia in a few glass vessels from ditch graves superimposed on a Seleucid funerary mound in Uruk-Warka. The vessels might have been an early variant, dated by German scholars to the late 2nd–3rd century AD (Van Ess 1992). Other jars of similar type were decorated with mould-blown patterns, dated in the Syro-Palestinian area to the 3rd–4th century AD (FIG. 4.4, 20–1). Some small flasks had a peculiar shape, with a tall cylindrical neck with a fold under the rim and three pulled-out feet (FIG. 4.10), and a few small jars were decorated with prunts on the body. Both types were found in Abu Skhair only (Negro Ponzi 1972; Al-Shams 1994); but the latter type is paralleled both in Iran (Fukai 1977), and in a group of glass vessels, which also contained a small ribbed jar, found in a Yemenite grave in the al-Jauf area (Robin and Vogt 1997, 209; Simpson 2002, 136–7). This has been tentatively dated on typological grounds to the 2nd–3rd century AD. However, another grave in the same Yemenite area, also assigned to a 2nd–3rd century date, contained a low bowl with deep-cut faceted decoration, which has now been recognized as a late Sasanian product (Simpson 2000, 66, n.5; 2002, 101, no. 118).

• A chronological horizon of 4th–5th century AD, for (ditch?) graves with prevailing furnishings of a single glass vessel. The glassware types still include small jars and small flasks, some of them decorated with applied coils and/or round pellets. These decorative techniques, found only on the Umm Khesham vessels (FIG. 4.12–13, 16, 18), are rare among published Mesopotamian finds. Jars of both types, however, were found together in a ditch grave in Babylon (Reuther 1926, 263, Taf. 95:233), dated at the time to the late Parthian period together with a neighbouring ditch grave. In contrast, this included Sasanian furnishings: a glazed amphora, a small glass bottle with ribbed body, exactly similar to 4th to 5th-century bottles of the same type from Veh-Ardashir, and a brown purple glass cone with faceted decoration (Reuther 1926, Taf. 95:234), which finds close parallels in south Russian grave furnishings of the second half of the 4th century AD (Likhter 2000). Glass jars with trailed coils and applied pellets have also been found in Iran (e.g. Kordmahini 1994, no. 69), as well as in Bahrain, where a small bottle with applied pellets, a small jar with interlaced applied coil on the body and a small jar with pulled-out pinching in herringbone pattern have been found in a single funerary area, the al-Maqsah cemetery, locally dated from the 5th to the 7th century AD (Boucharlat-Salles 1989; Nenna 1999, 191, nos 304–6). The latter jar, with its very rare pattern, was found, however, both in Umm Khesham (FIG. 4.7) and in Abu Skhair, where it was associated with a Sasanian seal attributed to the 4th century AD (Al-Shams 1994), and it was still in use in the late Sasanian period (Whitcomb 1985, fig. 58, from Qasr-i Abu Nasr, in Iran).

The Umm Khesham cemetery also had a late Sasanian phase, possibly with ditch graves, but no glass furnishings can be associated with it on the grounds of the Report data.

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SASANIAN GLASS FROM NINEVEH

ST JOHN SIMPSON

INTRODUCTION

The exceptional survival of complete faceted glass bowls in Far Eastern treasuries and tombs, and the appearance of hundreds of vessels via the Iranian art market has excited public interest in Sasanian glass since the 1960s. However, there have been remarkably few archaeological studies or even catalogues of this material. The principal sources which now enable a preliminary classification are the archaeological sequence from the city of Veh Ardashir (Negro Ponzi Mancini 1984; Negro Ponzi 1987; 2002), groups from smaller sites such as Tell Mahuz, Kish, Nippur and now Kush (Negro Ponzi 1968/69; Meyer 1996; Moorey 1978, 122–46 and fiche; Price and Worrell 2003), pieces from independently dated Far Eastern contexts (e.g. An Jiayao 1987) and, for typological purposes, authenticated objects known from the art market (e.g. Fukai 1977).

THE SITE OF NINEVEH

The material presented here comes from the site of Nineveh which is located on a major crossing of the river Tigris opposite the city of Mosul in northern Iraq. This settlement fell under Sasanian political control after the Roman ceding of this province to Shapur II (309–379) following the defeat and death of Julian in 363; thenceforth, until its capture in 637/38 or 641/42 by an Arab army probably commanded by 'Utba bin Farqad, Nineveh flourished as an important town, bridgehead and fortress (Simpson 1996). The site has been excavated intermittently since 1842 (Reade 2000). Although the primary focus of these investigations were the palaces and temples of the Late-Assyrian citadel on the mound of Kuyunjik, all of the excavators commented on the depth of later occupation, and a representative proportion of the finds are in the British Museum and other collections. These include a considerable amount of Hellenistic, Parthian, Roman, Sasanian and Islamic material, and although much lacks any clear stratigraphic context and full quantification is impossible, Nineveh nevertheless provides one of the largest excavated assemblages of these periods from northern Iraq (Simpson forthcoming a). As salvage excavations of rural sites in this region during the 1980s produced relatively little glass, and the prospect of resuming archaeological fieldwork in Iraq looks increasingly grim, the value of old collections is enhanced if we are to gain any insights into the circulation of glass in this region.

The excavated material relating to Sasanian Nineveh consists of plain, mould-blown, reblown and cut glass, plus a number of identifiable and possible late-Roman imports. Some forms are typical of the published Sasanian repertoire, yet others are more unusual. Although only a small proportion of the original excavated finds were exported to Britain, the mistaken assumption by the 19th-century excavators that all of the glass was Late Assyrian, and thus considered remarkably early, probably ensured that a reasonably representative selection was made. Apart from areas of Sennacherib's and Assurbanipal's palaces in the south-west and north-east portions of Kuyunjik, most of these excavations consisted of tunnelling below the later stratigraphy and thus many of the late-period finds probably derive from these two parts of the site. Later and more extensive area excavations conducted between 1927–1932 in the intervening areas of the Temples of Ishtar and Nabu in the centre of Kuyunjik hint at the existence of a regular Partho-Sasanian architectural plan with mud-brick buildings on stone footings, and one or more cobbled streets measuring some 3m across (Thompson and Hamilton 1932, pls xci–xcii). They also produced 'fragments of some hundreds of vessels but only a few of the types can be completely restored' (Harden 1933, 184); some 267 fragments from the 1927/28 season are held in the Ashmolean Museum and were the subject of a pioneering analysis by Harden (1932; 1933). However, his manuscript was never published in full; and as it was completed before further excavations at other sites in Iraq and Iran had demonstrated the existence of a distinct Sasanian glass industry, the Sasanian glass was almost entirely subsumed within his so-called 'Early Arab' category. Absolute depths below arbitrary datum were recorded by the excavators for some of these objects, but more helpful or precise contextual information is unfortunately lacking in either the excavation records or the published accounts. External parallels are therefore used to suggest likely dates in this preliminary study.

PLAIN BLOWN GLASS

These consist of bowls, stemmed goblets, double-tube *unguentaria*, and a variety of small closed vessels, or so-called *unguentaria*. The first category is represented by several bases with high push-ups and unfinished pontil-marks (FIG. 1. 1–2). Similar bases recur in some numbers in Late-Sasanian domestic contexts at Kish (Harden 1934,

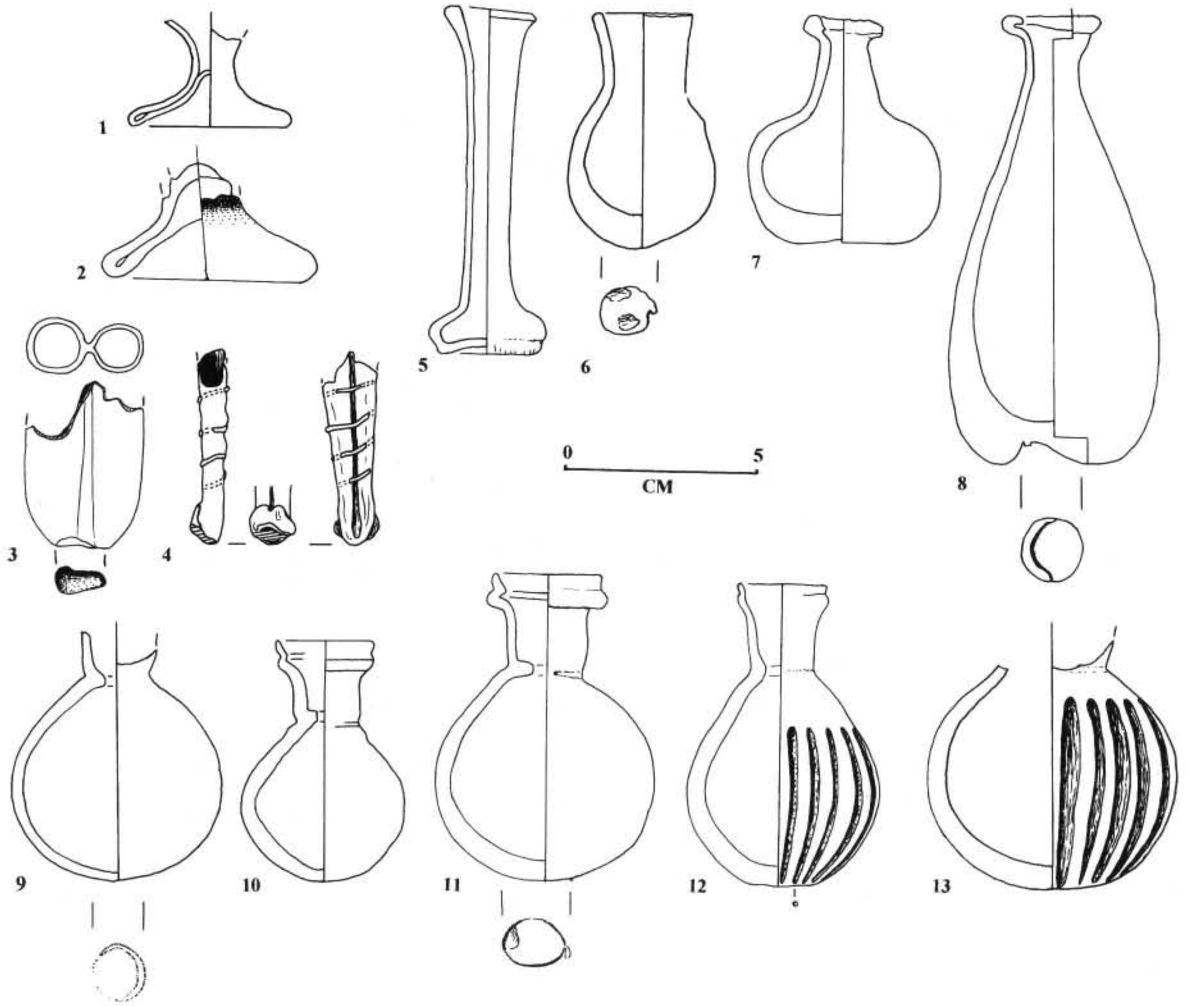

FIG. 1 Sasanian plain, trailed and mould-blown reblown glass from Nineveh

fig. 5.16; Moorey 1978) and Tell Abu Sarifa (Adams 1970, pl. 7, fig. 15.J2). The heavy weathering which characterizes Sasanian glassware is presumably responsible for the non-preservation of the walls or rims, but the sequence at Veh Ardashir suggests that these may have belonged either to plain stemmed goblets or to chalices (Negro Ponzi Mancini 1984, 34–5, figs 2.1, 3; Negro Ponzi 1987, 268, fig. B.type F).

At least four fragmentary double-tube *unguentaria* are also represented from excavations on Kuyunjik (FIG. 1.3–4), and a fifth was found in Iraqi excavations in the area of the presumed lower town and/or cemetery to the south (Abdul-Khaliq 1972, 49, pl. iii.20). The weathered fabrics, smaller size and finer threads suggest that these may be locally produced copies of the better-known Syro-Palestinian type. Other double-tube *unguentaria* have been excavated in graves at Abu Habba (al-Jadir and Abdullah 1988, pls 5.6, 18.3), Tell Mohammed 'Arab (Roaf 1984, 143, pl. xie) and Qasr-i Abu Nasr (Whitcomb 1985, 154, 156–7, fig. 58i), which confirms the wider circulation of this form in Mesopotamia and southern Iran.

A greater variety of small closed containers are represented at Nineveh. These included a small plain *unguentarium* with a tall neck (FIG. 1.5). This form represents a development from a type which began in the 1st or 2nd century AD and occurs throughout the Veh Ardashir sequence (Negro Ponzi 1966, 87, fig. 34; Negro Ponzi Mancini 1984, 37, fig. 1.9, 18–20); it is commonly found at other sites in Mesopotamia, including funerary contexts, namely at Babylon (Reuther 1926, I, 263–4, pl. 95), Tell ed-Der, sounding B (Gasche 1971, 47–8, pl. 29.1), Tell Gubba (Ii 1989, 189, 221, fig. 23, pl. 44, nos 115–17), Tell Mahuz (Negro Ponzi 1968/69, 318–25, figs 153, 158, nos 5–15), Nippur, Hill I (Peters 1897, II, 394, pl. VIII.4), Tell Songor, mound A (Kamada and Ohtsu 1988, 170, fig. 17, pl. 53, nos 5–15), Warka (Strommenger 1967, 34, Taf. 47.1), and Yorgan Tepa (Ehrich 1939, 548–9, pl. 140.k).

Other miniature containers included a small plain *unguentarium* with lightly flaring neck and pontil-mark (FIG. 1.6), which is one of the commonest types of excavated Sasanian glass in Mesopotamia (Negro Ponzi Mancini 1984, fig. 1). A single small plain green *unguentarium* with a folded-in lip (FIG. 1.7) again belongs to a type found at sites across Mesopotamia (e.g. Negro Ponzi Mancini 1984, fig. 1.13). Finally, a small plain bottle with a folded-in lip and off-centre pushed-in base (FIG. 1.8) belongs to a type first reported from Susa and which Lamm (1931, 361, pl. lxxv.4) suggested was a Late-Sasanian type influenced by

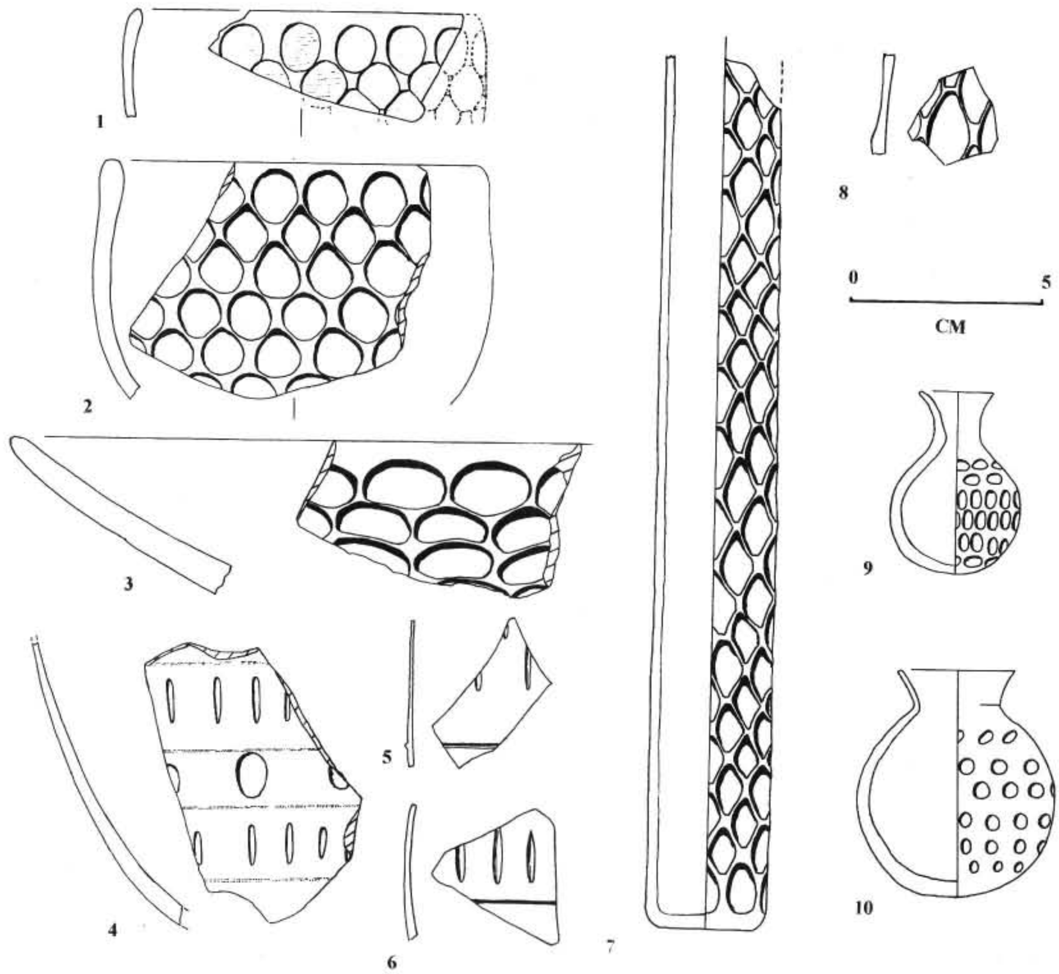

FIG. 2 Sasanian cut glass from Nineveh

Syrian production; examples have since been recognized from Abu Habba and Tell Bismaya in central Iraq.

MOULD-BLOWN REBLOWN GLASS

Small pear-shaped bottles with neck diaphragms and exceptionally thick walls belong to one of the most characteristic, yet least well known, types of Sasanian glassware. They occur throughout the Veh Ardashir sequence, and are represented at a large number of other sites in Mesopotamia (Negro Ponzi 1987). Both plain (FIG. 1.9–11) (Thompson and Hamilton 1932, pl. lxvi.35) and vertically ribbed types are represented at Nineveh (FIG. 1.12–13) (Thompson and Hutchinson 1929, pl. lvi.327; 1932, pl. lxvi.36). These vessels were made by blowing the paraison into a small wooden, clay or plaster mould; their pincered constrained necks were clearly designed to enable secure stoppers and the highly controlled sprinkling or pouring of liquid contents: measured capacities of several complete examples vary from as little as 20 or 30ml to as much as 110ml.

CUT GLASS

The cut glass belongs to six different forms, the first of which consist of fragments of small and medium-sized hemispherical bowls with fire-polished rims and overlapping rows of circular facets on the exterior (fig. 2.1–2). They either have a light-brown fabric which is typically covered with a thick opaque dark grey enamel-like weathering layer, or have a light-green fabric with white or yellowish weathering. They belong to a well-known type of Late-Sasanian cut glass now dated to the 6th and 7th centuries (Negro Ponzi 1987, 270–2, fig. C.types P–Q), a dating supported by evidence from Ctesiphon (Puttrich-Reignard 1934, 39), and Urbnisi in Georgia (Chilashvili 1964, 119, fig. 53). Bowls of this form reached as far east as the tomb of Ankan (d. 535) and the treasury of Shomu (d. 756) in Japan; those examples which have been measured have capacities of 290–380ml, thus broadly comparable to the stemmed goblets although about half that of the tall rounded-base beakers reportedly found in graves in Gilan.

The second category is represented by a single sherd belonging to a type of shallow open bowl, originally measuring about 50mm high and 210–30mm across at the thick fire-polished rim, with flaring sides decorated with four or more rows of large deep facets cut from the bottom upwards, and originally with a single facet on the underside to ensure a secure resting position (FIG. 2.3). As is the case with most other classes of Sasanian cut-glass, no plain examples of this form are known, and indeed only a very small number of complete faceted bowls survive. These include one recently found in Yemen (Simpson 2002, 101, no. 118), a small number said to derive from the Iranian art market, and a single example set in a later Byzantine mount in the Treasury at San Marco (Buckton *et al.* 1984, 195–7, no. 26; *cf.* Simpson, forthcoming b). The heavy faceting implies a Late-Sasanian, probably 6th-century, date for this group.

Several sherds decorated on the exterior with rows of shallow cut elongated facets separated by shallow oval facets belong to rounded base beakers (FIG. 2.4–6). The date, origins and distribution of this form are uncertain, yet plain versions are known from Tell Mahuz (Negro Ponzi 1968/69, 352–5, figs 157, 161, nos 62–4), a ribbed version is represented by a number of specimens allegedly found in Gilan and which are technologically related to other mould-blown reblown Sasanian vessels (e.g. von Saldern 1980, 152–3), and a faceted variety is known from Veh Ardashir (Negro Ponzi Mancini 1984, fig. 4.4).

A further category consists of cylindrical green tubes, of which several fragmentary examples were excavated at Nineveh in the 19th century (e.g. FIG. 2.7–8). The most complete of these measures over 223.5mm in length, 30mm across, with an individual capacity of over 85ml (Layard 1853, 597; Perrot and Chipiez 1884, II, 307, fig. 191; Pinder-Wilson 1963, 34–5, pl. xvb; Harper *et al.* 1978, 157, no. 80). Only the lowermost portion of each survives, and a subtle depression marks the position of carefully ground pontil-marks on their bases. The exteriors are covered with deep overlapping facets which were cut commencing at the bottom. These containers belong to a type usually, albeit somewhat implausibly, interpreted as letter holders, and examples of which have been excavated at Veh Ardashir (Negro Ponzi 1987, 272, fig. C.type Q), Qasr-i Abu Nasr (Whitcomb 1985, 155, 158–9, fig. 59e, pl. 43, top left), Takht-i Suleiman (D. Huff, pers. comm.) and Fort 12 on the Gurgan wall (Kiani 1982, 36–7, fig. 29). They appear to date to the early decades of the 7th century, although a plainer version continues as late as the 9th century. A number of additional Late-Sasanian and Early Islamic examples are known from the Iranian art market (e.g. Overlaet 1993, 258, nos 106–7).

Another type of cut glass consists of two miniature faceted bottles (FIG. 2.9–10). These presumably functioned as perfume bottles and have capacities of 7.5 and 15ml respectively. The deliberate spacing of the facets suggests that they date to the 4th or possibly 5th century, and in one case, the facets were left unpolished. Finally, two sherds survive belonging to one or more thick-walled hemispherical footed bowls decorated with polished double circular facets (not illustrated). This probably 6th-century type appears to have been relatively scarce, and is also only represented in small numbers at Kish (Moorey 1978), Tell Songor (Kamada and Ohtsu 1988, 158–9, fig. 17, pl. 53.Gl.1), Veh Ardashir (Negro Ponzi Mancini 1984, 40, fig. 4.12–13) and Susa (Lamm 1931, 365, pl. lxxx.4).

LATE-ROMAN IMPORTS

Harden was the first to recognize these, and there are more than previously recognized from any other Sasanian site. They include lamps, open bowls with cracked-off rims and

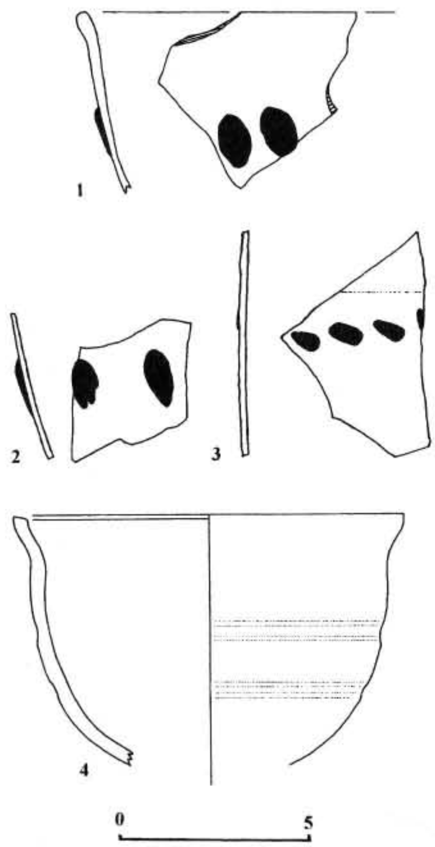

FIG. 3 Late-Roman imports from Nineveh

square bottles. Among the first category are several sherds belonging to clear vessels decorated on the exterior with regularly spaced blue prunts (FIG. 3.1–3): these are typical of sites in the eastern Mediterranean and Black Sea and probably functioned as lamps (*cf.* Weinberg 1988, 87–94, pls 4–18) and, although reported from the Iranian art market (e.g. Fukai 1977, 32–4, 50–1, pls 8.21–2; Overlaet 1993, 259, no. 108), are attested from excavation at only one other Sasanian site, namely Veh Ardashir (Negro Ponzi Mancini 1984, 34). Given their frequent association with churches and synagogues in the eastern Roman empire, it is tempting to interpret these finds as evidence of furnishings from one of the historically attested churches in the bishopric of Nineveh (Simpson forthcoming c).

Several other sherds were found belonging to wheel-abraded open bowls with a greenish tinge and cracked-off rims (FIG. 3.4). These resemble a late-Roman form found at Jalame (Weinberg 1988, 94–8) and Mezad Timar (Stern 1985), and may indeed be imports as their relatively unweathered fabrics differ from the excavated Sasanian glass. However, it should be noted that there is an equivalent Sasanian tradition decorated with cut facets, of which examples are known from Tureng Tepe in Iran (Boucharlat and Lecomte 1987, 173, pls 99.6, 156b; Fukai 1977, 29, 40–1, figs 14–15, pls 6–7), eastern Arabia (Zarins *et al.* 1984, 42, pl. 50.10), and Hwangnam Daech'ong in Korea (Whitfield 1984, 93, no. 84). Caution should therefore be paid to ascribing an origin for these plain versions without further analysis (*cf.* also Fukai 1977, pls 6–7; Grose 1978, 4, fig. 24; Harper *et al.* 1978, 154; Overlaet 1993, 262–3, nos 111–12).

CONCLUSIONS

The range of glassware at Nineveh appears to be generally representative of Sasanian urban or other important residential sites in Mesopotamia. It is not known where the Sasanian glass was manufactured, but it was most probably imported from central Iraq where there is archaeological evidence for large-scale glass production. The types include open bowls and goblets or chalices probably used for drinking, and a variety of small plain or ribbed bottles which surely represent the discarded packaging of a perfume industry. These bottles are ubiquitous in Mesopotamian graves but in this case derive from a settlement context. As Theophylact Simocatta (*History* V.5.8) describes 'drenching' Persian banqueters 'with perfume' prior to holding the final toasts, these objects might even be regarded as an essential household item. There are, in addition, certain specialized forms, such as long tubes and lamps, which excavations suggest are exclusively found in non-funerary contexts either in Iran or Iraq. The occurrence of the heavily faceted glassware confirms the circulation of this at the far western end of the Sasanian empire, although it has not yet been reported from eastern-Roman contexts (and thus, like Sasanian silverware, may not have found favour there). However, some degree of (apparently one-way) commercial interaction is indicated by the presence of some late-Roman pieces. In contrast, the plain stemmed goblets, bowls with cracked-off rims, double-tube *unguentaria* and lamps circulated in Sasanian Mesopotamia and the eastern Roman empire alike, but here appear to reflect eastern versions of Roman types; these types have not yet been reported from excavated sites in highland Iran which supports the impression that glass did not circulate evenly within the Sasanian empire and underlines the necessity for caution when citing unprovenanced parallels. Finally, the heavy enamel-like opaque weathering which characterizes most of the material is typical of excavated Sasanian glass, and differs from the minimal weathering on the late-Roman pieces from the same site. Future analysis of the glass from other periods is expected to enable a longer-term perspective on these patterns of distribution and consumption of material culture at Nineveh.

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THE LATE ANTIQUE WORLD

THE PRODUCTION OF HIMT GLASS: ELEMENTAL AND ISOTOPIC EVIDENCE

Ian C. Freestone, Sophie Wolf and Matthew Thirlwall

Introduction

Sometime late in the 4th century or early in the 5th century AD, a new glass composition became widespread in Europe and the Mediterranean regions. Typically transparent and yellowish green to deep olive in colour, as opposed to the more bluish green glass typical of the Roman world in the preceding period, it was termed HIMT, for its (then) unusually high iron, manganese and titanium contents (Freestone 1994). The same compositional type was isolated by Mirti *et al.* (1993) as the 4th-century component of the Roman glass assemblage from Aosta and it has been identified as a distinctive glass group by Foy and co-workers (e.g. Foy *et al.* 2003, group 1).

The apparently sudden introduction and widespread occurrence of this glass type may be indicative of a substantive change in the location of primary glass production, and hence may reflect a change in regional political or economic factors. Alternatively the colour change might reflect a change in taste of the consumer.

Here we outline the compositional characteristics and occurrence of HIMT glass and provide some indicators as to its possible origin.

Composition

Major elements

Representative analyses of HIMT glass are provided in TABLE 1 and compared with typical Roman glass of the 1st–3rd centuries (Jackson *et al.* 1991). HIMT is a soda-lime-silica glass with potash and magnesia each below 1.5%, indicating that the alkali used in its manufacture was mineral soda. Even so, it is readily distinguished from earlier glass by, for example, its higher magnesia content (FIG. 1). Lime contents are relatively low for Roman glass, typically in the range 5–6.5%, while soda is at the high end of the range for Roman naturally coloured glass, usually from 17–20%. However, the key diagnostic features of this glass group are the oxides of iron, magnesium, manganese and titanium which are not only significantly higher than

TABLE 1 Examples of glass compositions; Leicester mean from Jackson *et al.* (1991)

	C1st–3rd Leicester *n=75*	HIMT London *n=14*	HIMT Carthage *n=1*
SiO_2	NA	66.38	64.77
TiO_2	0.10	0.33	0.68
Al_2O_3	2.33	2.47	3.18
FeO	0.60	1.15	2.07
MnO	0.26	1.90	2.66
MgO	0.55	0.92	1.29
CaO	6.43	5.99	5.24
Na_2O	18.4	18.54	18.74
K_2O	0.69	0.57	0.44

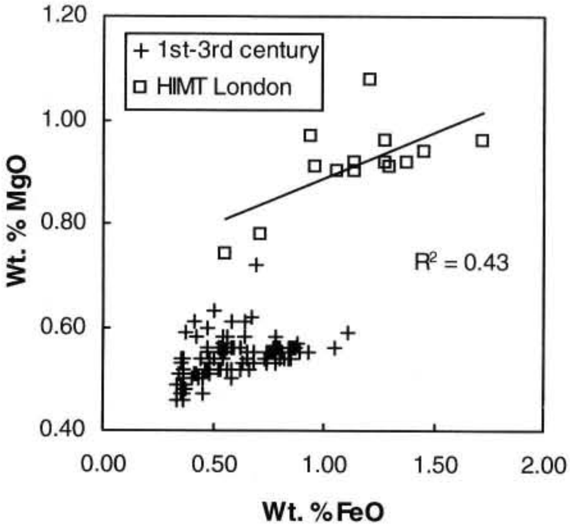

FIG. 1 Magnesium and iron oxide contents of HIMT glass from Billingsgate bath-house, London, compared with 1st–3rd century Romano-British glass from Leicester and Mancetter, taken from Jackson (1994)

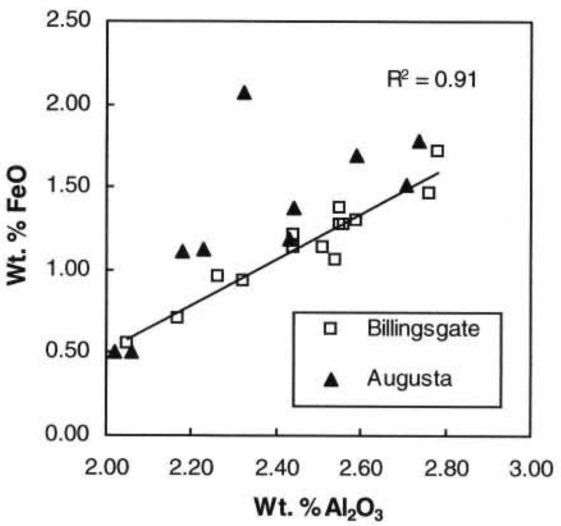

FIG. 2 Correlation between iron and aluminium oxides in HIMT glass. Filled symbols from Augusta Praetoria (Mirti *et al.* 1993), open symbols and trendline from Billingsgate, London

those of earlier Roman glass but strongly intercorrelated and also correlated with aluminium oxide, which shows an unusually large spread from just below 2% to just over 3% (FIG. 2).

Glass showing the characteristic elemental features of HIMT has been identified from Billingsgate bath-house, London (this study), Carthage (Freestone 1994; Foy *et al.* 2003), France (*ibid.*), Cyprus (Freestone *et al.* 2002a), Italy (Mirti *et al.* 1993; Verità 1995; Freestone *et al.* 2002b; see also Arletti *et al.* this volume), and Egypt (Freestone *et al.* 2002b; Foy *et al.* 2003).

Trace elements

In terms of its trace element composition, HIMT glass is typically characterized by high concentrations of high atomic number elements relative to, for example, the blue green glasses of the Levantine coast. Zirconium and, in particular, barium are not only elevated but also very variable (Mirti *et al.* 1993; Freestone *et al.* 2002a; Foy *et al.* 2003). The pattern of the light rare earths is similar to that of Levantine glass, however, although the absolute concentrations are higher (Freestone 2003).

Strontium and lead isotopes

Strontium and lead isotope compositions were determined by thermal ionisation mass spectrometry at the University of Oxford (lead) and Royal Holloway University of London (strontium). The glasses analysed for lead are not deliberately coloured and following Wedepohl and Baumann (2000) the lead is believed to be characteristic of the glassmaking sand. The lead isotope ratios of the group show a wide range, between $^{206}Pb/^{204}Pb$ = 18.4 and 18.9. $^{206}Pb/^{204}Pb$ shows a strong positive correlation with the variations in FeO, MgO, MnO, TiO_2 in the glasses (FIG. 3). The trends for lead versus metallic oxide for glasses from sites as diverse as Carthage, Billingsgate bath-house (London) and North Sinai are coincident, and this provides important support for the grouping together of the HIMT glass from these locations on the basis of their elemental analyses. The spread of lead isotope compositions is much greater than for a typical lead ore body.

While Sr is at around the same level in all of the glasses, $^{87}Sr/^{86}Sr$ is strongly correlated with their elemental compositions, being negatively correlated with FeO and Al_2O_3 but positively correlated with CaO (FIG. 4).

Discussion

Glass raw materials

HIMT glass is likely to have been produced from a mixture of sand with soda, such as that from Wadi el Natrun in Egypt, and its composition was largely controlled by these two components. However, manganese contents are high; for example, MnO/FeO for typical HIMT glass is commonly around 1.0, but averages 0.015 in the Earth's crust (Wedepohl 1995). Thus manganese was an intentional addition to the glass, which is normally considered to indicate its use as a decolorant (Sayre 1963).

The strong correlations observed indicate that HIMT is a mixture of two components: (1) a component rich in FeO, TiO_2, Al_2O_3, MgO and MnO, with high $^{206}Pb/^{204}Pb$ of *c.* 18.9 and with low $^{87}Sr/^{86}Sr$ of around 0.7080, and (2) a component with higher CaO, lower $^{206}Pb/^{204}Pb$ of *c.* 18.4 and higher $^{87}Sr/^{86}Sr$ at 0.7089. From general principles (Wedepohl and Baumann 2000; Freestone *et al.* 2003), the higher $^{87}Sr/^{86}Sr$ of (2) is close to that of Holocene ocean water, and indicates that the lime in this component was probably derived from shell. The strontium isotopes of component (1) on the other hand suggest a source for the lime other than modern marine shell. A potential source of this strontium is ancient limestone. Alternatively, the strontium in this end member may not be dominated by calcium carbonate but by other minerals, for example, silicates derived from volcanic rocks. Such a source would be broadly consistent with the enrichment in alumina and ferromagnesian components suggesting the presence of minerals such as feldspars, clay minerals and silicates such as pyroxenes and amphiboles, as well as the lower lime content, suggesting a reduction in calcium carbonate.

The two components of HIMT glass are therefore considered to be a beach or marine sand on the one hand and a sand relatively enriched in non-marine material on the other.

Mixture of what?

The two-component mixture of HIMT glass can be explained in one of two ways. On the one hand it might represent a naturally occurring mixture of sand particles originating in two geological source areas, for example in an estuarine environment, where fluvially transported sediment can mix with marine sand. The sand selected for each batch of glass would have unpredictable levels of iron, magnesium oxides etc. In such circumstances, the glassmakers would have added similar quantities of soda and manganese to the full range of sands. In this case no correlation of sodium and manganese oxides and other glass components would be expected.

An alternative possibility is that HIMT is a mixture of two glass types. The glasses at each end of the mixing trend

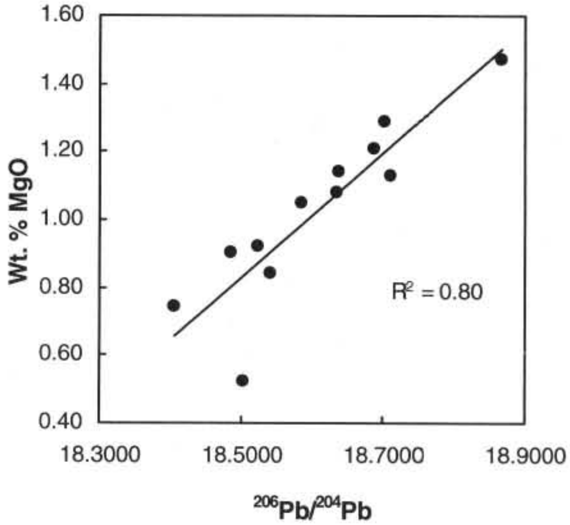

FIG. 3 Correlation of magnesia and lead isotopes in HIMT glasses from Carthage, North Sinai and Billingsgate

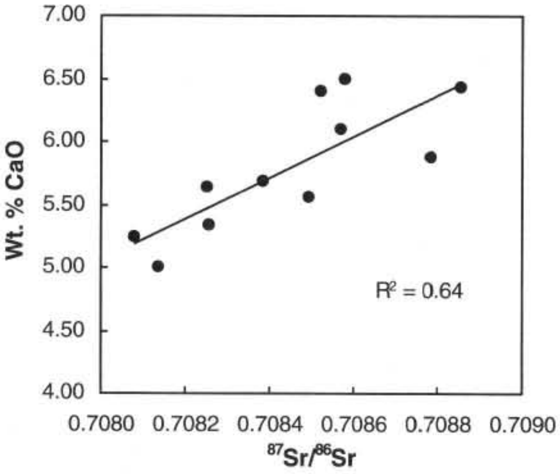

FIG. 4 Correlation of lime and strontium isotopes in glasses from Carthage and North Sinai

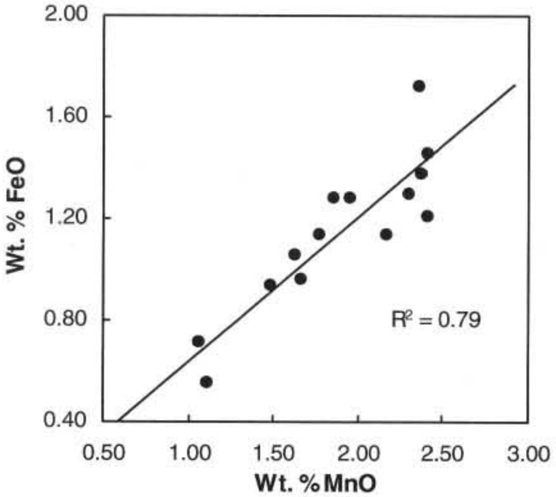

FIG. 5 Correlation of iron oxide and manganese oxides in glasses from Billingsgate bath-house, London

may in this case be expected to have different sodium and manganese oxide levels. FIGURE 5 shows manganese *versus* iron oxide levels for HIMT glass from Billingsgate bath-house, London. There is a strong correlation (R^2=0.79), indicating that the HIMT trend is the result of mixing two glasses. A negative correlation between Na_2O and FeO in these glasses supports this interpretation.

Mixing of glass compositions is a normal consequence of recycling broken vessel glass (cullet). However, the HIMT group is not easily explained in this way. In assemblages where vessels made of HIMT glass have been recovered with vessels of other compositions, for example with Levantine Type 1 glass, as on Cyprus, in North Sinai, and in Rome (Freestone *et al.* 2002a; 2002b; *cf.* Verità 1995), the two groups remain discrete, with limited intermixing, if any. If HIMT was the result of recycling cullet, then intermixing of the two end members with other glass types would be expected. In addition, the elevated levels of colorant and opacifier elements, such as copper, lead and antimony, which are commonly a characteristic of recycled glasses (e.g. Jackson *et al.* 1996; Mirti *et al.* 2000; Freestone *et al.* 2002a) are not observed in HIMT glass. Thus reuse of cullet does not readily explain the characteristics observed. The model which best explains the observed behaviour would appear to involve the mixing of primary chunk glass.

HIMT glass appears to have been formed by the mixing of chunk glass of two distinct compositional types, one produced from sand in which the strontium was predominantly derived from marine shell and the other in which the strontium was from a non-marine source. However, a production process which involves the mixing of two primary glasses, to the exclusion of glasses from other production centres, strongly implies a close proximity of the furnaces producing the glasses being mixed. If this were not the case, then the exclusive relationship between the two end-members could not be maintained.

Possible sources

From the foregoing, it would appear that a near coastal region is the most likely source of HIMT glass. Here, beach sands, or possibly sand from a raised beach, may co-locate with sand contaminated by fluvially transported material having a distinctive elemental and isotopic signature, for example in the vicinity of an estuary, or in a lagoon.

The geographical source of HIMT glass can only be speculated on at present. Foy *et al.* (2003) suggest an Egyptian origin for their group 1 (essentially HIMT glass) on the basis of the high titanium content, which is common to glass from Egyptian sources. Several lines of evidence appear consistent with this view. Firstly, the lead isotope composition of the low-iron (marine strontium) end-member is close to the mean lead isotope composition of Mediterranean sediments (Wedepohl 1972), so is consistent with Mediterranean beach sand. Interestingly, unpublished data by us show that Byzantine glasses from the Levantine coast are similar in lead isotope composition. In addition, the low $^{87}Sr/^{86}Sr$ ratio of the high-iron end-member is consistent with a strontium source dominated by the Tertiary limestones of North Africa or by (carbonate-free) particulate matter from the Nile, which in the Delta has $^{87}Sr/^{86}Sr$ in the region of 0.707 (Krom *et al.* 1999). The light rare earth elements in HIMT glass show a similar pattern to those of glass from the Levantine coast, as has been shown (Freestone 2003, fig. 4). This is consistent with the suggestion that the ultimate sources of the sands used to make these glasses were similar, as would be expected from the sands derived from the Nile, which supplies sediment round the south-eastern coast of the Mediterranean, as far north as the Bay of Haifa.

There are other, more general arguments that can be used to argue an Egyptian origin for the HIMT group. First, the glasses have high soda contents relative to most Roman glass, suggesting that natron was a relatively inexpensive commodity and that the Egyptian natron deposits were relatively accessible. HIMT glass is more abundant in Egypt (North Sinai) than in northern Israel, suggesting an origin in the south. Finally, the complex Egyptian coastline would appear to provide the type of environment envisaged from the elemental and isotopic evidence, where sandy material with a strong terrestrial component might be juxtaposed with marine beach sands.

The suggestion that HIMT glass is ultimately an Egyptian product is, of course, speculative, and to a certain extent driven by current understanding of glass production in Late Antiquity, where all of the primary production centres so far discovered are located in North Africa or Syria-Palestine. However, it appears to fit most of the information available.

Technology

Current technological models for primary glass production focus upon the large tank furnaces of Palestine, where in the order of eight tonnes of glass were melted in a single firing. However, although a number of primary glass production centres have been located in Egypt (Nenna *et al.* 2000), the technology may not have been identical as similar remains of tank furnaces have yet to be reported. Attention is drawn to the work of Saleh *et al* (1972) at the Wadi Natrun, and the possibility that in this region raw glass was made in large pots. If HIMT glass represents, as suggested above, a mixture of chunks of primary glass made from two different sands, then its characteristics would be easier to explain if batches were produced on this scale, as smaller batches would be more likely to be mixed before transport.

The role of pyrolusite, MnO_2 in glass decolouration has been considered to be to oxidise iron from the divalent Fe^{2+} state, which gives a marked blue tint to the glass, to the weaker chromophore, Fe^{3+}, which gives a virtually colourless glass (e.g. Sayre 1963; Schreurs and Brill 1984). This is clearly not the case for HIMT glass, which is commonly yellowish to olive green. According to Schreurs and Brill (1984), olive green is a very reduced colour, including contributions from both the amber ferri-sulphide chromophore and blue Fe^{2+}. Thus HIMT glass is likely to be strongly reduced, which at first sight is paradoxical, given that it contains substantial manganese oxide, an oxidising agent. The solution proposed here is that pyrolusite was not added to oxidise Fe^{2+} to Fe^{3+} and decolour the glass, but to oxidise sulphur and reduce the activity of S^{2-}. When present in small amounts, S^{2-} may produce an amber glass but under very reducing conditions it may combine with Fe^{2+} to precipitate droplets of iron sulphide, making a black glass (for iron sulphide blacks see Stapleton and Swanson 2002). Thus the purpose of MnO_2 additions in HIMT, and possibly other 'Roman' glass, may have been to prevent the glass from turning black, rather than to make it colourless.

Conclusions

The compositional complexity of HIMT glass results from the mixing of two components. One has characteristics close to those of Mediterranean beach sand, while the other is rich in TiO_2, FeO, MgO, Al_2O_3 and high atomic weight trace elements, has high $^{206}Pb/^{204}Pb$, but relatively low $^{87}Sr/^{86}Sr$. Manganese oxide may have been added to oxidise sulphur and prevent the glass turning black. A tentative production model is proposed which involves the mixing of primary glasses produced from geochemically distinctive, but geographically proximal sands. Careful study and comparison of the compositions of well-controlled assemblages of HIMT glass from sites across the late-Roman world are needed to test, modify or refine this model.

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GLAS AUS EPHESOS: HANGHAUS 1 UND EINE WERKSTÄTTE DES 6. JAHRHUNDERTS N.CHR. AUF DER AGORA

Barbara Czurda-Ruth

Die Baugeschichte der Hanghäuser in Ephesos, sicher Wohn- bzw. Amtshäuser hoher römischer Beamter und daher äußerst luxuriös ausgestattet, reicht von späthellenistischer bis in byzantinische Zeit; verheerende Erdbeben in den Jahren 23, 262 und um 360 machten umfangreiche Wieder- und Umbauten notwendig, das letzte im Jahre 612 bedeutete den endgültigen Niedergang der Stadt (Lang-Auinger *et al.* 1996 und 2003; Ladstätter 2002).

Demnach reicht das Formeninventar der über 1000 Glasfunde aus Hanghaus 1 von den sog. hellenistischen Schalen und den farbigen bzw. grünlichen Rippenschalen bis zu den frühbyzantinischen 'Leitformen' wie Stielgläser und Lampen.

Das früh- und mittelkaiserzeitliche Material zeigt im Großen und Ganzen die im Osten des Reiches bekannten Typen, aber auch einige Besonderheiten:

Millefioriglas liegt nur einmal in Form einer verbrannten Platte vor, von den fünf Fragmenten aus einfärbig opakem Glas ist ein hellgrünes rechteckiges Schminktablett erwähnenswert, wie sie vor allem aus dem Westen bekannt sind (Museum Adria MAN, IG 22039: schwarz opak und MAN, IG 80204: weiß opak; Pasaje Cobos, Tarragona: Price 1987, 67, fig. 2.7; Slg. Wolf: Stern and Schlick-Nolte 1994, 106 und 326, no. 98, fig. 202: 1.H.1.Jh.n.C.)

Farbig durchscheinendes Glas kommt vor allem bei den Hellenistischen Schalen vor (40 Stück, vorwiegend bernsteinfarben, auch blau und vielle gelbgrünlich) so wie bei den Rippenschalen, wo die Dominanz der Schalen mit kurzen Rippen der Form Isings (Isings 1957) 3c (ausschließlich in amber und gelbgrünlich) auffällt; das Verhältnis zu den Schalen Isings 3a+b beträgt 2:1. Die im Westen im frühen 1.Jh. weit verbreiteten 'Zarten Rippenschalen' Isings 17 fehlen völlig, ein Befund, der sich weitgehend mit Sardis (von Saldern 1980, 12–13) und anderen vorderasiatischen Fundorten deckt.

Besonders bemerkenswert ist eine grün durchscheinende Schale der Form Isings 12 mit figürlichem Schliffdekor, der Darstellung eines Wagenrennens (COLOUR PLATE 27): einer nach links auf die Wendemarken zufahrenden Biga folgt ein zweiter Wagen, darunter ein Streifen mit kleinen Zuschauern; der Boden zeigt Reste eines geschliffenen Sterns, umgeben von einem Kranz unregelmäßig angeordneter ovaler Facetten (Outschar and Lang-Avinger 1993, 12). Diese Schale erinnert in ihrer gesamten Gestaltung (Form, Farbe, Standflächendekor) z.B. sehr an die mit Vögeln und Blattranken bemalte Schale aus Muralto,Tessin (Biaggio Simona 1991, 62–71, pl. 3,4, figs 4, 5, 6, 35), die in spätaugusteischer-frühtiberianischer Zeit entstanden und somit ziemlich zeitgleich mit der geschliffenen aus Ephesos sein dürfte. Diese stammt aus der untersten, mit großer Wahrscheinlichkeit in die 1. Hälfte des 1. Jahrhunderts n.Chr. zu datierenden Schicht eines Brunnens. Es handelt sich daher wohl um eines der frühesten Exemplare mit figürlichem Schliff, wenn auch äußerst primitiv ausgeführt und eher eine Ritzung als Schliff. Das Motiv hält sich, wie eine Schale aus Trier in hochentwickelter Schlifftechnik zeigt, bis ins 4.Jh (Fremersdorf 1967, 173–4, pl. 233),

Der Schwerpunkt unserer derzeitigen Forschungen liegt aber auf dem ersten Nachweis einer Glaswerkstätte in Ephesos, ihrer Konstruktion, Produktion und eventuellen Verbindung mit dem späten Material aus den Hanghäusern.

In den Jahren 1997 und 2000 förderten Grabungen auf der Tetragonos-Agora in zwei Kammern einen Befund zu Tage, der auf eine glasverarbeitende Werkstätte schließen lässt (Scherrer 1998).

Die frühkaiserzeitliche Agora war an der Wende vom 4. zum 5.Jh. einer großangelegten Renovierung unterzogen worden, die dabei entstandenen kleinen Räume wurden dann bis spätestens 612 zumindest zum Teil gewerblich genutzt. In den *c.* 4 x 5m großen Kammern J und L fand sich etwas Keramik der Periode 580–620, viele kleine Bronzemünzen des 4. bis 6. Jh.s sowie an Glas eine große Zahl an kleinsten Fragmenten, Schmelzabfall, Rohglasbrocken und sieben Münzgewichte.

Die Stratigraphie zeigt drei übereinanderliegende, jeweils nur 30–50mm dicke Lehmböden, die voneinander durch ie eine bis zu 60mm dicke Aschen-Sand-Ausgleichsschicht getrennt sind, was eine Gesamtstärke von maximal 350mm ergibt. Jeder dieser Lehmböden beinhaltete eine Unzahl der erwähnten Glasreste und im Ganzen an die 900 schlecht erhaltene Minimi. Die Schlußmünzen stammen aus den Jahren 538 bis 598, was die gesamte Anlage in die 2. Hälfte des 6. Jh.s datiert.

Zum ältesten Boden gehört ein direkt an der Türschwelle aufgebauter Schmelzofen, von dem nur der birnförmige Grundriß einer durch Brand rot verfärbten Bodenplatte im Ausmaß 600 x 300mm und etwas aufgehendes Mauerwerk erhalten sind (COLOUR PLATE 28). Westlich davon und direkt über dem Feuerungsbereich im Ofennordteil breitet sich eine ausgeprägte Aschenschicht aus, der extrem viele kleine Glasstücke beigemengt waren. Spuren weiterer Öfen fanden sich laut Angabe von P. Scherrer auch in den beiden jüngeren Schichten, womit für jeden der drei Böden die Existenz eines zugehörigen Schmelzofens feststeht, was die von D. Pouille für Cesson-Sévigné konstatierte kurze Lebensdauer (maximal 30 Jahre) solcher Öfen bestätigt (Pouille und Labaune 2000, 146).

Weitere Indizien für eine Glaswerkstätte sind neben dem Glasabfall in Form von Nuggets, Fäden, verschmolzenen Gefäßresten etc. sowie den Rohglasbrocken auch ein Stück gebrannten Lehms mit Glasschlacke, das als Rest der Ofenwand oder eines Schmelztiegels gedeutet werden kann (COLOUR PLATE 29; Foy 1990), und ein weiteres gewölbtes, mit Glasfluß überzogenes Fragment, das wie der Rest einer Röhre (Glasbläserpfeife?) aussieht (COLOUR PLATE 30).

'It seems now that local workshops were built in most of the cities, at least during the Late Roman and Byzantine period to supply the daily needs of glass vessels, glass oil-lamps and windows' (Gorin-Rosen 2000, 63) und genau dieses Glas für den täglichen Gebrauch (Tafelgeschirr, Schalen, Lampen) scheint auch auf der ephesischen Agora hergestellt worden zu sein. Auch Fensterglas fand sich in vielen Fragmenten der üblichen Art in den verschiedensten Grüntönen, aber auch als Randfragmente von runden Scheiben, sog. Bull-eyes.

Für die Interpretation des Befundes sind aber besonders die in Kammer L (eines) und in Kammer J (sechs) gefundenen gläsernen Münzgewichte von Bedeutung (während es im übrigen Agorabereich nur zwei weitere gibt): sie sind alle aus hellgelbgrünlichem Glas verfertigt, fünf weisen ein justinianisches Blockmonogramm auf, zwei das Kreuz monogramm eines Johannes, ein Monogramm, das z.B. auch auf Silbergefäßen aus der Zeit des Mauricius Tiberius (597/98) bekannt ist (Feissel 1986, 138 Anm.101). Eine Münze dieses Kaisers aus dem obersten Boden 1 bildet auch die Schlußmünze des ganzen Komplexes, womit alle Gewichte in den von den Münzen vorgegebenen chronologischen Rahmen passen.

Die kleineren Gewichte, von denen vier stempelgleich sind, wiegen zwischen 1.035 und 1.8g und entsprechen daher wohl reduzierten Semisses bzw. Tremisses, während die beiden größeren Gewichte mit 4.3g ziemlich genau den reduzierten Solidus treffen (Karwiese 1998, 11).

Die Ausgabe solcher Münzgewichte oblag ursprünglich dem Stadtpräfekten von Konstantinopel, doch in Anbetracht der weiten Ausdehnung des Reiches kam es bereits unter Justinian zu einem Kompetenzkonflikt zwischen den Institutionen und damit auch zu einer teilweisen Auslagerung der Produktion in große Provinzstädte (Feissel 1986, 140–2). Haben wir hier auf der Agora für Ephesos eine solche Werkstätte gefunden? Vier stempelgleiche Stücke aus einem Raum, allerdings von zwei verschiedenen Böden, legen diese Vermutung sehr nahe. Offen bleibt vorläufig die Frage, ob und in welchem Zusammenhang die *c.* 900 Minimi damit stehen oder ob etwa Glas und Bronze im selben Betrieb verarbeitet wurden, wie es in Entremont der Fall gewesen sein dürfte (Foy 2000, 148).

Betrachten wir nun im Überblick die übrigen in Kammer J und L gefundenen Glasfragmente, von denen sich 320 durch Rand-, Boden- oder auffällige Wandbildung bestimmen ließen.

Neben drei Fragmenten von Rippenschalen, die nach ihrem Material auch als spätantik gelten müssen, und zwei dickwandigen Fragmenten früher Schalen, handelt es sich ausschließlich um Formen, die mit den anderen Befunden aus den Kammern J und L übereinstimmen. Den weitaus größten Teil machen gerundete Ränder jeder Art (*c.* 50%) aus sowie Kelchfüße (*c.* 17%), wie sie auch 'among the most frequent vessel types in Early Byzantine Sardis' (von Saldern 1980, 53: *c.* 500 Stück) anzutreffen sind. Auffällig ist, daß mit Ausnahme eines einzigen Stückes, das auch durch seinen Mittelstempel eine Sonderstellung einnimmt, alle Kelchfüße, sowohl die von der Agora als auch die 155 Exemplare aus dem Hanghaus, im Gegensatz zum gemischten Vorkommen an vielen Fundplätzen, ausschließlich die Bodenplatte mit hohlem Rand aufweisen. Meint von Saldern dazu: 'feet do not appear to have been made systematically with, or without, folded edge' und interpretiert das als Manifestation des unterschiedlichen individuellen Geschmacks des Handwerkers (von Saldern 1980, 54), sehe ich auf Grund der Homogenität unseres Materials darin eher die Orientierung nach dem Konsumentengeschmack. Lokale Varianten treten demnach auch nach 400 auf, selbst wenn im Allgemeinen eine große Uniformität der Glasgefäße, 'a rather conservative tradition in a region situated on the periphery of the mainstream of glass development' zu Lasten des Dekor- und Formenreichtum zu beobachten ist (von Saldern 1980, 36).

Auch die Farbverteilung ist von einiger Aussagekraft: von 38 zarten Stielen ohne Knopf aus Hanghaus 1 sind alle mit einer Ausnahme aus dem typischen 'syrischen' blaugrünlichen Glas (von Saldern 1980, 37), während von den mehr als doppelt so vielen Stielen mit Knopf (99) nur 18, also *c.* ein Fünftel, aus diesem Material bestehen, die übrigen gelbgrünlich in allen Schattierungen bis zu olivfarben, einige gelb oder hellblau sind. Ein Vergleich mit den Resten aus der 'Werkstätte' ist leider nur bedingt möglich, da dort kaum Bodenplatten mit Stiel erhalten sind, wo aber doch, sind Stiele ohne Knopf blaugrünlich (fünf Stück), von den anderen sind 29 gelbgrünlich und zwölf blau.

Auch ein Überblick über Material aus anderen kleinasiatischen Ausgrabungen, soweit durch Materialeinsicht vor Ort oder aus der Literatur zugänglich, bestätigt die Annahme von lokal differierenden Typen und daher wohl auch Produktionsstätten. So scheint das Glas in Aphrodisias sowohl in Qualität, Farbe als auch Formen überhaupt von anderer Beschaffenheit zu sein, während in Sagalassos neben vielem Vergleichbaren gerade bei den Kelchgläsern die selben Unterschiede wie zu Sardis auffallen: es gibt kaum Kelchstiele mit Knopf, dafür viele mit einer 'floralen' Bodenplatte, wie sie mir von keinem anderen Ort, auch nicht von Ephesos, bekannt sind; Übereinstimmung hingegen besteht in der Verwendung von blaugrünlichem Glas für Stiele ohne Knopf.

Wenn auf Grund der bisherigen Ausführungen die Herstellung von Kelchgläsern in Kammer J vermutet werden kann, so trifft das auch auf einen Teil der mit ihnen oft in früh byzantinischen Schichten vergesellschafteten Lampen zu. Gemäß der Funktion der Hanghäuser als Wohnhäuser handelt es sich sicher um Beleuchtungskörper für den privaten Gebrauch. Es fanden sich Reste der meisten wohlbekannten Typen mit und ohne Henkel, mit Standfläche oder mit 'Stielen' aller Art, wobei speziell ein gedrehter aus fast farblosem, leicht gelbstichigem Glas von ausgezeichneter Qualität zu erwähnen ist. Die übrigen Lampenfragmente aus dem Hanghaus 1 sind ebenso wie die spätantiken Flaschen in der Mehrheit aus blaugrünlichem Glas und entsprechen somit fabric 1 bei den Lampen Typ 2, 3 und 4 aus Sardis (von Saldern 1980, 46–53: Schwerpunkt 5./6.Jh.); der dortige Typus 1 konnte in Ephesos nicht festgestellt werden, dafür aber wieder eine Form, die sowohl in Sardis als auch in Sagalassos unbekannt ist: dreihenkelige Lampen, deren Henkel schwanzartig am gedellten Boden enden (FIG. 1. 813, 814). Alle vier Exemplare aus Hanghaus 1 stammen aus der Taverne XIIb und sind somit ins 6.–7.Jh. zu datieren; zwei davon sind aus blaugrünlichem, eines aus grünlichem und eines aus gelbgrünlichem Glas, die fünf analogen Fragmente von der Agora alle hellgelbgrünlich, ein weiteres ist von besonderer Art: ein dunkelblau durchscheinender Henkel war auf den farblosen Gefäßkörper angesetzt. Dieser Lampentypus scheint eher selten zu sein; einzelne Exemplare sind aus Korinth (Davidson 1952, 80, 98, pl. 54), Paphos, Zypern (Uboldi 1995, 109, fig. 3.10: tipo I.3), Anemurium (Stern 1985, 44–7, fig. 3), Jalame (Weinberg 1988, 82, 85, fig. 4–43.374) sowie aus dem von Ephesos nicht allzu weit entfernten Iasos (Baldoni and Berti 1998, 76, fig. 10) bekannt, vor allem aber aus Istanbul: dort in Saraçhane (Hayes 1993, 400, figs 150, 152) sind sie ebenso wie in Ephesos vergesellschaftet mit Kelchfüßen mit hohlem Rand und Knopf sowie mit Lampen mit Stiel aus dem 6.–7.Jh., laut J.W. Hayes 'a feature not generally noted elsewhere and perhaps peculiar to the products of the Constantinople region', und daher aus lokaler Produktion (Hayes 1993, 400). Ephesos als Provinzhauptstadt schien sich also nicht nur bei der Erzeugung der Münzgewichte, sondern auch der Gebrauchsware nach Vorgaben aus der Reichshauptstadt gerichtet zu haben.

Für eine solche lokale Produktion wurde, worüber allgemeiner Konsens besteht, sowohl Altglas als auch importiertes Rohglas verwendet. Davon fanden sich in den Kammern J und L über 100 Stück in allen Grünschattierungen von fast farblos bis oliv, aber auch in Blautönen (COLOUR PLATE 31). Zwölf davon wurden in die materialanalytischen Untersuchungen einbezogen, die dank der finanziellen Unterstützung durch den Jubiläumsfonds der Österreichischen Nationalbank möglich waren, und durch die Untersuchung weiterer 110 Fragmente aus Hanghaus 1 und zehn von der Agora ergänzt werden, wobei Bedacht darauf genommen wurde, alle umfangreicheren Formengruppen zu erfassen. Die Untersuchungen werden am Institut für Naturwissenschaften und Technologien in der Kunst an der Akademie der bildenden Künste in Wien unter Leitung von Prof. Manfred Schreiner von Frau Mag. Katharina Uhlir-Dietrich durchgeführt, wobei vor allem das Raster elektronenmikroskop und die Mikroröntgen-fluoreszenzanalyse zum Einsatz kommen. Die vorläufigen Ergebnisse zeigen eine große Homogenität der Funde aus Kammer J, die am ehesten der Gruppe Levantine I nach Freestone (Freestone *et al.* 2000, 65–83) entspricht, eine eventuelle Übereinstimmung mit den späten Funden aus Hanghaus 1 ist noch zu überprüfen. Wir dürfen auch nicht außer Acht lassen, daß die zufällige Entdeckung eines so kleinen Workshops in keinem Verhältnis zum tatsächlich benötigten Produktionsvolumen steht.

Eine abschließende und ausführliche Dokumentation der hier vorgestellten Befunde ist in Zusammenarbeit mit St. Karwiese (Münzen), S. Ladstätter (Keramik), S. Metaxas-Lochner (Münzgewichte), M. Pfisterer (Münzen) und P. Scherrer (Ausgräber), für deren fachliche Unterstützung schon hier gedankt sei, in Vorbereitung.

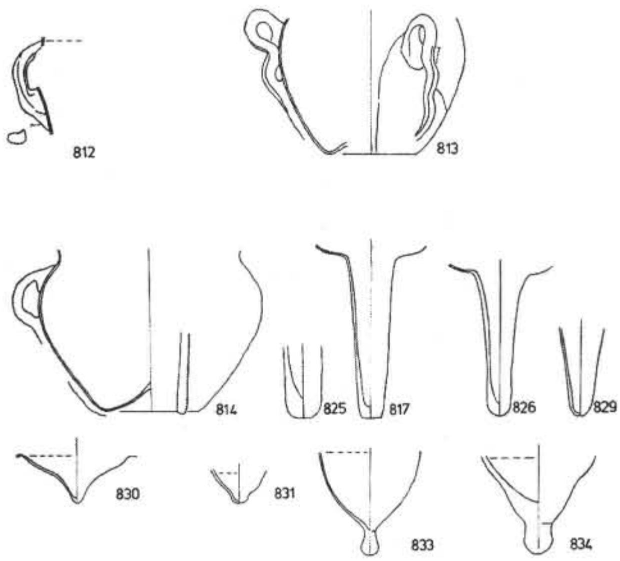

FIG. 1 Lampen aus Hanghaus 1

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CHRONOLOGICAL AND ECONOMIC ASPECTS OF GLASS LAMPS FROM THE FINNISH EXCAVATIONS AT JABAL HARÛN NEAR PETRA

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The mountain Jabal Harûn is situated approximately 5km outside the ancient city of Petra in Jordan. The Petra area has many remains from ancient times and the site was in active use even in the early Byzantine period. On the mountain plateau of Jabal Harûn, *c.* 1250m above sea level, are situated the ruins of a monastic complex, that was in use at least from the early 5th century until the early 8th century. The site, covering an area of some 2400m^2, is being excavated by a Finnish research team under the direction of Professor Jaakko Frösén from the University of Helsinki. Between 1998 and 2003 a total of 25 trenches have been opened and partly or completely excavated (FIG. 1) The building complex is divided into three parts, where the northern part has been identified as a possible hostel for pilgrims. The central part has a chapel and a church and a central courtyard around a cistern. At least parts of the kitchen facilities and storerooms were situated in the southern part of the complex (Frösén *et al.* 1999; 2000; 2001a; 2002; forthcoming).

The excavations at Jabal Harûn have produced a fair amount of glass material, though most of it is in a rather fragmentary state. The material from the 2002 and 2003 seasons is still not completely analysed, so the figures presented here are based on the material from the first four excavation seasons from 1998 to 2001. However, a preliminary study of the 2002 and 2003 material shows that the overall picture more or less stays the same. From the point of view of the glass material, the most interesting trenches – yielding the largest amounts of glass up to the 2001 season – are trenches C, D, E, and I, J and K (Frösén *et al.* 2001b, 379–82)

The glass material from the first four excavation seasons includes around 1500 identifiable fragments (rim fragments, handles, window panes, stems, wick holders etc). The unidentifiable bodysherds are approximately twice as many. From the identifiable fragments roughly half belong to glass lamps, a quarter of the material consists of window panes and the final quarter represents other types of vessels, such as cups, jugs, flasks and bowls. The large amount of fragments from glass lamps gives a good opportunity to attempt to create a typology and chronology for glass lamps from the site.

THE GLASS LAMPS FROM JABAL HARÛN

The glass lamps from Jabal Harûn are represented by two major types: one is a bowl-shaped lamp with three handles designed for suspension and single use (FIG. 2). At Jabal Harûn these lamps usually also have a wick holder or wick-tube made of glass (COLOUR PLATE 32). The other lamp type has a stem and was designed to be used in a *polycandelon* or chandelier (FIG. 3). Both types have been used simultaneously in the different buildings at the site, mainly in the church and the chapel (Frösén *et al.* 2001b, 380).

There are five variations at Jabal Harûn of the bowl-shaped suspended lamp with handles, starting from relatively small lamps with rounded rims, continuing with lamps with roundish folded rims or flat narrow folded rims, and finally middle and broad folded rims (Frösén *et al.* 2001b, fig. 3). These are all usually made of natural coloured, slightly bluish greenish glass. It seems that the type with the rounded rim is the oldest one. At Jabal Harûn only fragments of this type have been found from the lowest levels of the excavation, that is mainly from a sounding in trench E, under preserved floor levels of the apse in the church (Frösén *et al.* 2000, 398; 2001b, 380). There are several stratified deposits on the site, trench D being one of the more important ones (Frösén *et al.* 2000, 396–8), with a relative chronology dated by pottery and other archaeological evidence. (For more detailed information on the site formation process see Frösén *et al.* 1999; 2000; 2001a; 2002; forthcoming.) The relative chronology of the lamps is based on the relative chronology of the different deposits on site, while the dating of the different types is based on pottery dates and comparison with dated glass material from other archaeological sites nearby. Corresponding types of lamps to the above mentioned type with rounded rim have been found during the Swiss excavations at ez-Zantur in Petra and some of these are dated by an earthquake layer to the mid 4th century (Kolb and Keller 2000, 366–7). Thanks to the close co-operation with the Swiss excavation team in Petra, the material from Jabal Harûn can be compared with the material from the site at ez-Zantur. A more general comparison with the material from the Petra church has also been possible (Fiema *et al.* 2001, 370–6).

The two types of bowl-shaped lamps with narrow folded rims, one with a more roundish fold and the other with a flat fold, seem to belong to a middle phase in the relative chronological sequence. The type with flat narrow folded rim was found together with the lamps with rounded rims in the sounding in trench E and also occurred with the type with rounded narrow folded rim in trench D, in the lowest strata below the original floor level (Frösén *et al.* 2001b, 380). The type with a rounded fold has parallels at least in the material from ez-Zantur and from the Petra church – at

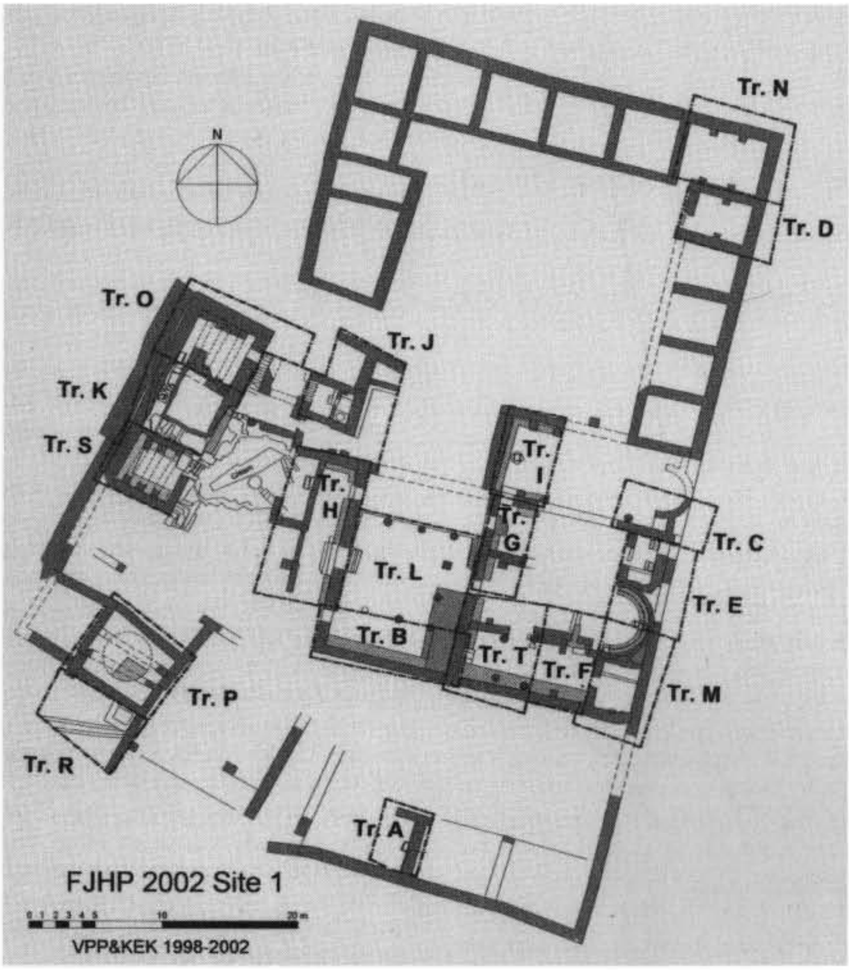

FIG. 1 Plan of the excavated site on Jabal Harûn

ez-Zantur they are found in an early 5th-century context (Kolb and Keller 2000, 367–8).

The latest type of bowl-shaped lamps with handles and wick holders from Jabal Harûn are the larger lamps with middle or broad folded rim. Some examples of middle broad rim occur together with narrow folded rims in trench D, in the strata originating just above the original floor level, while the middle folded rims are typical in the higher up loci, representing reoccupation after disuse (Fröséen *et al.* 2000, 398), occurring there together with some examples of broad folded rims (Fröséen *et al.* 2001b, 380). Especially the large lamps with broad folded rim seem to be typical of Jabal Harûn (FIG. 2). Similar lamps have not, to my knowledge, been encountered elsewhere in the Petra region, but are known from Rehovot in the Negev (Patrich 1988, 134–6, pl. 12). However, there is no evident chronological difference between the lamps with middle or broad folded rims, and other evidence suggests that this difference in the size of the fold width, which seems to be connected with the overall size of the lamp, could simply be due to the demand of different-sized lamps or to the production of different craftsmen. Based on other excavated material, these two types seem to represent 6th and early 7th-century types. There are also fragments of one or two lamps of a variant made of greenish glass with middle-sized folded rim, which slopes outwards creating a more open vessel. This lamp type probably also belongs to one of the later phases during the 7th and 8th century (FIG. 2). Following my paper at the AIHV congress in London I was kindly informed by Y. Israeli of a similar lamp found at Masada in Israel and by F. Silvano of parallels found at the excavations at Medinat Madi in Egypt. A parallel is also found in Jerash (Meyer 1988, 212, fig. 12T).

The typology and relative chronology of the stemmed lamps belonging to chandeliers is not yet very well defined in the Jabal Harûn material, but some major points can be pointed out. The stemmed lamps, which are rather simple in their design, do not give many possibilities for variations. The major variations, besides the quality and colour of the glass material, occur in the properties of the stem and the size and shape of the cup. One also has to keep in mind that differences in shape do not always have to be related to changes in time, but can be due to the craftsmanship and personal style of different glass blowers. The older type of stemmed lamps seem to have a rather slim stem and a relatively long solid part in the tip of the stem (FIG. 3, top). The later types seem to have thicker stems, sometimes conically widening upwards, and with the hollow part reaching more or less to the bottom of the stem (FIG. 3). The cup part of the lamp seems usually to be a bit globular in shape, with a rounded rim, sometimes going slightly inwards, or a type with straighter walls and the base slightly curving up where the stem and body meet. It is possible that one of the earlier types of stemmed lamps might have

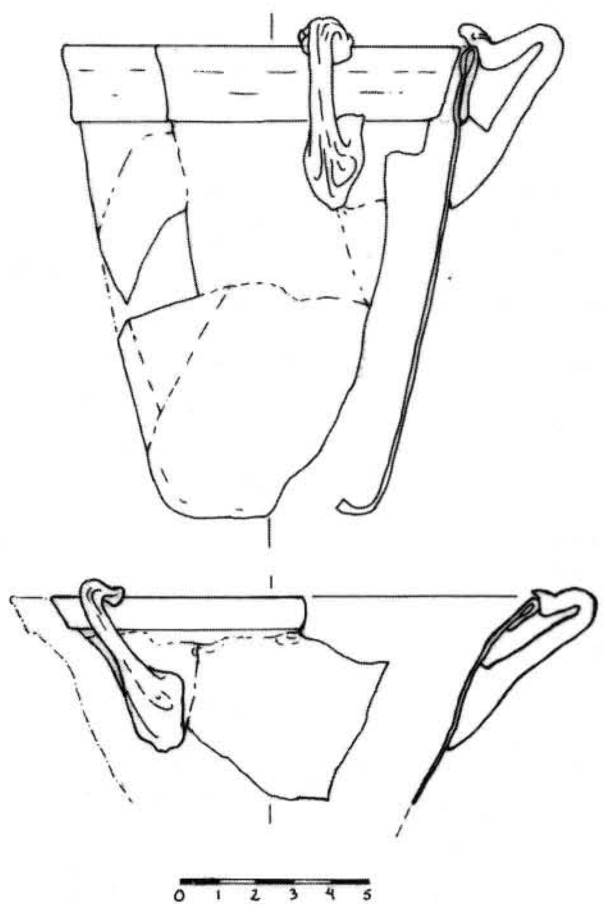

FIG. 2 Bowl-shaped lamp with broad folded rim and lamp with outward turning folded rim made of greenish glass

had a more conical shape, with a slightly outward turning rounded rim. But this assumption is made on only a couple of glass fragments found in trench D. One example of a solid stem, with a knob-like thickening in the end represents the latest phase of *polycandelon* type lamps at Jabal Harûn (FIG. 3, bottom).

The largest quantity of lamp fragments is represented by the bowl-shaped lamps with middle or broad folded rim and the lamps with a hollow stem and rather globular cup. These fragments also mostly come from levels in the middle or upper part of the excavation, that is deposits belonging to the later phases of the relative chronology of the site, as for example the deposited glass heaps in trench J (Frösén *et al.* 2001a, 364), or destruction layers (Frösén *et al.* 1999; 2000; 2001a; 2002; 2003). Both these facts support the suggestion that these types represent the latest phase of glass lamps in use in a large quantity on Jabal Harûn, in other words the latest ecclesiastical use of the chapel and the church during the 6th century and the first half of the 7th century.

COLOUR IMPURITIES IN THE GLASS

Except for a few specimens, most of the glass lamps are made of a slightly bluish greenish, natural coloured glass material. An interesting feature in some of the fragments, mostly belonging to the 6th or early 7th century, is an impurity of yellow glass inside the ordinary bluish greenish glass material.

The yellow glass in combination with the ordinary bluish greenish material occurs in one lamp base with part of a wick holder (COLOUR PLATE 32). That this combination of different colours is not necessarily done for decorative reasons, is clear from another lamp base, where the yellow material occurs as stripes in the lamp base and mostly seems like an accidental impurity of yellow inside the bluish greenish glass. This similar type of impurity or mixture of colour is found, in different degrees, also in other glass fragments (COLOUR PLATE 33). It occurs in several fragment of lamps of both *polycandelon* and bowl-shaped types, as well as in some window panes and a couple of fragments from other vessels, coming from deposits belonging to the later phases of the site.

There can be several reasons for the occurrence of these stripes of a different colour in the glass material, one being chemical and due to e.g. uneven oxygen levels in a single batch, or another being that glass of different colours, and possibly different composition, for some reason has been melted or mixed together in the batch. Variation in oxygen content in a melt with a high amount of manganese can produce usually pink, colourless or bluish colours (for colours produced by minerals, see e.g. Bezborodov 1975, 35, 62–73). But in the case of the glass from Jabal Harûn the stripes are of a yellow colour, which also can be seen in some pieces of window panes of purely yellow colour, a colour which, beside the ordinary bluish greenish glass, is not unusual in the period in question (Keller 1996, 301). It is therefore likely that the fragments with mixed colour from Jabal Harûn are due to a mixture (either deliberate or, more probably, accidental) of glass of different colours and possibly of different composition in the batch. Remelting of two different colours in a batch usually would give a muddy colour (Stern 1999, 451), but if the remelting is taking place under poor conditions, the temperature in the beginning could be too low to completely mix the colours and the glass of possibly different compositions, producing stripes in the first vessels produced and only gradually mixing the glass to a more even, but muddy colour in subsequent vessels. That this could be the case in the material from Jabal Harûn is shown by other glass fragments with a more muddy greenish colour, but still with some yellow stripes showing in the glass material. It may be noted that HIMT (High Iron Magnesium and Titanium oxide) glass occurring in the Roman world in the 4th to 6th century, commonly has a yellow-green colour (Freestone *et al.* this volume). No chemical analyses of the Jabal Harûn material have been made, but it is possible that the yellow glass in the mixture, as well as some other glass fragments from the site, could be of a different composition and of the HIMT type.

It is well known that glass was recycled in the Roman period (Stern 1999, 451), and at Jabal Harûn there are some signs that broken glass has been collected and stacked, maybe for further use as cullet. Of special note in this regard was the large amount of large glass fragments, representing vessel types belonging to the last phases of the site, found in the small room in the north-eastern part of trench J (Frösén 2001a, 364; Frösén 2001b, 379–80) suggesting that this glass material could have been intended for reuse.

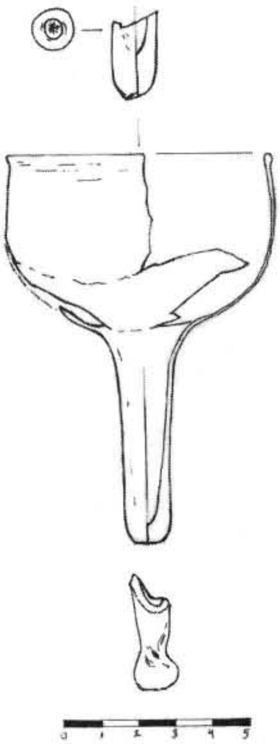

FIG. 3 *Polycandelon*-type lamp fragments

The fact that many of the glass fragments at Jabal Harûn are made of rather poor-quality glass containing a lot of bubbles seems to indicate the use of a large amount of cullet (Stern 1999, 451–2) and that the vessels used at the time were made out of recycled glass material. The occurrence of the fragments with yellow stripes also points in this direction.

This leads to some thoughts on the economic aspects of the production of glass items for the monastic complex at Jabal Harûn. We know that in the 6th and 7th centuries the general economic situation in the Petra region already was weakened (Fiema 2002, 239–41), and raw material for glass blowing therefore probably was difficult to come by. The monastic complex was still functioning and needed a fair amount of glass items as, for example, replacements for broken lamps, other glass vessels and windows. It is possible that the monastery was involved in collecting its broken glass material (indicated by the finds in trench J) and delivering it in the form of cullet for the production of the new vessels needed, to facilitate access to the possibly hard to come by raw material. The commission for new glass vessels might have been give to either some local workshop, or maybe the glass cullet was given to travelling glass blowers to use in the production of the items needed at a temporary workshop in the vicinity of the monastery. In addition to the cullet, the monastery may itself have provided at least some of the raw material needed. If the monastery itself delivered the required glass material or glass in general was difficult to come by, the glassworkers would have had to make do with the raw material delivered or available, and make it last as well as possible for the items needed. All available raw material would probably have been used, even if it contained different colours. The glass blowers might at first have tried to use the different coloured cullet separately, producing items like the all yellow window panes found at Jabal Harûn and the lamp with an all yellow wick holder (COLOUR PLATE 32). But eventually different coloured cullet was used together, resulting in vessels with yellow stripes (COLOUR PLATE 33) and gradually items with a muddy greenish colour. We can not be sure if this mixing of colours happened only once or several times, but the material from the later phases at Jabal Harûn definitely shows signs of some form of glass recycling (both as collections of broken glass, as in trench J, and as the glass vessels themselves showing signs of being made out of cullet).

The research on the glass material from Jabal Harûn is still in progress and the hypothesis here presented has to be confirmed by further studies. But it gives the opportunity to understand some of the economic and production processes related to the manufacture of glass lamps and other glass items for use at ecclesiastical complexes in the Byzantine Near East.

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THE ISLAMIC WORLD

GLASS IN EARLY ISLAMIC PALACES; THE NEW AGE OF SOLOMON

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Our awareness and knowledge of glass production in the lands of the eastern Mediterranean during the early Islamic period have grown with published information regarding the finds emerging from controlled archaeological excavations carried out in the region since the 1930s, while scientific analyses undertaken in more recent times have alerted scholars and students alike to the exciting possibility of isolating certain regional productions. So it is perhaps opportune to explore avenues first signposted by C.J. Lamm (1941), that is: looking at the early medieval chronicles, the geographies, the scientific works and other literary evidence to ascertain how glass was perceived in contemporary society and culture, and whether these perceptions were enduring over time or whether tastes and fashions changed frequently. From the works of al-Jahiz (d. *c.* 868 CE) in Arabic we see that in some circles, especially those in the eastern provinces of the Abbasid empire, that is today's Turkmenistan and Afghanistan, glass vessels were preferred over gold ones because, so the argument went, they were non-porous and non-absorbent, as well as transparent; and that even broken and repaired pieces had a certain second-hand value (McNeill and Waldman 1973, 125–6). And the 11th-century inventory descriptions collected by Ibn al-Zubayr (al-Qaddumi 1996, 77, 132, 183) reveal that in this early period, the clearness and thickness (as demonstrated by its heaviness) of glass were greatly appreciated while contemporary shiny 'glazed' fabrics were admired and compared to the brilliant fire-polish surface of glass vessels (Goitein 1999, 174). In this short paper, I wish to look briefly at just one type of glass – that used in an architectural context.

The early rulers of the Islamic Middle East often ordered the incorporation of glass into the architectural decorative schemes of their palaces, as well as those prestige religious buildings such as the major glass mosaic projects embellishing the Dome of the Rock (Jerusalem) and the Great Umayyad Mosque (Damascus). Architectural glass sherds have been recorded from archaeological excavations of some five of the 17 so-called Umayyad 'desert palaces', constructed in the 8th century before the regime's collapse in 749 CE; five other such sites are considered too ruined to yield useful archaeological results, while Amman and Anjar are viewed as problematic (Grabar 1993, 93). The mosaic schemes at Jerusalem and Damascus, mentioned above, although fragmentary, have received much academic attention (e.g. Grabar 1968; Finster 1970), especially concerning the possible symbolic significance of their pictorial compositions. However, very little information about the glass excavated in the Umayyad palaces has been published with the exception of recent reports by Naama Brosh (1990) and Hayat Salam- Liebich (1978) concerning Khirbat al-Mafjar (Israel) and Qasr al-Hayr al-Sharqi (Syria) respectively; Lafond (1968) indicated architectural glass sherds were discovered at Qasr al-Hayr al-Gharbi (west of Palmyra, Syria) but included no details. Occasionally the location of these so-called palaces are in areas long associated with glass production but in some cases, such as Qasr al-Hayr al-Gharbi and al-Sharqi, west and east of Palmyra respectively, there is no previous history of glass manufacture in the area.

The Umayyad caliphate (661–747 CE) clearly wished that such building complexes promoted ideas of temporal power, authority and prestige so that all those passing through the doors appreciated through their surroundings that this was a residence of an important political personage. The Umayyad rulers may not have adopted the title *malik* (king) but individually they saw themselves as fulfilling this role. The 'palaces' were lavishly decorated with intricate plaster-work, wall and floor-paintings, mosaics and window glass, but were these details included simply to amaze the eyes of the visitor, to entertain and delight the patron and his courtiers or was there another, more symbolic, purpose?

Those who have travelled in the Middle East are aware of the many myths linking the Quranic Prophet Sulayman (the Biblical Solomon) with such sites as Achaemenid Pasargard and Persepolis, constructed in 6th and 5th century BCE, while the Roman temple complex at Baalbek (Lebanon) was, according to the early Islamic commentators, a huge magnificent palace built by Solomon for his Egyptian consort; both Persepolis and Baalbek were described in early Arabic sources as *maiʿab Sulayman* (Solomon's resort) (Soucek 1975, 256). Melikian-Chirvani (1971) and Priscilla Soucek (1976) have shown how these myths continued to appeal to medieval Islamic society; Soucek in particular suggests that the glittering and colourful 7th-century glass mosaic decoration inside the Dome of the Rock, Jerusalem, itself one of the largest interior surfaces to be covered in this manner, may be seen as conscious, deliberate usage to remind the observer of the magnificence, the justice and the temporal and spiritual power of Solomon, for the Arabic commentator, Wahb b. Munabbih (d. *c.* 730 CE) stated that the ceiling and walls of the original temple constructed by Solomon were decorated with rubies and other jewels, while Dinawuri (d. *c.* 895 CE) spoke of that building shining at night because of the gold and precious stones used in its embellishment. This could be linked to another type of decorative architectural glass, usually associated with Christian Syria; the so-called 'gold-sandwich' tiles (e.g. inv. no. 54.1.82, Corning Museum of Glass) variously attributed to *c.* 9th–11th-century Syria or Iraq.

Returning to the Umayyad desert palaces, when the locations of the architectural glass sherds are noted in the published reports – which is not always the case – it appears these were concentrated in the larger main rooms (designated as 'audience halls' by the archaeologists) as at Qasr al-Hayr al-Sharqi or in the bath-house as at Khirbat al-Mafjar, in which numerous window glass sherds of many colours, some cold-painted, were found. It should be noted that this latter site is located not far from Tiberias, whose historic bath-house had long been associated with Solomon (Dow 1996, 114). Furthermore, some modern scholars have suggested that the first phase of construction of this Khirbat al-Mafjar site, which includes the luxurious bath-house, was undertaken during the reign of Umayyad ruler Sulayman b. Abd al-Malik (r. 715–717). If this is so, it is logical to suppose that Sulayman was keen to promote any association with such a legendary Quranic prophet; after all he chose Jerusalem, the city most associated with the prophet-king, as his capital of the Umayyad empire. If the bath-house was in fact part of the later building commissioned by Caliph Walid II (r. 743–744), there is still a connection as Walid referred to himself as 'the son of Da'ud' (King David), that is Solomon (Soucek 1993, 119).

But this leads us to the question, why link glass with Solomon? The simple response is, because the Arab commentators did. According to al-Tabari (d. 923 CE), perhaps the most important and influential of the early Islamic historians, Solomon possessed 'one thousand houses of glass ... in which there were three hundred wives and seven hundred concubines transported on the wind' (Brinner 1991, 154). As well as his fabulous powers which included the ability to understand and speak the languages of wild animals and birds, and to hear all the news carried on the breeze, he had a magic mirror which showed him all the major towns in the known world (EI2 'Sulayman b. Dawud'). Of course this could refer to a large polished metal mirror but it should be remembered that numerous small glass mirrors, backed with lead or copper, set in plaster of Paris, have been found on Sasanid and early Islamic sites and that many Christian pilgrims to the Holy Land then wore such items about their necks to 'capture' the holy light, thought to emanate from saintly relics (Flood 1999, 323–6).

At Qasr al-Hayr al-Sharqi, built around 728–729 CE, numerous coloured window glass sherds were also found during excavations. More importantly for my argument, several examples of a distinctive kind of glass 'tile' were found, probably relating to 9th-century occupation of the site: small in size, a series of four moulded clear glass squares, each about 10mm square and 7mm thick, grouped in a square form but with broken edges (suggesting it had been originally larger in size), set in plaster, as displayed in the Palymra museum (inv. no. 115/8197) (Salam-Liebich 1978, 140). Further north during the 1952 excavations at Raqqa, a similar form of glass tile was found in the so-called 'audience hall' of the Abbasid caliph al-Mu'tasim (r. 833–842), which is shown in the Raqqa Room of the National Museum, Damascus, and, according to Lamm (1928, 118, fig. 66), in the 'audience-hall' of the mid 9th-century Jawsaq al-Khaqani palace complex at Samarra (Iraq). The Raqqa fragments (FIG. 1) are also of a transparent colourless glass, with a slight green or turquoise tinge. There is every indication that they were made by pouring hot glass into an iron mould containing regular rows of small square indentations, but instead of breaking this up into separate cubes after annealing (as in late 19th/early 20th-century manufacture), the cast 'sheet' was used as it was. According to Salam-Liebich (1978) and Abdul-Hak (1960, 88–9), reporting on Qasr al-Hayr al-Sharqi and Raqqa respectively, remains of plaster were found still adhering to the relief surface, so it was this face that was pressed into the wet plaster, presenting a smooth glassy surface to the observer.

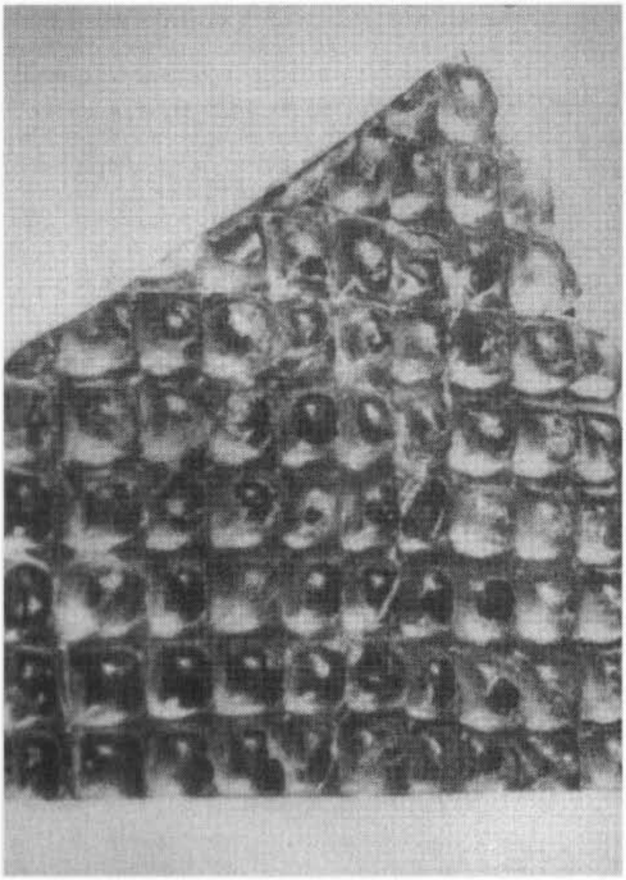

FIG. 1 Fragment of glass tile from Raqqa; after Joundi *et al.* 1976, fig. 79

Again, we have a possible association with the Solomonic myth, for al-Tabari and others describe that one of Solomon's one thousand glass palaces was built by his *jinns* (supernatural beings) with the express purpose of dissuading Solomon from any romantic liaison with Bilqis (or Balqis), the Queen of Sheba. Afraid that their power at court would be diminished by the influence of such an astute, intelligent, beautiful, charming lady, they had heard she had but one failing: hirsute legs. They were convinced if Solomon saw this with his own eyes, he would jettison any idea of a relationship; as al-Tabari recorded

> The demons argued 'Build a structure for him that will show him that, so he will not marry her'. They built him a castle (*qasr*) of green glass, making floor tiles (*tawabiq*) of glass that resembled water. They placed within those tiles every kind of sea creatures, fish, and the like, then they covered it up ... (Brinner 1991, 162)

This episode is briefly mentioned in the Quran, chapter 27, v. 44. On her arrival, the *jinns* uncovered the pavement and, thinking it was a stream, Bilqis lifted her robes as she walked towards Solomon and showed indeed she did have this problem (COLOUR PLATE 34). However, they were thwarted. Solomon, although shocked, was so charmed by her company, he determined she would be his queen. His courtiers were dispatched to find a solution and thus the first depilatory paste was invented (Brinner 1991, 163) which, according to Wahb b. Munabbih, was made from lime collected from bath-house pipes (thus another association of bath-houses and Solomon) (Soucek 1993, 115). The legend with or without further embellishments remained a favourite story in early Islamic society, being narrated in numerous tales associated with the early prophets of Islam and then illustrated in certain anthologies in later centuries, such as the Safavid Persian manuscript *Majalis al-Ushshaq* of 1552, prepared for Sultan Husayn Mirza (Ousley ms. Add. 24, fol. 127b, Bodleian Library, Oxford).

Perhaps this legend could be also the inspiration behind the employment of the series of individual glass and mother-of-pearl shapes, lozenge and ovoid, as found also in the Jawsaq al-Khaqani building, Samarra, mentioned above. It is not known whether the setting patterns suggested by Lamm (1928, pl. x, xi) were those of the original scheme but the Abbasid poet, al-Bukhturi, certainly confirms indirectly that glass was used as revetment and flooring in Abbasid palaces as he described a certain palace room in the following words:

> the glass walls of its interior/ were waves beating upon the seashore/ As if its striped marks were streaks of rain clouds arrayed between clouds dark and light (Scott-Meisama 2001, 73).

Such stories could be dismissed simply as myth and fantasy but there is no doubt that they endured over the centuries. Many Ottoman and Persian court painters continued to find the subject matter inspirational for their pictorial manuscript compositions. In 16th-century Istanbul, Sultan Suleyman the Magnificent (r. 1520–1566) was referred to by court chroniclers and commentators as 'the [new] Solomon of the Age' (*Suleyman-i Zaman*), and this analogy he promoted, ordering rose-granite columns to be taken from the Temple of Jupiter in Baalbek to embellish his new mosque in Istanbul (Necipoglu 1985). And it is tempting to assume that whenever his grand-daughter, the princess Ismihan Sultan, took her bath in the glass-paned pavilion she had constructed, overlooking the gardens of her palace in Uskadar, she thought of that Solomon and Bilqis meeting (Necipoglu 1997).

Abbreviations

EI2 *Encyclopaedia of Islam*, 2nd edn. 'Sulayman b. Dawud'. Leiden and London, Brill, Luzac.

OSIA *Oxford Studies in Islamic Art*. Oxford.

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EARLY ISLAMIC LUXURY GLASS VESSELS FROM RAMLA - LOCAL PRODUCTION OR IMPORTED?

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During a small salvage excavation in Marcus Street in Ramla, a large quantity of glass was found together with other small finds – mainly pottery. The excavation took place in 2000 and was conducted by Mr Ron Tueg on behalf of the Institute for Maritime Studies at Haifa University.

Ramla was founded in the first quarter of the 8th century AD during the Umayyad period; the only city founded by the Moslems in Palestine during the Islamic period. It is located on the crossroads between the coast and Jerusalem and was designated to serve as the capital of *Jund Filistin* (FIG. 1). These facts contributed to the city's rapid growth and its development as an important commercial centre.

In the excavated area a few architectural elements from the Umayyad period (AD 661–749) were exposed but glass vessels related to them were not found. Most of the finds are dated from the second half of the 8th century to the 11th century AD. It is possible that this living quarter was destroyed in the earthquake of 1033 and was not inhabited afterwards.

The excavation yielded a large quantity of glass, of which 704 diagnostic fragments were counted. Only a few small vessels were found intact. The finds demonstrate a wide variety of forms and types of tableware, oil lamps and storage vessels. A total of 13.2% of the indicative fragments was decorated. The most popular type of decoration was that of applied threads. Surprisingly, only one fragment was decorated by tong-pinching. Lustre-painted glass is rare; whereas mould-blown and cut-decorated vessels are more abundant. The vessels from the last three groups will be presented and discussed in more detail.

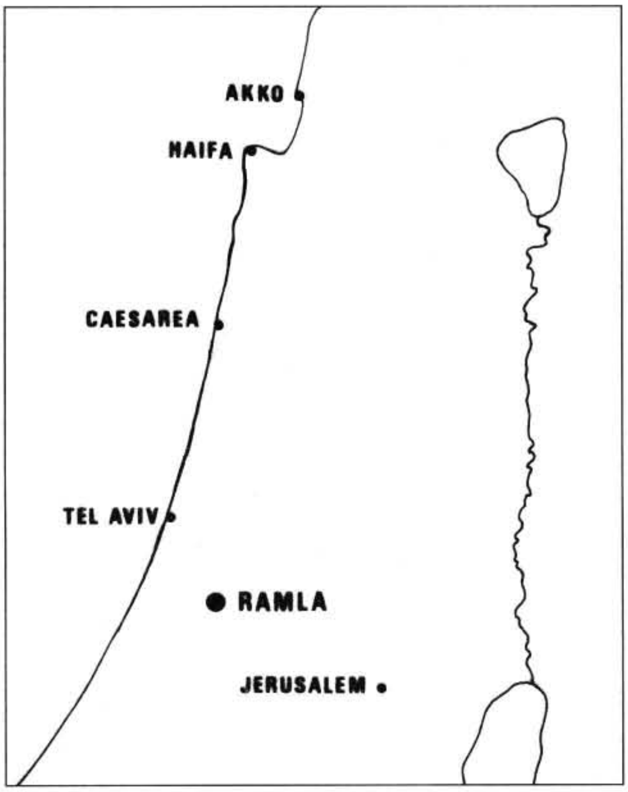

FIG. 1 Location map showing Ramla

The first group comprises the fragments decorated in the mould-blowing technique. It consists of various patterns. Fragments of vessels, such as bottles and a jar, show variations of ribbing. The globular body fragment (FIG. 2.1) was adorned with projecting vertical ribs with a wide space between them. This fragment was found in a cesspit (Locus 198) that was constructed in the 9th century and was transformed into a dump pit in the 10th century. It seems that most of the glass in this locus belongs to the first phase of the cesspit, dating to the 9th and early 10th century. Bottles with such vertical ribbing were found at Caesarea in stratum VII, dating from the second half of the 8th century to the late 9th century (Pollak 2003, 168, fig. 2.25, 28) as well as at Samarra (Lamm 1928, 44, Abb. 31). The material is of common, light bluish green glass, similar to other simple vessels in the locus or in the stratum in general. It is possible that the vessel was of local production, either in Ramla or in the vicinity. Several other vessels with vertical ribbing (FIG. 2.2, 3) can be dated to the Fatimid period (late 10th and 11th century). The jar fragment (FIG. 2.2) of light green glass was found within a floor locus (Locus 119). The latest dated pottery in the locus is from the 11th century. A jar similar in form, although without decoration, is known from the Serçe Limani wreck, and dates to the first third of the 11th century (van Doorninck 1990, 118, fig. 77).

A base of a vessel (FIG. 2.3), with deep impressions of the mould, is made of an emerald green glass; a rather rare occurrence in our excavation. The fragment was found in a surface locus dating to the Fatimid period. Several fragments of bases and lower parts of vessels have patterns that can be interpreted as honeycomb (FIG. 2.4, 5), while other bases have geometric patterns (FIG. 2.6). A body fragment of light green glass (FIG. 2.7) is decorated with circles in rows and columns that is reminiscent of a bottle from Deir al-Naqlun in Egypt dating to the Fatimid period (Mossakowska-Gaubert 2003, 186–7, fig. 1.type 5).

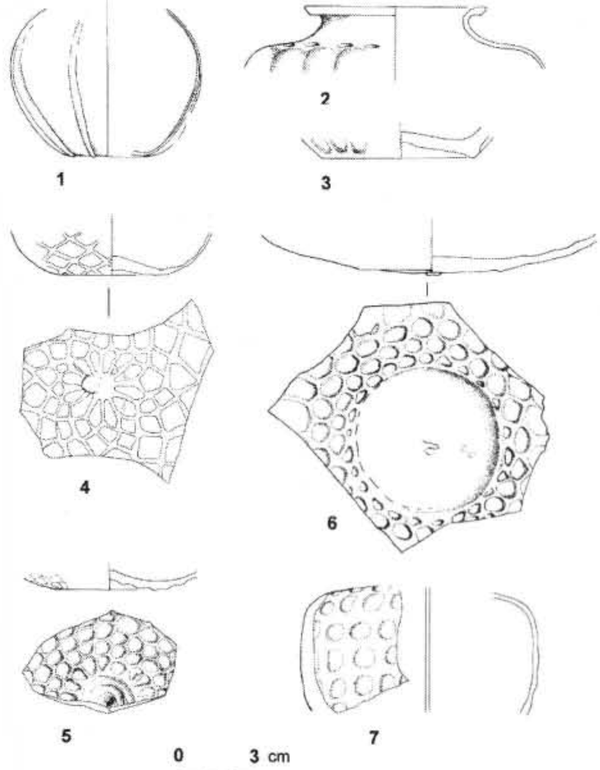

FIG. 2. Mould-blown vessels

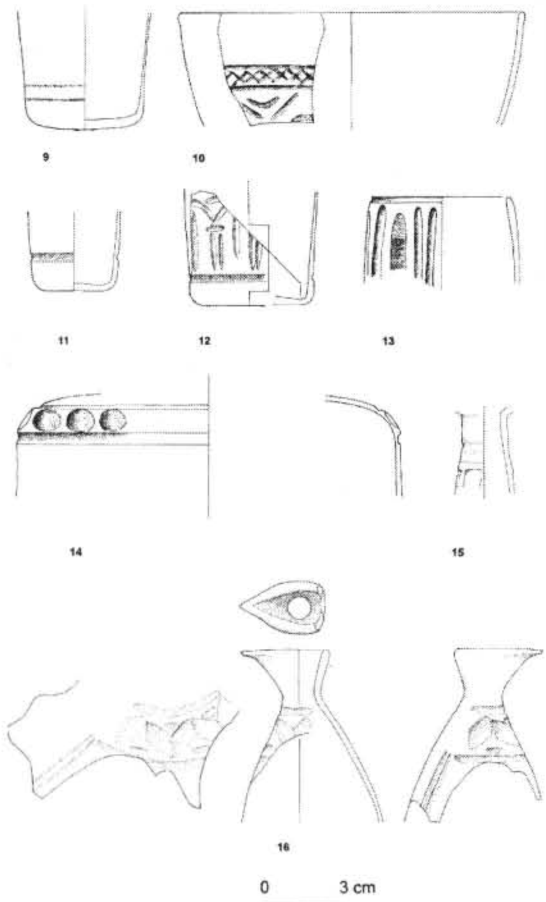

FIG. 3 Glass decorated by cutting

The second group of decorated vessels is the lustre-painted, or the so-called stained glass. Our excavation yielded only a few stained fragments, which were found together in the same locus (Locus 213). Locus 213 is the foundation or the lower fill of a pit or cistern that contained a large quantity of glass. Most of the glass in this locus is of a homogeneous nature; bluish-green glass of rather good quality, without bubbles or impurities. The locus contains a variety of vessel types that are typical of the Abbasid period. The stained fragment belongs to a cup with a convex base (COLOUR PLATE 35). It was painted most probably with copper and silver oxides that produced the brown stain; applied on both sides of the vessel. On the exterior surface, the painting consists of hexagons forming a honeycomb pattern, bordered by two concentric horizontal lines that mark the base. Small stars fill the hexagons every alternate row. The painting on the inside completes the pattern by adding additional rows of stars in the empty spaces left on the outside. Towards the base a small segment of petals is preserved. This design of floral pattern or a star is known from other lustre-painted cups but the pattern on the body is less known.

Lustre-painted glass is associated with an Egyptian provenance, but in this case the nature of the material resembles the rest of the vessels in the locus, most of them common wares containing an outstanding number of cups, probably similar in type to the one with stained decoration. Some of the cups are plain while others are decorated with trails. These vessels were probably produced in the vicinity, and possibly in one workshop. This similarity suggests that the stained vessel could be produced in the same workshop.

The third group contains cut-decorated glass. This group can be further subdivided, according to the characteristics of the curving, to four types of cutting: shallow cut or abraded (FIG. 3.9, 10); linear cut or U-shaped cutting (FIGS 3.11–13, 4.17); facet cut (FIG. 3.14–16); and relief cut (FIG. 4.18). The range of the glass colours contain mainly shades of green, yellowish green, and colourless with greenish tinge. Blue and colourless glass is rare.

A colourless bowl of good quality glass (FIG. 3.10) is decorated with shallow-cut decoration consisting of a frieze of cross-hatching bordered between two stripes, followed by a pattern of diagonal and crescent-shape shallow grooves. It was found in a robber trench (Locus 029) dating to the 11th century.

The beakers and bottles with cut decoration (FIG. 3.9, 11, 12, 14, 15) are known from numerous sites in the Islamic lands and beyond, as far as China (Jiayao 1991, 133, fig.16). The decoration on the beakers range from shallow abraded lines above the base (FIG. 3.9) through deep U-shaped, horizontal grooves (FIG. 3.11), to an intricate design of the central frieze that contains an arcade of arches (FIG. 3.12). Semi-circular arches rest on a single capital delineated by single horizontal grooves. The columns under them are represented by double horizontal grooves. The glass is yellowish green and greenish. Beakers of this type were found in large quantities in the Serçe Limani wreck as well as at Nishapur (Kitson-Mimmack 1988, 39–51, 59–62; Kröger 1995, 156–7, fig. 211). Bottles with a flange rim, truncated conical neck decorated with cut facets, wide horizontal shoulder and cylindrical body decorated with cut grooves that border a frieze of round facets (FIG. 3.14, 15), are associated with an Iranian provenance, although they are found throughout the Mediterranean area as well (Scanlon and Pinder-Wilson 2001, 86–9, fig. 41.i–o). These vessels were found in loci dated to the Fatimid period (10th and 11th century).

A miniature cosmetic flask with globular body and thick disk base is made of blue glass (FIG. 4.17, COLOUR PLATE 36). The funnel-shaped neck is missing. The body is decorated with a groove band below the neck. On the body is a frieze with a double series pattern consisting of diagonal and crescent-shaped grooves. The vessel was found in a surface locus and is associated with the latest period of the excavated area (late 10th century). It might be of Egyptian provenance.

FIG. 4 Glass decorated by cutting

Two ewer fragments were found in the excavation. Both have a pear-shaped body. This shape derives from the Persian Sasanian tradition. One of the ewers, of yellowish green glass and beak mouth, is decorated with diamond-shaped facets below the neck (FIG. 3.16). The other ewer fragment, even though in a state of poor preservation, is of outstanding interest. It belongs to a relief cut-decorated ewer made of colourless clear glass with a very thin wall (FIG. 4.18, COLOUR PLATE 37). The fragment is of the neck and upper side part. It can be related to the group of vessels associated with the Buckly ewer and the rock crystal ewers. The bordering strip is preserved. The curving is of high quality work. It contains delicate details of half palmette and S-shaped motifs with leaf ending, and a segment of petals or foliage design (Buckly 1935, 66–71; Whitehouse 1993; Contadini 1998, 22–5; Scanlon and Pinder-Wilson 2001, 102–5). It was discovered in a foundation layer for a floor (Locus 161) dating to the 10th century (early Fatimid period).

Conclusion

The decorated, luxury glass from the Early Islamic period in Ramla, as exemplified by finds from the excavation, consists mainly of mould-blown and cut-decorated vessels. Tong-pinched and lustre-painted glass is rare. Some of the mould-blown glass can be considered local products and the same is proposed for the lustre-painted vessel. Chemical analysis and comparison with material from Egypt might give a more accurate result. The cut-decorated vessels, dating to the Fatimid period, were most probably imported. Although some of the vessels show Eastern influences they might be imported from Egypt.

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ISLAMIC LUSTRE-STAINED GLASS FROM RAYA BETWEEN THE NINTH AND TENTH CENTURIES

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INTRODUCTION

Lustre-stained glass is a subject of great interest in the study of Islamic glass. The fragment of a bowl with lustre-stained decoration bearing the year A.H.163 (AD 779) in Coptic letters owned by the Islamic Museum of Arts in Cairo is known as the oldest example of this kind (Abd al-Rawuf 1971, fig. 4). Excavations in Fustat by the American and Japanese missions have found early Islamic lustre-stained glass (Scanlon and Pinder-Wilson 2001, 110–14; Shindo 1992, vol. 1, 317, vol. 2, 584–5). Additionally, important objects were found at Raqqa (Institut 1993, 420–1) and other Islamic sites.

After the polychrome lustre-stained glass of the 9th century, the monochrome lustre-stained glass from the end of the 10th century, the so-called 'Fatimid lustre', is said to have been revived in Egypt. These techniques were applied to glazed ceramics, and the lustre painter applied it to both ceramics and glass (Lamm 1941).

A total of 198 pieces of lustre-stained glass were found in Raya, where the mission of the Middle Eastern Culture Center in Japan, directed by Mutsuo Kawatoko, has conducted excavations since 1997 (Kawatoko 2003; Shindo 2003). These are important archaeological materials which fill the gap of monochrome lustre between the 9th and 10th centuries. Moreover, rare orange lustre-stained and polychrome lustre-stained glass was also found, so these are valuable data. In this paper, I consider the chronology and the trade of lustre-stained glass in the early Islamic period, based on the finds from Raya.

LUSTRE-STAINED GLASS FROM RAYA

I divide the lustre-stained glass from Raya into two groups: a brown-stained group painted with copper and silver; and an orange-stained group painted only with copper. Among 206 pieces of lustre-stained glass found at Raya between 1987 and 2002, there are 175 pieces of the former group – including 165 of a brownish-monochrome type and ten of a two-coloured type, and 31 pieces of the latter group – including seven of the monochrome type and 24 of the polychrome type.

As for the relationship between the lustre and the colour of the glass, the majority is pale bluish green, the main colour of Raya glass. This is followed by deep blue, colourless, pale blue, blue and pale purple. Among these, the colourless glass is limited to monochrome or to two-colour kinds, and the pale blue, blue, deep blue and pale purple are limited to orange or polychrome kinds. Based on the results of chemical analysis *in situ* in the field by portable XRF (X-ray fluorescence), pale bluish-green glass with monochrome or two-coloured painting belongs to the group with a low content of potassium and strontium, while one piece of clear colourless glass with the monochrome lustre-stained decoration and all the deep blue with the orange or polychrome lustre-stained decoration belong to the group with a high content of potassium and strontium (Sawada *et al.* 2003; Sawada *et al.* this volume).

The most common shapes of the brownish lustre-stained glass are a cylindrical beaker and a bowl. There are two standard sizes *c.* 120mm or 80mm in rim diameters. Additional shapes are shallow bowls or dishes, bowls, jars and bottles with a cylindrical neck. The pigment is put on the outside and, for the beakers, partly covers both sides. For the bowls and shallow dishes it is mainly on the inside, while for the jars and bottles it is mainly on the outside. In total, 85 pieces are on the outside, 73 on the inside and 17 on both sides. In general, while the pigment covered both sides in the early Islamic period, it was on the outside in the Fatimid period so the Raya materials occupy the transition between them.

The main motifs are arabesque, plant, geometric figures, and script (FIGS 1.1–19, 2.3, 4). Designs of animals or birds are rare. There is only one monochrome gazelle motif (FIG. 2.1), coarsely done, and one two-coloured motif of a fish (FIG. 2.2). The bird design, which was fashionable in the early lustre-stained glass, was not present.

As for the script, nine pieces bear Arabic letters (FIG. 2.3–9). The word supposed to be *'amal* meaning 'manufactured by' in Arabic can be seen at the centre of the interior of the base in the style which is called 'the floriated Kufic style' (FIG. 2.3). But the beginning and the ending of the word are missing, so the reading is uncertain (Clairmont 1977, no. 146). A similar example between the 9th and early 10th century is in the Benaki Museum (inv. no. 3.535). In Raya there is also another base fragment with a similar script, and one fragment of a body with the letters which probably are a part of *'amal* (FIG. 2.4, 5).

In the case of the three fragments of cylindrical beakers the word runs from the bottom up (FIG. 2.6, 7). Lustre-stained glass with a similar design was found in the Abbasid palace in Raqqa dating from the end of the 8th to the beginning of the 9th century (Institute, no. 314) though the style of script is different, and this pattern was also applied to vessels with impressed or wheel-cut decoration (Damascus National Museum inv.A.16032).

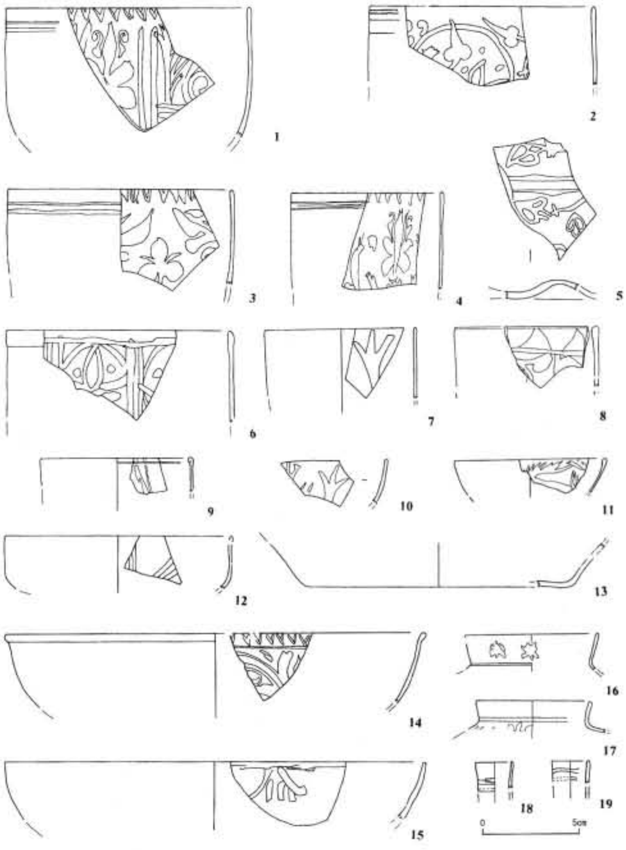

FIG. 1 Lustre-stained glass from Raya © iia, meccj

V-shaped motifs below the rim appear on 20 pieces, 19 of which are painted on the interior of the bowls (FIG. 1.1, 3, 4, 14). This motif is quite rare, but is paralleled by an important cup in the Corning Museum of Glass, although the pattern is a combination of the V-shaped figures and dots. The Corning cup has a Kufic inscription which says 'made in Damascus' (Carboni and Whitehouse 2001, no. 102). Seven pieces bear an inverted triangle instead of the V-shape (FIG. 1.8). The most popular patterns in Raya are plants or arabesque. But if compared with the earliest examples, the plant patterns are a little stylized and inferior in quality.

There are ten pieces of two-coloured lustre-stained glass. They include the above-mentioned pieces with the motifs of fish and script (FIG. 2.2, 8).

Orange-stained glass can be divided into two types: a monochrome type painted thickly all over the surface, and a polychrome type painted with orange and other colours.

Seven pieces of the monochrome type were found (FIG. 2.10). With regard to colour, four pieces are deep blue, and the other three are pale bluish green, pale green, and pale purple. They are bowls with a characteristic rim which is folded outward. They remind me of the lustre-stained glass bowl with black pigment from the Famen Temple in China (An Jiayao 1991, fig. 10).

Among the polychrome lustre-stained glass are objects which are stained over the entire surface with designs applied in black pigment, and others which have, in addition to the orange lustre, dots or lines of black or white elaborately applied (FIG. 2.11–15). Twenty-two of these were found of which fourteen are deep blue, five are pale bluish-green, two are pale blue and one is pale green.

Examples of orange lustre with black pigment were extensively or fully painted on the inside or outside of the surface, the motifs applied with a brush in bold strokes (FIG. 2.15). Some fragments were found which are similar to the jug in the Corning Museum of Glass (Carboni and Whitehouse 2001, no. 106). They have an outline of patterns made by thin vermilion lines, and the inside and the adjacent parts of the outline are filled with orange-lustre. The examples with the more exquisite patterns (FIG. 2.13, 14) are similar to the polychrome lustre pottery of the same period. They are thought to have been produced in Iraq between the 9th and 10th century (Ettinghausen 1984, 853). In the Islamic Museum of Art in Cairo (inv. no. 6061:2), there is an example of the same type with the inscription of 'Basri' as read by Ettinghausen.

Chronology and characteristics of the lustre-stained glass from Raya

The strata of Raya are clear, but artefacts which provide dates, such as coins, are few. Although the fort is in the Byzantine style and old texts refer to the existence of this city in the 6th century, the glassware excavated from this fort site is concentrated between the 9th and 10th century. This is evident from the context of the room in which the lustre-stained glass was found (Kawatoko 2003).

Brown lustre-stained, incised, colourless, threaded and blue threaded glass were found in the same spot in room

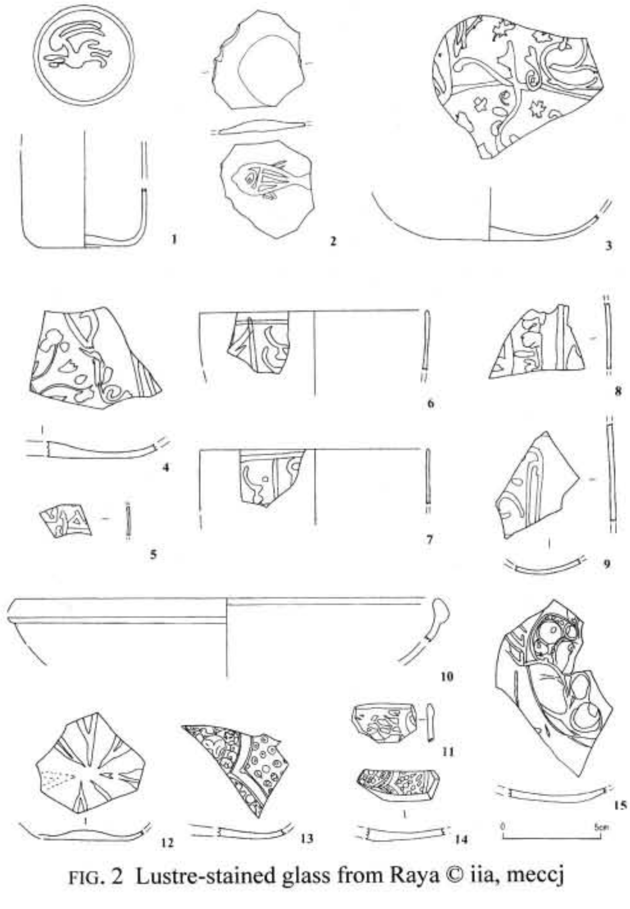

FIG. 2 Lustre-stained glass from Raya © iia, meccj

TABLE 1 CATALOGUE OF THE PIECES (RD=rim diameter, BD=base diameter, th.=thickness)

Room	Level	Shape		Colour Glass/Lustre	Size (cm)
21-9	10.012	beaker	rim	pale bluish green/pale brown (both sides)	RD *c*. 13.0, th. 0.2
-	8.752	beaker	rim	pale bluish green/brown (both sides)	RD *c*. 12.0, th. 0.2
	9.829	beaker	rim	pale bluish green/brown (both sides)	RD *c*. 12.0, th. 0.3
-	5.686	beaker	rim	pale bluish green/brown (both sides)	RD *c*. 8.0, th. 0.1
	9.52	dish	base	pale bluish green/brown (outside)	BD *c*. 12.0, th. 0.2
21-9	9.736	beaker	rim	pale bluish green/brown (outside)	RD *c*. 12.0, th. 0.2
21-9	9.593	beaker	rim	pale bluish green/pale brown (inside)	RD *c*. 7.0, th. 0.1
-	5.789	beaker	rim	pale bluish green/pale brown (inside)	RD *c*. 8.0, th. 0.2
-	8.79	beaker	rim	pale bluish green/brown (inside)	RD *c*. 8.0, th. 0.1
	10.315	shallow bowl	rim	pale bluish green/brown (inside)	RD *c*. 22.0, th. 0.2
-	6.954	bowl	rim	pale bluish green/brown (inside)	RD *c*. 9.0, th. 0.2
-	6.734	shallow bowl	rim	pale bluish green/brown (inside)	RD *c*.12.0, th. 0.2
21-5	10.41	dish	base	pale bluish green/brown (inside)	BD *c*. 14.0, th. 0.2
	9.343	shallow bowl	rim	pale bluish green/brown (inside)	RD th. 22.0, th. 0.2
	7.954	shallow bowl	rim	pale bluish green/brown (inside)	RD *c*. 22.0, th .0.2
-	10.739	jar	rim	pale bluish green/brown (outside)	RD *c*. 7.0, th. 0.2
-	4.468	jar	rim	pale bluish green/brown (outside)	RD *c*. 6.0, th. 0.2
2-2	9.212	bottle	neck	pale bluish green/brown (outside)	RD *c*. 2.0, th .0.1
8-6	8.846	bottle	neck	pale bluish green/brown (outside)	RD *c*. 2.0, th. 0.15
8-6	8.888	beaker	base	pale bluish green/pale brown (inside)	BD 5.0, th. 0.2
-		?	base	pale bluish green/yellow (inside), brown (outside)	th. 0.2
-	6.524	shallow bowl	base	pale bluish green/brown (inside)	BD *c*. 8.0, th. 0.2
	9.495	shallow bowl	base	pale bluish green/pale brown (inside)	BD *c*. 11.0, th. 0.3
-	6.352	?	body	pale bluish green/brown (outside)	th. 0.1
-	6.499	beaker	rim	pale bluish green/pale brown (outside)	RD *c*. 12.0, th. 0.2
-	5.689	beaker	rim	pale bluish green/brown (outside)	RD *c*. 12.0, th. 0.2
-	6.73	beaker	body	pale bluish green/yellow, brown (outside)	th. 0.2
20-4	8.894	?	body	colourless/brown (outside)	th. 0.2
8-14	9.541	shallow bowl	rim	dark blue/orange (both sides)	RD *c*. 23.0, th. 0.3
-	9.452	?	rim	pale bluish green/orange(both sides), black (inside)	th. 0.3
20-3	8.487	?	base	pale bluish green/orange(both sides), black (inside)	th. 0.1
12-5	10.014	?	base	pale bluish green/orange(both sides), white (inside)	th. 0.3
12-5	10.419	?	body	pale bluish green/orange(both sides), white (inside)	th. 0.45
-	9.061	shallow bowl	body	pale bluish green/orange(both sides), black (inside)	th. 0.35
-	8.637	shallow bowl	body	pale bluish green/orange(both sides), black (inside)	th. 0.4

no. 2-2. This fact should give these pieces of decorative glass a common date. The chief decorative glass in those days has been found with lustre-stained glass at depths of 0.5–0.8m in several rooms, for example, in room no. 2-5 and room no. 21-9.

Room no. 8-6 is a small room with a depth of about 2m from the surface. It contained many artefacts. Regarding glass vessels, 456 large fragments, including 81 pieces of decorative glass, were found in this room. Fifty-one of these are moulded or impressed glass. They were scattered throughout the layers. Eight pieces of lustre-stained glass were found. As for other decorative glass, mosaic, imbedded, wheel-cut, incised and ribbed glass was unearthed in stratigraphically top to bottom layers. It is thought that these layers were accumulated in a short time, so that there is no great difference of date in these kinds of decorative glass.

The artefacts from the monastery of Wadi al-Tur, situated 13km to the north of Raya, are similar, showing its close relation with Raya. As for lustre-stained glass, the kinds are more abundant than those at Raya, and include red lustre-stained and Fatimid monochrome lustre-stained glass (COLOUR PLATE 38). This shows that the Raya glass has its own characteristics of date and place of production. The pale bluish glass with brown lustre, which comprises the majority of Raya glass, has a low content of potassium and magnesium. It is the composition of Roman glass and the early Islamic glass in Egypt and Syria in which natron was used.

Secondly, the polychrome lustre-stained glass fits the brown lustre-stained glass of bluish-green material in respect to date, but its composition is high in strontium. This type is thought to have been produced in Iraq and imported with a lot of lustre-painted pottery, so that the difference between them cannot be attributed to the date but to the place of production.

One piece of brown lustre-stained colourless glass from room no. 20-4 in Raya is different in composition from the pale bluish-green glass (FIG. 2.9). There is a recognized similarity in style and composition if compared with the beaker with a bird motif in the Middle Eastern Culture Center in Japan (Shindo 2002, no. 52). The bird motif is more similar to the early Fatimid lustre-painted pottery than to the early Abbasid type (Wenzel 1971; Shindo 2000a, fig. 6.1; Scanlon and Pinder-Wilson 2001, fig. 44b). The bird motif painted in thin lines on the lustre-stained glass, seen in the Fustat examples, is paralleled by the realistic depiction of the early Abbasid type. The bird on this beaker, however, is painted only on the outside, while the early type is on both sides. Accordingly, the minor example found in room no. 20-4, apart from the concentration of the others in the Raya site, is regarded as dated to the end of the 10th century.

Conclusion

The finds from Raya cover a gap of monochrome lustre-stained glass between the 9th and 10th century, and at the same time show the condition of the lustre-stained glass trade, including polychrome objects.

The glass vessels from the Famen Temple in China (An Jiayao 1991; Kröger 1999) are well known as examples of the Asian trade in Islamic glass. The recent excavations at Ko Kho Khao in the central part of the Malay Peninsula and at Ku Lao Cham in Vietnam in South-east Asia are highly informative about this trading route. The finds from these sites are very similar to those of Raya. They suggest that these artefacts were traded on the maritime route (Shindo 2000b). Although the most active stage of the Persian Gulf route, whose base was Siraf, was in the period between the 9th and 10th century, the Red Sea route was also already in use. The Raya glass is thought to have been brought from Syria or Egypt, yet it is quite reasonable to think that these goods were loaded on a ship bound southward because Raya was a port city.

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CHEMICAL COMPOSITIONS OF ISLAMIC GLASS FROM EGYPT ANALYSED AT THEIR EXCAVATION SITES WITH A NEW PORTABLE X-RAY FLUORESCENCE SPECTROMETER

TAKASHI SAWADA, AKIKO HOKURA, IZUMI NAKAI AND YOKO SHINDO

INTRODUCTION

Almost all Islamic glasses have been known as soda-lime-silica (Na_2O-CaO-SiO_2) glasses and represent two fundamental traditions of ancient glassmaking techniques, in which soda-lime-silica glasses were made with either natron (natural mineral substance of sodium carbonate) or with a soda obtained by burning certain kinds of littoral or desert plants (e.g. *Salicornia herbacea, S. fruticosa, and S. Lignosa*) (Brill 2001, 25; Lucas 1989, 179; Nicholson and Henderson 2000, 195). The glasses made with natron, referred to as natron-based or, simply, natron glasses, generally contain magnesium oxide (MgO) and potassium oxide (K_2O) at a concentration of approximately 1.5% or less. In contrast, the glasses made with the plant-ash soda called plant ash-based or plant-ash glasses contain MgO and K_2O at approximate concentrations greater than 2.5% (Brill 2001, 25; Sayre and Smith 1974, 47). It is considered that natron glasses in Egypt are associated with the tradition of Roman glass production, and were produced until the 9th century. The production of natron glass then began to decline, and production of plant-ash glass became common (Brill 2001, 25). The cause of this change is unclear.

The change in the chemical composition of Islamic glasses should lead to an understanding of the changes in trading and/or glass production techniques. To elucidate the details of this transition in glassmaking techniques, precise quantitative analysis is necessary to distinguish between natron glass and plant-ash glass. Many researchers have utilized analytical instruments in the laboratory using destructive sample preparation for a limited number of samples. However, recently, it has been strictly forbidden to take archaeological artefacts excavated in Egypt abroad. In 2001, we therefore developed a portable X-ray fluorescence (XRF) spectrometer for in-the-field analysis of archaeological objects, and we have been carrying out non-destructive analysis using this instrument at excavation sites in Egypt (Nakai *et al.* 2002, 331; Nakai *et al.* in press). XRF analysis using the portable spectrometer has been found to be effective for qualitative and semi-quantitative analyses of major and minor trace elements in glasses.

However, according to the analytical results, the detection of magnesium (Mg), which is the element used for the classification of Islamic glass, is difficult for this portable XRF spectrometer because of the interference peak produced by the instrument. In addition, the XRF intensity of elements is essentially sensitive to surface condition, and that of K in glass excavated could be greatly affected by its burial conditions. We have therefore attempted to characterize Islamic glass using other elements. As described in last year's excavation report (Sawada *et al.* 2003, 49), it was found that the glasses excavated from Raya and Wadi al-Tur can roughly be classified into two groups based on the ratio of XRF intensities of potassium and calcium (K/Ca) *versus* the intensity of strontium normalized to that of the Compton peak (Sr/Pd Compton) plot. In addition, by referring to the analytical data for the glasses excavated from Fustat obtained with ICP-AES (Motizuki 1992, 411, 729), we have found that the magnesium content correlates with that of strontium. Natron glasses with MgO and K_2O levels of *c.* 1.5% or less were also found to have low strontium contents, and the plant-ash glasses containing MgO and K_2O in excess of *c.* 5% each have relatively high strontium contents. Strontium comes mainly from calcium-rich raw materials, such as limestone, marine shells, and plants (Freestone *et al.* 2003, 19; Šmit *et al.* 2002, 344). It was therefore expected that a comparison of the strontium contents could allow us to classify Islamic glasses excavated in Egypt. We also attempted to identify other characteristic elements suitable for classification of the glasses analysed.

A large number of glass artefacts were found at the archaeological sites of Raya and Wadi al-Tur in the southern Sinai Peninsula, Egypt. Raya was used as a port city, so the excavated glasses exhibit diverse types of decoration. It is estimated that this site was in use from the 6th to 9th century (Kawatoko 2003), spanning the change in glass composition. It is therefore expected that Raya will supply very important information for this change in the composition of Islamic glasses. Some excavated glasses have been typologically classified by Y. Shindo (Shindo 2003, 180). Our present study focused on those glass artefacts for which there was the greatest need to have chemical analysis. The chemical composition of glass is generally reflected in that of its raw materials; the correlation between the elements is also important information to estimate the raw materials used for glass production. We report herein the analytical results for Islamic glasses excavated in Egypt, thus revealing the relationships between the chemical composition, shape and provenance of raw materials and dates.

EXPERIMENTAL

XRF spectrometer

The portable XRF spectrometer, the OURSTEX 140 prototype, was brought to the excavation laboratory at al-

TABLE 1 NUMBER OF GLASS SAMPLES ANALYSED DURING THE SUMMER OF 2001 AND 2002

Excavation site	non-decorated	lustre-stained	colourless	incised or cut	moulded	glass weight	others*	total
Raya	46	24	31	17	6	0	37	161
Wadi al-Tur	0	22	22	13	4	11	5	77
Fustat	0	7	0	0	0	0	0	7
total	46	53	53	30	10	11	42	245

* Raya: impressed, Wadi al-Tur: Byzantine lamp

Tur (popular name: al-Tur House) in the Sinai Peninsula, Egypt, and the elemental analysis by XRF technique was carried out in cooperation with the excavation team (Director, Dr M. Kawatoko).

The spectrometer was developed for in-the-field analysis of archaeological artefacts at excavation sites. It was equipped with a silicon drift detector (SDD), a digital signal processor (DSP), and two monochromatic X-ray sources obtained by doubly bent toroidal monochromators of graphite (0002) and PET (200), and white X-rays with/without a Zr filter. The graphite monochromator was used for obtaining Pd Kα X-rays for analysis of middle and heavy elements, and that of PET was used for obtaining Pd Lá X-rays for analysis of light elements; a capillary was used to obtain white X-rays for analysis of heavy elements. The X-ray beam diameter on the sample was *c.* 3mm. The X-ray source and the detector are installed in a vacuum chamber with a window made of prolene film (4μm thickness). Because this film separates the sample and vacuum chambers, the XRF signals of light elements can be detected even though the sample is in air. This spectrometer is very useful for analysis of archaeological artefacts, as it allows us to carry out non-destructive analysis in air; since the X-ray tube current was very low (below 1.0mA), no damage was found on the analysed samples.

The data storage and processing are carried out using a laptop computer (Nakai *et al.* 2002, 331; Nakai *et al.* in press). The instrument is portable, yet it can produce high-resolution spectra (the measured full-width at half-maximum, FWHM, at Mn Kα line is 150 eV). We report herein the data obtained using Pd Kα X-rays.

Samples

The samples excavated from Raya, Wadi al-Tur and Fustat were subjected to analysis. The glasses classified by type are summarized in TABLE 1, and photographs of some typical samples are shown in FIG. 1 as examples. Glass weights constitute some of the most important artefacts, because the letters stamped on them enable us to date when they were produced. In the present study, we have analysed eleven glass weights, five of which (samples 1–5) have been dated to either the middle of the 8th or to the 11th century (Kawatoko 1995). The details of these dates are described as follows: 1 734–754, 2 769–774, 3 996–1021, 4 1012/13, 5 1036–1094 AD (FIG. 4).

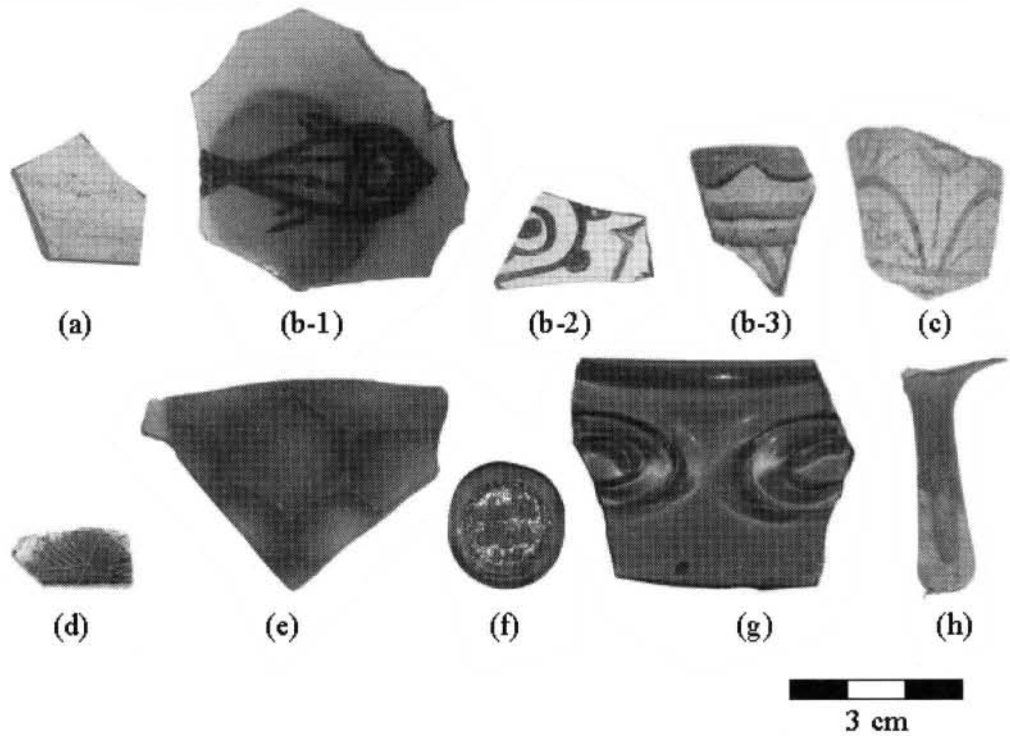

FIG. 1 Some representative photographs of the glasses analysed in the present study. (a) non-decorated, (b-1) lustre-stained, (b-2) lustre-stained and colourless, (b-3) lustre-stained, (c) wheel-cut, (d) incised, (e) moulded, (f) glass weight, (g) impressed, (h) Byzantine lamp; © iia, meccj

Method of data processing

The intensity of the XRF signal (in cps: counts per second) was obtained by subtracting the background from the peak of each element in the spectrum. This was then normalized to that of the scattered Pd Kα line (Compton scattering), which was used as an excitation X-ray source. Elemental quantification from the XRF intensity to the oxide concentration was carried out using a calibration curve method utilizing the normalized intensity. Details of data analysis were reported in our previous paper (Sawada *et al.* 2004). The correlations among some of the elements are discussed based on their calculated concentrations.

Results and discussion

We first attempted to determine the relationship between calcium (Ca) and strontium (Sr), which have chemically similar characteristics. Their elemental concentrations were calculated as oxides and the analytical results are shown in FIG. 2 as a SrO *versus* CaO plot. This shows that there are two characteristic groups that are presumed to be derived from different calcium sources. SrO is proportional to CaO in one group, while in the other, the SrO content is almost constant at a low level. The former group was produced using calcium sources containing strontium, and the latter one was made using materials with low strontium contents. Furthermore, it seems that the former group roughly corresponds to the group of plant-ash glass, which have relatively high potassium contents. From these results, the calcium sources for each group were identified. The former group seems to have a correlation between potassium, calcium and strontium, suggesting that plant ash was probably used as a calcium source. It is known that there is a correlation of calcium and strontium in sea shells, but they contain extremely low levels of potassium (Freestone *et al.* 2003, 19). It is therefore considered that the glass artefacts in the former group were not produced by using sea shells because they have relatively high potassium content. On the other hand, the calcium source for the glass artefacts in the latter group was considered to be limestone because it contained strontium at a low concentration.

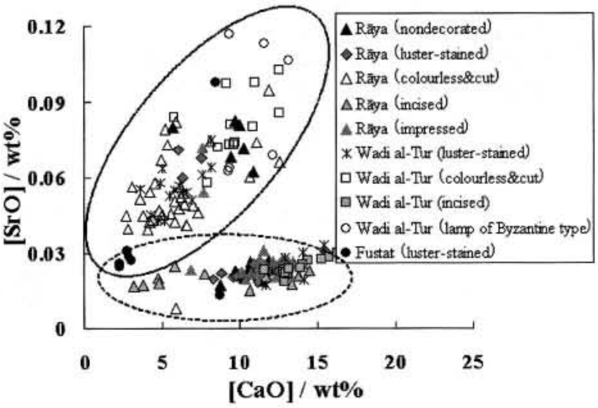

FIG. 2 SrO (wt%) *versus* CaO (wt%) plots for the glasses analysed

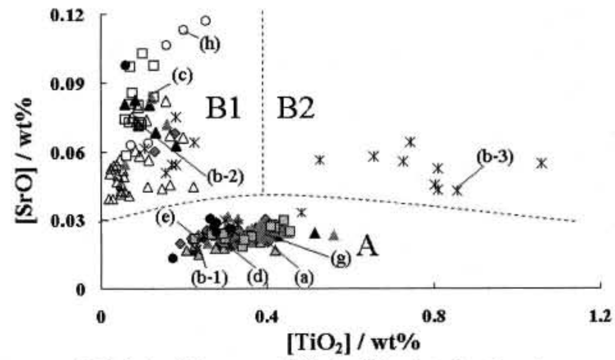

FIG. 3 SrO (wt%) *versus* TiO_2 (wt%) plots for the glasses analysed. The symbols used are the same as those given in FIG. 2

The concentrations of SrO *versus* titanium oxide (TiO_2) are plotted in FIG. 3. This shows that the glass artefacts studied can clearly be classified into three groups (A, B1, B2), with a dotted line separating the three areas. The samples shown in FIG. 1 are identified in FIG. 3. The glasses in Group A correspond to natron glass, and those of Group B to plant-ash glass on the basis of the SrO content. As can be seen in FIG. 3, natron glasses with low levels of SrO have medium TiO_2 content; in contrast, plant-ash glasses with higher SrO exhibit either lower TiO_2 or higher TiO_2 levels. Titanium is probably derived from impurities in the sand (Šmit *et al.* 2000, 718) or contamination from the glass furnace.

With regard to decoration, Group A, which was considered to be natron glass, included all of the incised glasses, most of the glasses with impressed decorations, those that had been pinched and moulded and approximately half of the lustre-stained glasses. The bluish green glasses, which are the dominant colour among the Raya glasses, are also natron glasses; moreover natron glasses with lustre-staining were only bluish-green glass. In contrast, Group B1, which is considered to be plant-ash glass, included the wheel-cut glasses, approximately half of the lustre-stained glasses, some glasses with impressed decorations, as well as those with moulded or pinched decorations. In addition, all of the colourless glass is in Group B1. Group B2 is also considered plant-ash glass, and included the lustre-stained glasses and a moulded glass; these items were excavated only from Wadi al-Tur. It is considered that these glasses have the possibility of being precious articles imported from elsewhere.

We also analysed eleven glass weights, five of which could be assigned, as noted above, either to the middle of the 8th or to the 11th century. The distribution of these glass weights in the SrO *versus* TiO_2 plot are shown in FIG. 4. In this plot, the glass weights of the 8th century belonged to Group A, and those of the 11th century belonged to Group B1. This division is interesting as the identification of the 8th-century weights as natron glass and those of the 11th century as plant ash gives additional evidence for the classification of Islamic glass by using SrO *versus* TiO_2 plots.

Conclusion

Since 2001, we have carried out non-destructive and in-the-field analysis of archaeological artefacts excavated

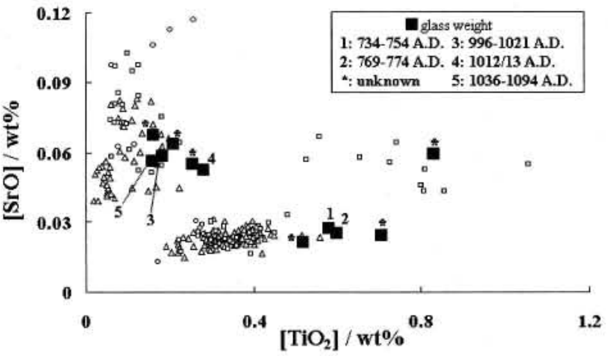

FIG. 4 The chemical composition of the analysed glass weights with year numbers except for the samples with an asterisk shown in the SrO *versus* TiO_2 plots (FIG. 3)

from Raya and Wadi al-Tur in Egypt. The results of the present study show that Islamic glass excavated from Raya and Wadi al-Tur can be roughly classified into two groups based on SrO *versus* TiO_2 plots. These two groups correspond to the origin of the alkali sources, natron glass and plant-ash glass in the Islamic periods.

The results obtained by a portable XRF spectrometer demonstrate that it is possible to carry out non-destructive, in-the-field chemical classification of Islamic glasses based on their titanium and strontium contents. This analysis proved helpful to archaeologists for typological classification. In future studies, it is expected that this type of chemical analysis will provide additional important information in the field of archaeometry.

Acknowledgments

We would like to express our thanks to Dr M. Kawatoko for supplying the archaeological artefacts at the excavation laboratory in al-Tur. This research was supported in part by a Corning Research Grant in 2002. The author (A.H.) wishes to thank Corning Inc. for their financial assistance. The present work has been supported partly by a grant in aid of scientific research from the Ministry of Education, Science, Sport and Culture, Japan.

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BIG MAMLUK BUCKETS

Rachel Ward

We have become preoccupied with identifying fakes amongst the genuine objects in our collections or on the market. But this enthusiasm can go too far and several of the finest medieval Islamic enamelled glass vessels have been accused at some time of being 'too good to be true' (the Palmer Cup) or 'looking too 19th century' (the Cavour Vase). 'Middle Eastern enamelled glass' is not that susceptible to weathering; even archaeological fragments often remain quite clear and those vessels that found their way into European treasuries have usually survived in a near perfect state, making them candidates for suspicion. To make matters worse, 14th-century Cairo and 19th-century Paris shared a taste for lavishly ornamented objects to such an extent that 14th-century Egyptian objects looked quite at home in a 19th-century Parisian salon (this was after all the reason that they were imitated in the first place). Equally, I feel quite sure that Parisian *objets de vertu* would have been avidly collected by Mamluk amirs if their position in history had been reversed. The result of this shared aesthetic is that to modern eyes, genuine Mamluk objects can look more 19th century than their French imitations.

The subject of my paper is a small group that has suffered more accusations of fakery than any other: big Mamluk buckets, large, heavy, cylindrical containers, between 200 and 280mm high, with a pronounced flange below the rim. Five of these are known, and three of them have been pronounced 19th century at some point in their life. My interest in this group was aroused by a bucket sold at Christie's in the Rothschild sale in London in December 2000 as French, 19th-century Mamluk style (Christie's 2000, 66–7, 44–7, lot 16). I will focus on this vessel (COLOUR PLATE 39) before discussing others in the group.

The history of the Rothschild bucket is unknown before 1884 when it was published for the first time by Edouard Garnier as part of the Spitzer collection in Paris (Garnier 1884, 297, fig. 1). It was published twice more by Garnier in 1886 and 1891, and once by Gerspach in 1885. It was acquired by Baron Alphonse de Rothschild at the sale of the Spitzer collection in Paris in 1893. The Rothschild inventory numbers P.48 over 310 are inscribed on a circular ticket on its base. Rothschild had a special case made to contain the bucket and the enamelled blue glass bottle (now in Qatar, Museum of Islamic Art) which he bought at the same sale. While in the Rothschild collection it was discussed in publications by Schmoranz (1899, 20, 33), Rouveyre (1926, fig. 61) and Lamm (1929–30, vol. 1, 306, vol. 2, pl. 115.12). It remained in the possession of the Rothschild family until the Christie's sale in December 2000 when it was acquired by a private collector.

The bucket is 210mm high. It is made of thick glass which has a brownish tinge and some large and many tiny bubbles. A broad inscription band runs around the vessel just below the flange. The cursive arabic inscription in blue enamel is set against a winding white scroll with animal-head terminals in green, yellow, white and black, and red leaves. The thick red enamel ground and border of the inscription appear pinkish but were originally gilded. Below this band are, alternately, lion roundels and double-headed birds. The roundels are framed in red with gold lobes as an outer edge and a gold ground. The lion, in blue enamel, is shown striding to the left, with its right paw raised and its long tail doubling back over its rump. The double-headed eagle is outlined in red and filled with gold. Its heads are in profile, its wings outstretched and its claws clasp the dragon-headed terminals of its tail. Around the base and rim of the bucket are friezes of red palmettes, once gilded all over, with small green enamel dots decorating alternate palmettes on the lower frieze. A narrow twisted and knotted cable, outlined in red and filled with gold, runs around the vessel just above the flange.

This object hits all the alert buttons at once: excellent condition, extravagant decoration and an unusual form with a disarming similarity to 19th-century champagne buckets. A provenance in the Spitzer collection provides little reassurance. No doubt this is why Christie's attributed the bucket to 19th-century France. So far as I know, no one disagreed with Christie's verdict and the bucket was acquired by a collector who, ironically, was attracted to it because he thought it such an unusual example of French 'Mamluk revival' glass.

Christie's backed up their attribution for the bucket by suggesting that Schmoranz and Migeon both thought it was a fake, but actually no scholar has ever questioned its authenticity in print. Christie's claimed that 'Schmoranz obviously was not enamoured of this beaker' after quoting a whole section of his text (Christie's 2000, 66). But in his text Schmoranz never queries the authenticity of the bucket; on the contrary, he compares it to the two Kassel beakers which both have an impeccable provenance. His vicious sarcasm is directed at Garnier's effusive and inaccurate description of the bucket. In a classic put-down of an inferior colleague, he quotes Garnier's text with his own corrections in square brackets: Garnier describes the lions as red, Schmoranz points out that they are blue; Garnier describes the Kufic script and Schmoranz states that it is actually a cursive inscription. Garnier talks of the dominant

TABLE 1 ANALYSES OF THE GLASS AND ENAMELS OF THE ROTHSCHILD BUCKET BY JULIAN HENDERSON

Colour	Colourless matrix	Opaque white enamel	Opaque green enamel	Opaque blue enamel
Na_2O	13.8	12.2	2.9	11.2
MgO	3.7	2.9	0.4	2.5
Al_2O_3	0.9	0.8	0.3	3.6
SiO_2	69.0	52.5	26.9	66.3
P_2O_5	0.2	0.3	0.1	0.4
SO_3	0.2	0.2	0.1	1.3
Cl	0.7	0.6	0.2	0.6
K_2O	2.9	3.7	0.9	4.2
CaO	6.7	6.5	1.7	8.1
TiO_2	0.1	0.1	nd	0.2
Cr_2O_3	nd	nd	nd	nd
MnO	0.5	0.4	nd	1.0
Fe_2O_3	0.4	0.5	0.4	0.4
CoO	nd	nd	nd	nd
NiO	nd	nd	nd	nd
CuO	nd	nd	0.2	nd
ZnO	0.1	nd	0.1	0.1
As_2O_3	nd	nd	nd	nd
SnO_2	nd	12.0	4.3	nd
Sb_2O_3	0.1	0.2	0.1	0.1
BaO	nd	nd	nd	0.1
PbO	nd	6.6	57.3	0.1

nd – not detected
Typical levels of detection in ppm (95.5% probability level) are: Na_2O – 760; K_2O – 250; CaO – 170; Fe_2O_3 – 640; CuO – 1200; PbO – 200

yellow colour, Schmoranz asks where? And so on ... (Schmoranz 1899, 33). Christie's assumed that Migeon doubted the object because he omitted it from his publications. But that is not evidence that he thought it a fake, after all most enamelled glass was omitted from his publications. Lamm, the greatest authority on Islamic glass of the 20th century, who was not reticent about proclaiming an object fake, attributed the bucket to his Damascus group and dated it 1260–1270 (Lamm 1929–30, vol. I, 306, vol. II, pl. 115.12).

Despite its excellent condition, the bucket does have some indications of age: there is a small crack in the base, irridisation within the cavity of the domed base, chips in the enamels and much of the gilding has come off. Furthermore it does not look like any of the 19th-century products. Their inauthenticity is normally revealed by the clear quality of their glass, the clumsy rendition of their arabic inscriptions, the precise outlines of their decoration, the perfect quality of their enamels and their recycling of certain stock motifs such as lotus roundels and arabesque scrolls. None of the imitations known to me use the decorative motifs nor the thick *impasto* effect seen on this vessel.

The brownish, bubbly quality of the body glass, the range and application of the enamels are all consistent with the visual appearance of Mamluk glass vessels and analyses of the body glass and enamels by Julian Henderson show them to be absolutely normal for a 14th-century Middle Eastern glass object (TABLE 1). Henderson's most significant discovery was that the blue enamel is coloured by lapis lazuli rather than cobalt. Lapis lazuli was frequently used in blue enamels on Mamluk glass but is unknown from any other period and was never used in European enamels, therefore its presence in enamels is conclusive evidence of medieval date and a Middle Eastern provenance. Furthermore, the body glass contains about 0.6% chlorine which is much higher than would be expected from glass produced after the middle of the 19th century when chlorine levels go down to 0.1–0.2% (Ian Freestone pers. comm.). Henderson and Carboni's paper in this volume give some useful additional distinctions between 14th and 19th-century enamelled glasses which confirm the early date of the bucket. One is the level of magnesium in the body glass (less than 0.5% in the 19th century and between 2 and 6% in the 14th century: the bucket has 3.7%. Another is the level of potassium which at 2.9% for the bucket is more typical of production in the 14th century than in the 19th century.

The bucket has the distinctive base structure unique to beakers produced in the Middle East in the 13th and 14th century. Bill Gudenrath has demonstrated how it was formed: a separate pad of glass was applied to the foot of the vessel which causes the inner wall to dome while the top part is pulled down in the centre where it touches the pad, leaving a distinctive dimple in its top (Tait 1998, 52–3). This technique died out in the Middle East towards the end of the 14th century and was never used in Europe. It is one of the main arguments used by Hugh Tait to prove the medieval date of the Palmer Cup (Tait 1998, 50–5).

Every detail of the decoration on the bucket can be paralleled in Mamluk glass vessels and archaeological fragments. I can illustrate only one example, a fragment from Fustat in Berlin which shares several of the bucket's most distinctive decorative features: thick *impasto* red enamel with gilding on top, big looping scroll terminating in open-mouthed animal heads, loose floating tendrils and dots of enamel (FIG. 1).

FIG. 1 Fragment of a beaker, gilded and enamelled glass; L. 54mm, D. 2–2.5mm; Museum für Islamisches Kunst, Berlin no. I.2467

Unlike many of the 19th-century vessels, the inscription is neither gibberish nor formulaic (FIG. 2). On the contrary, it seems to relate specifically to the function of the bucket as a finger bowl. It is written in informal cursive style in two sections of equal length. Each section begins above and to the left of one of the lions (which walk in the same direction as the text) and in front of an animal head terminal which also points to the left (the other animal heads face right or down). One section is clear. It reads *Ana ihtiwa' al-ma' al-sirr* which can be translated as 'I contain pleasant water'. The other section is more enigmatic but it may read *Ina 'ithyar al-anamil surrati* 'Indeed, dust of the fingers is my reward'. A longer version of the same inscription is found on two 14th-century round-bottomed brass bowls of a type generally used as finger bowls in the Mamluk period (Cairo, Gayer Anderson Museum, unpublished; Berlin, Museum für Islamisches Kunst, see FIG. 3). Sarre (Berlin 1986, 103) translated the inscription on the Berlin bowl as 'Die zehn Finger haben mich zum Gefass gebildet, ich umfasse kühles Wasser'(Ten fingers made me. I contain cool water). Whatever its precise translation, the recurrence of this unusual inscription on two 14th-century metal bowls which were unknown in the 1880s when the bucket first appeared is powerful evidence in favour of its authenticity.

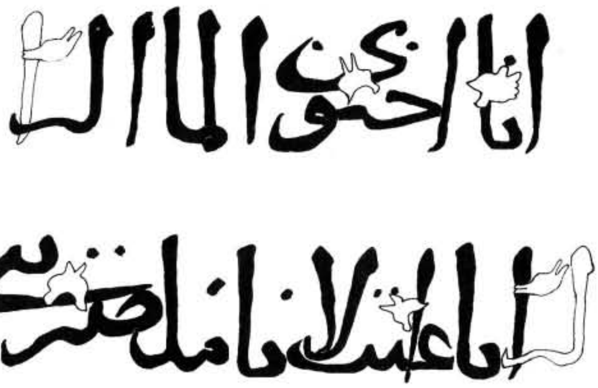

FIG. 2 Drawing of the inscription on the Rothschild bucket

Large and heavy, especially when filled with water, these vessels were, inevitably, accident prone. Fragments of the distinctive rim and pinched flange have been found at Fustat. These are decorated in a variety of styles and suggest that the buckets were produced over a considerable period of time (for illustrations of some of these see Lamm 1929–30, vol. 2, pl. 119.17, pl. 132.26 and 28, pl. 133.1, pl. 182.2; Henderson and Allan 1990, figs 1, 2a). Apart from the Rothschild bucket, only four buckets remain intact. The finest of them is in the Historisches Landesmuseum in Kassel (COLOUR PLATE 40). This bucket has an impeccable provenance as it has been in the museum since its foundation in the 1770s, long before reproductions of Mamluk glass began. Many of its stylistic features, such as the knotted kufic pseudo-inscription, the blue enamel frames, white scroll, floating tendrils and sketchy floral scroll recur on the series of lamps made for Sultan Barquq (1382–1399) and so it can be attributed to the last quarter of the 14th century.

FIG. 3 Engraved brass bowl, diam. 240mm; Museum für Islamisches Kunst, Berlin, no. I.3590

Three other buckets are close in shape and style to the Kassel bucket and were probably made in the same workshop around the same period. One used to be in Prince Yusuf Kamal's collection and is now in the Museum of Islamic Art in Cairo (illustrated in Lamm 1929–30, vol. II, pl. 182.2). The second was in the collection of Madame Edouard André in 1929 but its present location is unknown (illustrated in Schmoranz 1899, 33, fig. 30; Lamm 1929–30, vol. II, pl. 179.11). Lamm suggested that it might be a fake but he gave no reasons for his view. Schmoranz did not doubt it and Lamm's drawing suggests that it is very similar to the Cairo and Kassel buckets in shape and layout and details of decoration. The third is in the Gulbenkian collection in Lisbon (no. 2377, illustrated in Ribeiro and Hallet 1999, 120–1, no. 8). This bucket is of more serious concern because of its close similarity to the mosque lamps bearing the name of the Mamluk amir Qusun, whose mosque in Cairo was built in 1329, some or all of which are known to be 19th century. If the Qusun lamp in the Metropolitan Museum is genuine (and it is thought to be – and was recently on display in the *Glass of the Sultans* exhibition in New York: Carboni and Whitehouse 2001, 232–4, no. 116) there is no reason why another vessel should not be decorated in a similar style, and the bucket has been published by Ribeiro and Hallet (1999, 120–1, no. 8) as a genuine 14th-century Mamluk object.

The Rothschild bucket is subtly different in size and shape to all of the other four surviving buckets. It is smaller: 210mm high whereas the others are around 260–70mm. It has a more flared body and a lower rim. It has a double base whereas they have a single base with a high kick. It is much closer in size and shape to two candlesticks, which are really just inverted buckets with a neck and socket attached, one in the Corning Museum (COLOUR PLATE 41) and another which used to be in the Eumorphopoulos collection but whose present location is unknown (illustrated in Hardie 1998, fig. 20.5). Doubts about the Corning candlestick, when it reappeared on the market in 1990, fell into both the 'it looks 19th century' and the 'too good to be true' categories. But there are numerous archaeological fragments decorated with similar geometric designs and it is now generally accepted as genuine and was on display at the Metropolitan Museum in the *Glass* *of the Sultans* exhibition (Carboni and Whitehouse 2001, 270–2). As Stefano Carboni pointed out in the exhibition catalogue, the distinctive geometric decoration of the Corning candlestick must postdate 1313, when that style of illumination was introduced into the Mamluk Empire. The design became enormously popular during the rest of that century, so it is difficult to date it more precisely by style alone. However, the use of high-lead red enamel painted on the interior of the vessel, a technical innovation which first appears on mosque lamps in the 1340s, suggests a date after about 1340. The arabesque decoration on the Eumorphopoulos candlestick, which can be compared to mosque lamps made for Sultan Hasan in the 1350s, confirms a date for them both in the middle of the 14th century.

Lamm dated the Rothschild bucket to 1260–1270, probably because lion roundels were, until recently, assumed to represent the blazon of the Mamluk Sultan Baybars who ruled 1260–1277 (Lamm 1229–30, vol. I, 306). In fact the lion motif was used decoratively throughout the 14th century (Ward 1998a, 31). Lions very similar to those on the bucket appear alternately with the sun image on the Berlin brass bowl (FIG. 3). Like the two glass candlesticks which it resembles and the two metal bowls bearing the same inscription, the Rothschild bucket should probably be dated to the middle of the 14th century. I suggest that it stands at the head of a series of enamelled glass buckets and candlesticks that were introduced into the Mamluk repertoire in the middle of the 14th century and continued until the decline of the enamelled glass industry at the end of the 14th century. I hope that it can now retake its rightful place as a genuine and exceptionally interesting example of Mamluk enamelled glass.

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ISLAMIC GLASS FINDS OF THE THIRTEENTH TO FIFTEENTH CENTURY FROM JERUSALEM – PRELIMINARY REPORT

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In the course of excavations in the Jewish Quarter of the Old City of Jerusalem conducted in the 1970s by the late Professor N. Avigad, under the auspices of The Hebrew University of Jerusalem, large quantities of Islamic glass fragments were uncovered in the upper stratum. The upper levels of the Jewish Quarter in Jerusalem were mainly built up from the Crusader period – the 12th century – and remains of Crusader, Ayyubid, Mamluk and Ottoman structures are intermingled there. Remains of material culture of the Mamluk period (13th century–early 16th century) predominate and were uncovered in almost all areas of the Jewish Quarter (Avigad 1983, 247–57; Geva 2000, 27). Of these, only one marvered Islamic-period glass bowl has been published so far (Avigad 1983, pl. 302). The work on the final publication of the finds from this enormous undertaking has only recently begun.

The present paper focuses on a group of glass finds uncovered in a dump over an unused cistern, in Area T (locus 2155) near the Nea Church, at the southern end of the Cardo in the Jewish Quarter. The dump most probably served as a trash place for broken glass vessels. Of the approximately 140 fragmentary vessels in the group, the shapes of about 125 (some 90%) could be reconstructed – some almost in their entirety.

Unfortunately, this dump could not be precisely dated on stratigraphic grounds, but compared with known parallel material, the vessels under discussion here appear to be from the Mamluk period, principally from the late 13th to the 15th century. The shapes of these vessels and the decorative techniques are similar to those of glass vessels dating from the same period that were found elsewhere in the Middle East: e.g., in the excavations at Hama (Riis 1957, 30–69), Heshbon (Goldstein 1976), Fustat (Scanlon and Pinder-Wilson 2001; Shindo 1992), Quseir al-Qadim (Whitcomb 1983; Meyer 1992, 75–96) and al-Tur (Shindo 1993). While most of the vessels in our group resemble typical Mamluk vessels in shape and decorative style, some of them reflect innovations that suggest a production line specific to local Jerusalem workshops. The conjectured existence of such workshops is strengthened by the resemblance of many of the fragments in the group to contemporary glass vessels found in other areas of Jerusalem. The group is quite homogeneous in the glass fabrics and similarities among the vessel shapes, which suggests that the objects were all manufactured in one locality (Hasson 1983; Engle 1984; Gorin-Rosen forthcoming).

Colourless glass seems to have been the most popular type of glass of this group (70 vessels); most are of a yellowish tinge and fewer with a greenish tinge. The next most prevalent colour (47 vessels) is purple, which was popular in the 13th–15th century in the region of Syria. Eleven vessels in bright turquoise were also found, along with three vessels in cobalt blue, two honey-coloured vessels, and a few greenish vessels.

Although the glass has many bubbles and impurities, the variety of decorative techniques attests to great technical and artistic proficiency. More than half of the vessels are ornamented. The most prevalent decorative technique in this group was trail-marvering, in which white opaque threads were pressed into a transparent matrix in various patterns, mainly on purple glass (44 vessels), but also on turquoise (2 vessels) and one blue glass. The technique was used in a wide variety of vessels, including beakers, lids, bottles, jars and kohl bottles, but especially in basket vessels (8), bowls (8) and sprinklers (8) (FIG. 1). These vessels display several important characteristics. Most of the purple glass is translucent purple and not dark purple as it appears in much other marvered glass (Carboni 2001a, 309). The white trail is usually thin, and sometimes the trails are carelessly applied and protrude from the surface. The ornamentation usually begins at the base and continues to the rim of the vessel. The bowl rims are almost always decorated with a thicker white or pale-blue trail, beneath which several coils are placed closely together. The most common pattern, found mainly on the bowls, jars and the basket vessels is of a spirally wound white trail. About half of the bowls were blown in ribbed moulds; the wavy

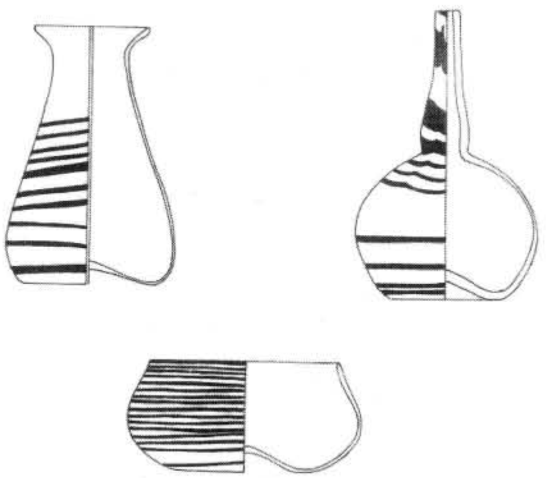

FIG. 1 Jar, sprinkler and bowl: purple with white trail marvered decoration; scale 1:2

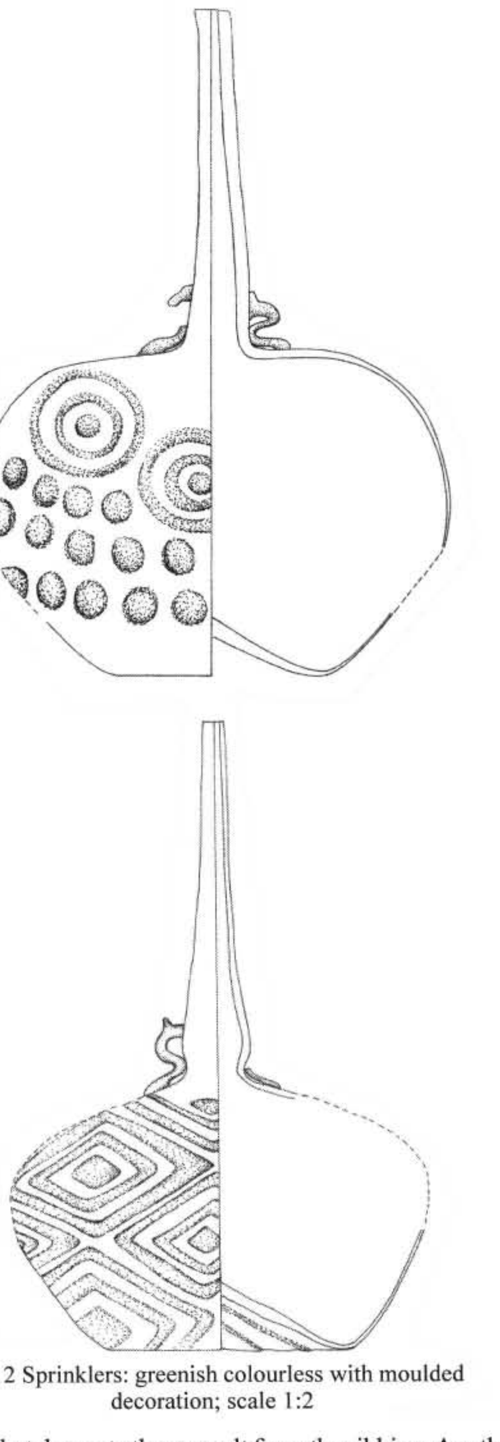

FIG. 2 Sprinklers: greenish colourless with moulded decoration; scale 1:2

patterns that decorate them result from the ribbing. Another type of pattern found mainly on bottles, sprinklers and kohl bottles was achieved by dragging the threads to form festoons or feather-like patterns, or dots.

Marvered vessels of the Mamluk period are known mainly from Syria and Egypt (Allan 1995; Shindo 1993; Carboni 2001a, 301–21; Carboni 2001b, 105–9, nos 55–60; Carboni 2001c, 185–8; Riis 1957, 62–9; Scanlon and Pinder-Wilson 2000, 106–8). It is particularly the large number of marvered vessels in the group that reinforces the assumption that Jerusalem was a centre for this technique during the Mamluk period (Rogers 1998, 71). Such vessels were found in many excavations in Jerusalem, e.g. the Temple Mount (Engle 1984, 67, 88, figs. 36, 54.a, c), the Damascus Gate (Neuburg 1949, 40; Wightman 1989, 98, nos 31, 36), Armenian Garden (Allan 1995, 14) and in the excavations at Herod's Gate (Gorin-Rosen, forthcoming). Industrial waste of marvered vessels was also found among the group of glass fragments from the Jewish Quarter acquired and published in the 1980s by the L.A. Mayer Museum for Islamic Art in Jerusalem (Hasson 1983, 109).

White or turquoise trails were also applied to many vessels around their rims, indicating that this was probably a common practice in local workshops. Sometimes the trail was wide and covered both sides of the vessel's rim; in other cases, the thread decorated only the outside or only the inside.

The second decorative technique found among the dump group is that of moulded glass. Nineteen such vessels were found, in a variety of colours: colourless glass, purple, turquoise, amber and greenish; and in a variety of shapes: oil lamps, bowls, pots, sprinklers, bottles, jugs and beakers (FIG. 2). The most common ornamental pattern was vertical ribbing, used to decorate vessels either vertically or diagonally. Other patterns include roundish indentations and diamonds. Moulded decoration was used in the glasswork of Egyptian and Syrian areas from the late 12th to the 14th century, but moulded sprinklers, like our examples, are rare (Carboni 2001a, 224).

Vessels whose entire surface was painted in red are a new find in Islamic glass research (Brosh 2004). The group includes eleven fragments made from greenish colourless glass painted in red enamel from which three small vessels – a bowl, a jar and a bottle – can be reconstructed. All these vessels are painted on the inside in sealing-wax red. The red enamel coloration is not applied evenly, and the clear glass can always be seen through small holes or bubbles in the paint. As opaque red glass was expensive, this practice may represent a cheap imitation of it. Fragments of such vessels are also kept today in the L.A. Mayer Museum for Islamic Art, Jerusalem (Hasson 1983, 110), and in the excavations at Herod's Gate in Jerusalem, at Kaakul (north eastern Jerusalem – Gorin-Rosen forthcoming) and at Beit She'an (Y. Gorin-Rosen pers. comm.).

Another type of glass unique to the Jerusalem workshops is represented by three turquoise glass vessels decorated with vertical pinched decoration – a bottle and two sprinklers (FIG. 3). This decorative technique is not known elsewhere in this period. Pinched decoration was prevalent in the Early Islamic period in the eastern Mediterranean and is not known in the later period.

The Jewish Quarter dump group is thus not only remarkable in its decorative techniques but also in the great variation of vessel types. The dump yielded about 14 different types representing approximately 50 assorted shapes. The predominant types are bottles, lamps, sprinklers, bowls, beakers, jars, kohl bottles and pots. These vessels can be divided into three main groups according to their functions: bottles, juglets and sprinklers for oils and perfumes; oil lamps, bowls and beakers – all used as lighting fixtures; and regular household vessels such as kohl bottles and pots. Most of the vessels in the group are bottles of various types, made of colourless glass with a yellowish

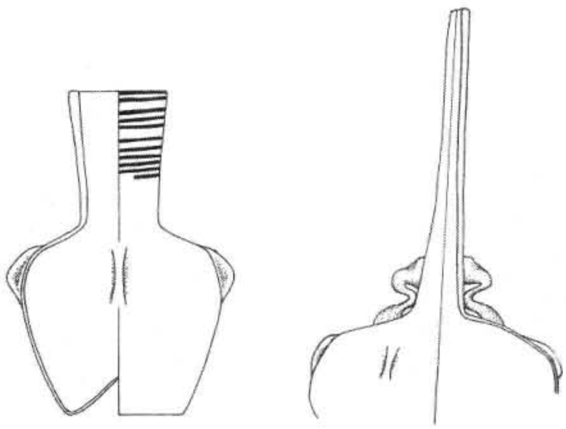

FIG. 3 Jar and sprinkler: turquoise with pinched decoration; scale 1:2

or greenish tinge. They are almost identical in size (150mm high) with only slight variations in shapes. All the bottles have globular bodies and concave bases with long cylindrical necks. Some have bulges on the neck close to the rim or the body, and some have handles.

A previously unknown type of oil bottle is basically a juglet (FIG. 4) of which four examples were found. Flasks with spouts are very rare in Early Islamic glass, but are quite common in later periods. Conceivably, this shape first appeared in the 14th century in the glassmaking workshops of the Jerusalem area. Such flasks have been manufactured to this day in the workshops of Hebron.

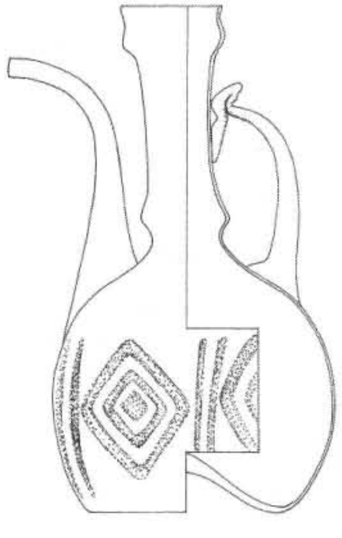

FIG. 4 Juglet: colourless with moulded decoration; scale 1:2

The type of vessel most identified with the Mamluk period is the sprinkler, characterized by a long narrow neck and globular body flattened on two sides, and a concave base with a kick. Sometimes such sprinklers, known as *omom* or *qumqum*, have snake-shaped handles. The 20 sprinklers found in this group comprise an assortment of glass colours (colourless glass, purple, turquoise, amber and greenish), range in size from 62mm high and 35mm wide to 170mm high and 100mm wide, and are decorated in various techniques: trail-marvering, pinched decoration and mould blowing.

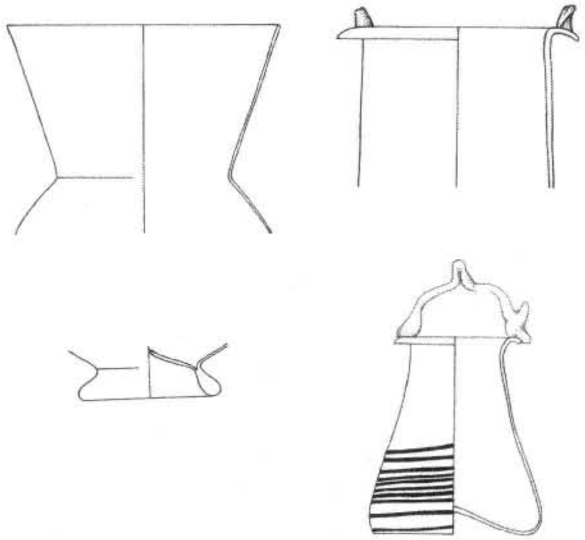

FIG. 5 Types of oil lamps. Vase-shaped: yellowish-colourless (left); cylindrical-shaped: yellowish-colourless (top right); basket-shaped: purple with white trail marvered decoration (bottom right); scale 1:2

The dump group includes 24 oil lamps representing three main types (FIG. 5): mosque lamps, stemmed oil-lamps and ring loop-handled cups. The familiar vase-shaped mosque lamp with flaring neck, has a globular body on ring base, sometimes with a tube for the wick attached inside. Stemmed oil lamps are small bowls having a tubular stemmed base for insertion in a suspended metal holder. Ring-loop-handled cup oil lamps are of two shapes. One is made from colourless glass with a cylindrical body and with a splayed rim having two small ring-loops on it for hanging. The second is the basket-shaped vessel, whose function is uncertain (Carboni 2001c, 186) but may have been used as a hanging lamp.

Basket vessels were found in Jerusalem (Engle 1984, 88; Allan 1995, 14; R. Hasson pers. comm.) as well as in Syria (Al-'Ush 1964, fig. 50). Ten such basket vessels were found in the dump group, all decorated with a white trail marvered on purple or turquoise glass. The body is piriform, the base flat or concave, and the ledge rim has a single central handle with a vertical pinched loop in the middle.

Most of the 15 bowls, of various sizes (diam. 40–160mm) almost all have the globular body, rounded rim and slightly concave flat base typical of the period. Nonetheless, bowls with a flaring body were also found. Here too, the most common decorative techniques were trail-marvering and blowing in patterned moulds.

The ten fragments of beakers found in the group have cylindrical bodies with incurving flared openings near the rim.

One of the most popular vessels of the period is the kohl bottle (Shindo 1993; Carboni 2001a, 305; Carboni 2001b, 106–7). Eight bottles were found, about half made of purple glass decorated with white marvered trails. They have long, inverted conical bodies truncated at the bottom. The colourless kohl bottles have pointed piriform bodies and elongated cylindrical necks. All the bottles have bulges in the necks.

A new type of vessel, representative of the larger household vessels in the group, is a pot, almost whole, made

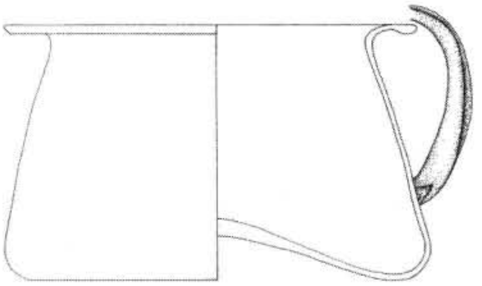

FIG. 6 Pot: yellowish-colourless with turquoise handle; scale 1:3

of colourless glass with a yellowish tinge and a turquoise handle (FIG. 6). The shape of this vessel is reminiscent of ceramic pots popular in the Mamluk period and found in many excavations in Israel. They are generally considered to be chamber pots or potties for children, and this glass pot may have served the same function. This was confirmed by one of the older glass craftsmen in Hebron, Abed Natcheh, who reported that at the beginning of the 20th century, his father and grandfather had manufactured glass chamber pots in their workshop and had even exported them to Egypt.

Examination of the diverse types of vessels in the dump group sheds new light on the nature of the glass industry in Jerusalem. Most of the vessels found in this dump were used for oils and perfumes, or for lighting fixtures. This may be the reason why these workshops were established in Jerusalem and Hebron in the 14th century. Two explanations may be presented.

The first is related to the conquest of the eastern Mediterranean countries by the Mamluks in 1260. The conquerors destroyed the coastal cities, wiping out the glassmaking centres there that had been in operation for hundreds of years. The second reason has to do with the Mamluks' policy of emphasizing the Islamic religious character of Palestine. They built many religious establishments and institutions in the Jerusalem area, necessitating the setting up of glassworking centres, close to where the products were needed. Thousands of lamps and lanterns were used to light up the various religious buildings. In addition, the number of pilgrims, Moslems, Jews and Christians, visiting the religious holy places steadily increased. These pilgrims needed bottles and sprinklers to hold the oils and perfumes they used in their religious ceremonies and rituals.

The Jerusalem Old City Jewish Quarter dump finds attest to the distinctiveness of the vessels manufactured in Jerusalem and Hebron workshops and the skill of the glass craftsmen there; but it is not less important that they indicate a connection to the Hebron glass workshops of our day. Not only the vessel types, as discussed above, recall the ancient glassmaking industry in Hebron and Jerusalem, but also the colours of the glass. Purple, blue and honey colours, and in particular turquoise, have characterized the products of the industry up to the present. Indeed, turquoise is the pride of these artisans because to this very day they claim to produce this colour in the same way their forefathers did over 500 years ago.

Acknowledgements

I thank Hillel Geva and Oren Godfeld from the Jewish Quarter excavations for permission to publish this material. I am also grateful to my colleague, Elena Lavorko, for reconstructing and handling these glass vessels, and to Rachel Hasson, the curator of the L.A. Mayer Museum for Islamic Art in Jerusalem for permission to study the Jerusalem material, and to Yael Gorin-Rosen for information about glass material from Jerusalem. The drawings are by Pnina Arad.

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GLASS FROM THE CRUSADER CASTLE AT MONTFORT

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The ruined Crusader castle of Montfort or Starkenberg (the modern name is Qalᶜat al-Qurain) is about 20km north-east of Acre (modern Akko) in northern Israel. It stands on the crest of a prominent ridge: hence its name, which in both French and German means 'strong mountain'. In the late 12th century the ridge and much of the surrounding countryside belonged to the French de Courtenay family; but in 1220 the site was purchased by Hermann von Salza, the head of the Teutonic Order. In 1226 the Teutonic Knights began to construct a castle, and a document of 1228–1229 mentions the 'new fortress called Montfort'. This fortress was the headquarters of the Teutonic Order until 1271, when it was attacked with siege engines and captured by the army of the Mamluk sultan, Baybars. The castle was left in ruins and the site was never reoccupied (Pringle 1986, 52–5). Most of the finds, therefore, belong to the period between 1226 and 1271, and were used by the Teutonic Knights and their retainers.

In 1925 Bashford Dean of the Department of Arms and Armor at The Metropolitan Museum of Art asked the Department of Antiquities of Palestine for permission to excavate a Crusader castle in the hope of recovering medieval weapons and armour. The Department granted Dean a permit to excavate at Montfort. The excavation took place in 1926, directed by W.L. Calver. In the course of a single month, Calver's workmen removed some 2000 cubic metres of earth and rubble from the ruins (Dean 1927). Despite these efforts, the excavators discovered few fragments of arms and armour. The other finds included carved stonework, coins, pottery, stone moulds apparently used for embossing leather (Nickel 1989, 36) – and 'countless fragments' of glass. At the end of the excavation, the Department of Antiquities selected outstanding finds for retention in Palestinian museums and at the same time presented a generous sample to The Metropolitan Museum of Art. The sample was received by the Metropolitan Museum in 1928 as the gift of the sponsors of the expedition, Clarence Mackay, Archer M. Huntington, Stephan H.P. Bell and Bashford Dean.

The finds at the Metropolitan Museum include more than 600 fragments of glass, most of which are small. They fall into two categories: window glass, some of which is painted, and glass vessels. The window glass, together with some of the carved stonework, came from Room J, which the excavators identified as the chapel. The glass as a whole was the subject of three presentations at the 2003 congress. Timothy Husband described the window glass and showed that the artist who decorated the window had been trained in France, while Lisa Pilosi and Mark T. Wypyski reported on the chemical composition of both the window glass and the vessel glass, and showed that the window panes and most of the vessels were made in the same general location. I described and discussed the typology of the fragmentary vessels. Unfortunately, Mr Husband was unable to submit his presentation to these *Annales*; the other contributions appear here and in the following paper.

The great majority of the vessel glass is transparent and it varies in colour from light green to pale yellowish green. A small minority is colourless or almost colourless but with a brown or purple tint. A somewhat larger minority has been softened by intense heat, which caused distortion and the accretion of pebbles. This may be evidence of a fire and, if so, it may indicate that the objects were in use when the castle was destroyed in 1271.

Most of the objects fall into three functional groups: drinking vessels, bottles and lighting devices. The drinking vessels include a gilded and enamelled beaker (in the possession of the Israel Antiquities Authority: Brosh 1999, 266) and fragments of several prunted beakers (which are at the Metropolitan Museum). The latter (COLOUR PLATE 42) are barrel-shaped, with a horizontal trail at the top and the bottom of the wall, three or more rows of prunts and a kick. The fragments of drinking vessels at the Metropolitan Museum also include a tiny piece of gilded and enamelled glass – probably another beaker – with an Arabic inscription.

Most of the bottles have a long, narrow neck, sometimes with a bulge near the top (COLOUR PLATE 43), and an onion-shaped body, a folded foot-ring and a kick (COLOUR PLATE 44). Some are plain, while others have an overall pattern of ribs produced by inflating the paraison in a dip mould. The glass is thin and one of the necks is decorated with a blue spiral trail (COLOUR PLATE 45). There are also three exceptional pieces (COLOUR PLATE 46): two are represented by the necks of smaller vessels with one or more bulges, and the third is a cylindrical neck of relatively thick glass, with a continuous horizontal trail.

The lighting devices include fragments of a gilded and enamelled hanging lamp with an Arabic inscription (now owned by the Israel Antiquities Authority: Dean 1927, 34–6, fig. 50) and (at the Metropolitan Museum) fragments of hanging lamps with a funnel-shaped neck, a globular or roughly globular body, three or more vertical handles and presumably a base with a folded foot-ring. The neck is decorated with a bright blue spirally wound trail and the handles are either very pale green (like the body) or bright blue (like the trail). On four of the six handles at the Metropolitan Museum the lower attachment was dragged down the wall with a tool that created a broad rectangular depression (COLOUR PLATE 47). This immediately sets them apart from the familiar gilded and enamelled lamps of Syria and Egypt, which never have handles shaped like this.

The location of Montfort in a region with a very long history of glassmaking (Sidon is only 60km away) and the identity of its occupants (Crusaders in a largely Moslem country) raise questions about the source of the glass. The three gilded and enamelled objects are clearly Islamic (i.e. decorated in a manner associated with craftsmen in the Islamic world) and so, I suggest, is the bottle with a horizontal trail on the neck (the form has parallels among gilded and enamelled vessels of the 13th century, such as Jones and Michell 1976, 142, no. 135). Equally clearly, most of the other objects fall outside the repertoire of Islamic glass as we currently understand it. Few parallels exist among the large quantities of glass excavated at Hama in Syria (Riis and Poulsen 1957, 30–116) and Fustat in Egypt (Scanlon and Pinder-Wilson 2001), and those that occur are of the simplest forms. Good parallels for some of the fragmentary bottles, the prunted beakers and the distinctive handles of the hanging lamps, on the other hand, were found in 13th-century (i.e. Crusader) contexts at Acre (Gorin-Rosen 1997, who notes additional parallels from other sites in the region as well as evidence for glassmaking at Acre itself). Parallels for the prunted beakers and some of the bottles, for example, were excavated from the remains of a 13th-century glass workshop at Somelaria, which is 5km from Acre and 20km from Montfort (Weinberg 1987). Similar material, of course, is familiar to us from excavations much farther afield: in Greece (for example, at Corinth: Davidson 1952, 107–22), on the Dalmatian Coast (Križanac 2001) and in Italy (Newby 2000). Indeed, many of the forms found at Montfort would fit comfortably into assemblages of 13th to 14th-century glass from Italy, such as the finds from Tarquinia (Whitehouse 1987).

Thus, the Teutonic Knights of Montfort used glass vessels of types which occur widely in the central and eastern Mediterranean, but had very few objects which are recognizably Islamic. The chemical analyses tell us that most of these vessels were made by local suppliers, who seem to have produced the kinds of objects that appealed to the Europeans because they were popular at home. Similarly, the painter of the French-style stained glass window used panes that had been made locally. It is interesting to contrast this local production of glass with the importation of ceramic tablewares from Italy and elsewhere in the same period (Pringle 1982).

This emerging pattern of glass production and consumption is not the whole story. It is clear today that, at least until the 13th century, the glass industry in the Levant continued to function in the way it functioned in the Roman period, when a small number of large workshops supplied raw glass to a larger number of small workshops, where the raw glass was made into objects (Freestone *et al.* 2000). In the Middle Ages, Tyre (27km north of Montfort) was the site of at least one large workshop where raw glass was produced, sometimes in spectacular quantities. A document from the Cairo Genizah, written in 1011, records the export of about eight tonnes of (presumably) raw glass from Tyre to Egypt (Carboni *et al.* 2003, 141–4, 148) and it has been calculated that the last time it was used, one of the early medieval or medieval furnaces uncovered at Tyre produced approximately 37 tonnes of raw glass (Aldsworth *et al.* 2002, 66). (The famous glass slab at Bet She'arim weighs approximately nine tonnes: Freestone *et al.* 2000, 66.) According to William of Tyre, high-quality glass, suitable for making vessels, was still exported from Tyre in the late 12th century (Carboni *et al.* 2003, 146–7) and it is reasonable to assume that the production of raw glass continued there in the 13th century. (Jacques de Vitry, who was bishop of Acre between 1217 and 1227, reported that fine glass was made at both Tyre and Acre, but he did not indicate whether he was referring to raw glass or finished objects: Carboni *et al.* 2003, 147.)

The evidence from Montfort and the other Crusader sites mentioned above suggests that, in the 13th century, the local glass industry consisted of at least one major supplier of raw glass (at Tyre) and a number of small workshops, where vessel glass of 'European' and 'Islamic' type, and window glass were made (Somelaria was one such workshop). The vessels and window glass from Montfort may have been produced in more than one workshop, but most of it seems to have been made with raw glass from a single source.

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PRELIMINARY COMPOSITIONAL STUDY OF GLASS FROM THE CRUSADER CASTLE AT MONTFORT

Mark T. Wypyski and Lisa Pilosi

The excavation of the castle of Montfort under the auspices of The Metropolitan Museum of Art in 1926 was one of the earliest modern investigations of a Crusader site. Its principal aim, to retrieve medieval arms and armour, was largely unrealized, leading Bashford Dean, curator of the museum's Department of Arms and Armor and chief sponsor of the project, to conclude that his 'costly gamble' had been 'a dismal failure' (*New York Herald Tribune*, 19 September 1927). However, in his 1927 report of the excavation, Dean also recognized the potential of the seemingly humble finds to illuminate the daily life of Europeans in Crusader settlements (Dean 1927). Subsequent fieldwork at other Crusader sites has provided a context in which to view the finds from Montfort and the previous paper by David Whitehouse discusses this connection as well as typological and stylistic affinities of the Montfort glass with contemporary European and Islamic glass vessels.

This paper presents chemical analyses of a selection of glass fragments from Montfort, which were undertaken in an attempt to determine the possible source(s) of the glass. One of the most intriguing questions arising out of any stylistic study of Crusader glass is whether the 'European'-type vessels were imported as finished objects or whether they were made using local materials. The excavation of a Crusader-period glassworking furnace with associated glass chunks and wasters at Somelaria in the 1960s showed that glass objects were being produced locally (Weinberg 1987). However, until recently, there was an insufficient corpus of compositional analyses to investigate the origin of the raw glass used at furnaces such as that found at Somelaria. Recent work by a number of scientists on the composition of medieval glass in both the Levant and Europe now provides a strong basis for comparison, thus making it possible to view Crusader glass in a contemporary context based on its composition. In 1981, Robert H. Brill selected a number of glass fragments from Montfort for study and published, without commentary, the chemical analyses of samples from 20 of them in 1999 (Brill 1999, vol. 1, 114, vol. 2, 245–6). Apart from this, no other chemical analyses of securely dated Crusader glasses are known to have been published. For this study, 42 samples from 37 fragments of glass, comprising a representative overview of the various colours and forms of glass, were analysed. As a result of these analyses it is now possible to make some suggestions about the origins of the glass from Montfort.

Analytical technique

Small samples of the glass fragments were removed using a diamond-edged scribe and embedded in epoxy. The embedded samples were ground, polished and given a conductive carbon coating. The samples were analysed at the Metropolitan Museum using an Oxford Instruments INCA analyser equipped with both energy dispersive and wavelength dispersive X-ray spectrometers (EDS/WDS) attached to a LEO Electron Microscopy model 1455 variable pressure scanning electron microscope (VP-SEM). Analyses were performed under high vacuum conditions at an accelerating voltage of 20kV, with a beam current of approximately 1nA used for EDS analysis, and 50nA for WDS analysis.

Weight percentage concentrations of the elements detected were calculated in comparison to a range of well-characterized standards and reference glasses (Verità *et al.* 1994). Peak overlap problems and the relatively high minimum detection limits (MDL) with the EDS were obviated with the use of the WDS detector to analyse for elements present or possibly present in very small amounts. The MDL with WDS under these operating conditions was estimated at *c.* 0.01% for most of the elements searched for here, with lead oxide estimated at *c.* 0.05%.

Results

Table 1 shows the quantitative results for the combined EDS and WDS analyses of 20 elements commonly found in ancient glasses (arsenic and antimony were also sought, but were not detected in the overall composition of any of these samples). The results, given in oxide weight percentages, are from EDS analysis for the major and minor components 1% or higher, while amounts less than 1% are from WDS analysis. Elements listed as 'nd' were not detected by EDS or WDS analysis. The samples are identified by the last part of the Metropolitan Museum accession number for the fragment, with a description of the fragment type and the colour of the glass. All of the glasses are translucent; most are colourless or weakly coloured. Semi-quantitative analyses, not listed in the table, were also undertaken on the red enamel from a gilded and enamelled vessel fragment (28.99.327) and inclusions in one of the blue glasses (28.99.65a).

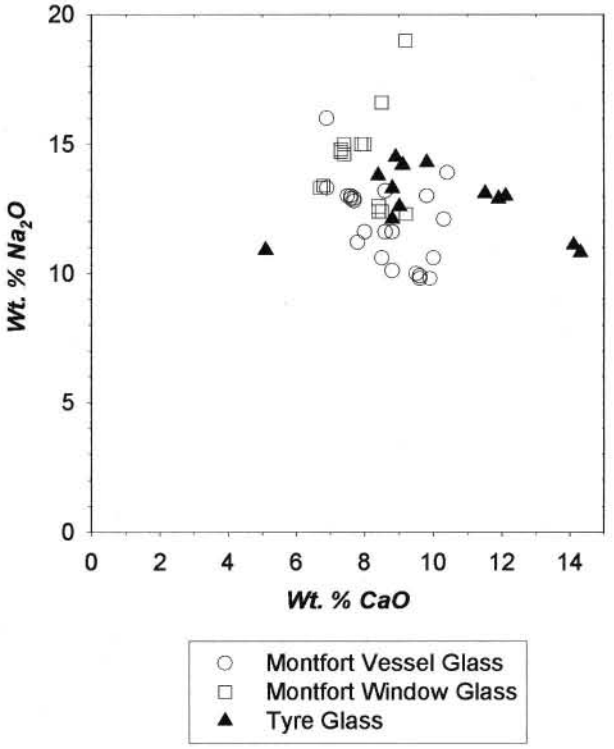

FIG. 1 Comparison of soda and lime concentrations of glasses from Montfort and Tyre (data from Freestone 2002)

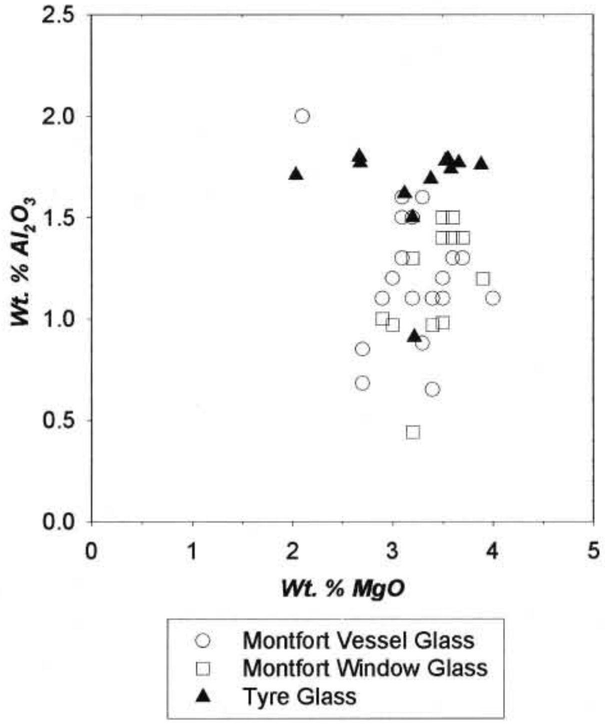

FIG. 2 Alumina and magnesia concentrations of glasses from Montfort and Tyre

Overall compositions

All of the glasses analysed have soda-lime-silica (Na_2O-CaO-SiO_2) compositions, with relatively high levels of magnesia and potash (MgO and K_2O). Soda contents vary between *c.* 10 to 15%, while lime generally varies between *c.* 7 to 10%. The soda content of the window glasses averages slightly higher than that of the vessel glasses, while the lime content averages slightly lower (FIG. 1). Magnesia values mainly range from somewhat less than 3 to a maximum of 4%, while potash varies from *c.* 2 to 3.5%, with an average ratio of magnesia to potash of *c.* 1.3 to 1. Alumina (Al_2O_3) levels were generally relatively low, from less than 1 to *c.* 1.5% (FIG. 2). Glasses with this type of composition are generally thought to have been produced using quartz pebbles as the silica source and the ash of halophytic plants as the alkali. The group of glasses analysed, however, is not homogeneous, and includes several compositional outliers. For example, a yellowish window glass fragment (28.99.326) contains significantly more soda than any of the other glasses, while a fragment of a prunted beaker (28.99.210) was found to contain significantly less magnesia and more alumina than any of the other samples analysed.

There are traces of other elements in all of the glasses, regardless of the colour, which were presumably added unintentionally with the raw materials of the primary melt. Chlorine (Cl) was consistently close to 1% in all of the glasses. Phosphate (P_2O_5) is also present in the glasses, from *c.* 0.2 to 0.5%. Traces of sulphur, titanium, strontium and barium oxides (SO_3, TiO_2, SrO and BaO) were also found in all of the glasses.

Colorants and decolorants

Iron oxide (reported here as Fe_2O_3) and manganese oxide (MnO) are present in all of the Montfort glasses. Both may be adventitiously introduced into glass along with the raw materials of the primary melt, and/or intentionally added as a colorant. Iron oxide is present in most of the glasses at *c.* 0.3 to 0.6%, although it is higher in the blue and green glasses, reaching a maximum of 1.6% in one of the blues (26.99.65a).

The amount of manganese oxide also varies, generally between *c.* 0.5 to 1%, but it is below 0.1% in a yellowish window glass fragment (28.99.326), and as high as 1.4% in a purple window glass fragment (28.99.614). Most of the manganese in these glasses was probably intentionally added in an attempt to produce a colourless or nearly colourless glass, by counteracting the colorant effects of the iron, or to colour the glass purple. The effect depends mainly on the oxidation state of the manganese and is not dependent on the amount present. For example, of the five glasses containing *c.* 1.5% manganese oxide, two are purple and three are colourless. In general, the amount of manganese oxide in the colourless or weakly coloured glasses is less than 1%, with an average ratio of manganese oxide to iron oxide of *c.* 1.5 to 1. Barium oxide contents were slightly higher in the two purple glasses than most of the others, including the high manganese colourless glasses. This might be evidence for the use of a different manganese ore source for purple colouration than that used to decolourize glass.

The seven samples of blue glass analysed (including both the applied blue decoration on the vessel glasses and the blue window glass) all contain cobalt oxide (CoO) as the colorant. In contrast to most of the colourless and weakly coloured glasses, these cobalt-containing glasses also

TABLE 1 EDS/WDS ANALYSES OF GLASS FROM MONTFORT (WT%)

MMA Acc no. 28.99.	Fragment description	Colour	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3	CoO	NiO	CuO	ZnO	SrO	SnO_2	BaO	PbO
327	Gilded and enamelled Islamic vessel	Colourless	12.1	2.7	0.85	68.2	0.34	0.26	0.74	2.6	10.3	0.08	1.2	0.50	nd	nd	0.01	nd	0.06	nd	0.04	nd
66b	Neck of Islamic bottle	Colourless	11.6	2.7	0.68	70.4	0.30	0.18	0.70	2.8	8.6	0.06	1.5	0.39	nd	nd	nd	nd	0.04	nd	0.02	nd
343	Base with kick	Colourless	13.0	3.3	0.88	67.7	0.29	0.22	0.84	1.9	9.8	0.12	1.3	0.39	nd	nd	0.01	0.01	0.05	nd	0.04	0.08
60	Cover (?) with knob	Colourless	11.6	3.3	1.6	69.6	0.31	0.17	0.84	2.6	8.8	0.07	0.57	0.39	nd	nd	nd	nd	0.03	nd	0.03	nd
548	Rim and neck of bottle	Colourless	13.0	3.2	1.5	70.0	0.24	0.21	0.85	2.5	7.5	0.05	0.47	0.32	nd	nd	nd	nd	0.07	nd	0.03	nd
82	Rim of urinal (?)	Colourless	9.8	3.5	1.1	70.4	0.36	0.17	0.87	2.5	9.6	0.18	0.67	0.56	nd	nd	0.02	nd	0.06	nd	0.06	nd
340	Base with kick and foot-ring	Colourless	10.6	3.7	1.3	68.2	0.49	0.25	0.79	3.0	10.0	0.18	0.69	0.61	nd	nd	0.02	nd	0.05	nd	0.05	nd
233	Internal rib	Colourless	11.2	3.5	1.2	70.7	0.51	0.20	0.81	2.7	7.8	0.13	0.56	0.53	nd	nd	0.01	nd	0.04	nd	0.01	nd
65f	Prunted beaker	Yellowish	13.9	3.4	0.65	66.9	0.26	0.30	0.82	2.6	10.4	0.07	0.29	0.30	nd	nd	nd	nd	0.06	nd	0.02	nd
210	Prunted beaker	Yellowish	16.0	2.1	2.0	67.7	0.34	0.17	0.98	2.3	6.9	0.17	0.51	0.81	nd	nd	0.01	nd	0.03	nd	0.01	nd
68	Handle of hanging lamp	Greenish yellow	13.0	3.1	1.5	69.9	0.24	0.21	0.87	2.6	7.5	0.06	0.49	0.34	nd	nd	nd	nd	0.06	nd	0.04	nd
101	Lamp (?)	Greenish	9.9	3.4	1.1	70.6	0.37	0.18	0.91	2.5	9.6	0.17	0.64	0.51	nd	nd	0.01	nd	0.05	nd	0.05	nd
69a	Rim and neck of bottle	Greenish	10.0	3.4	1.1	70.5	0.37	0.20	0.89	2.5	9.5	0.17	0.66	0.52	nd	nd	0.01	nd	0.06	nd	0.05	nd
551	Rim and neck of bottle	Greenish	9.8	3.6	1.3	69.8	0.47	0.21	0.87	2.6	9.6	0.19	0.60	0.65	nd	nd	0.02	nd	0.05	nd	0.06	nd
544	Rim and neck of bottle	Greenish	10.6	3.5	1.2	70.6	0.39	0.24	0.81	2.6	8.5	0.13	0.71	0.55	nd	nd	0.02	nd	0.06	nd	0.05	nd
289	Base with kick and footring	Greenish	9.8	3.4	1.1	70.4	0.36	0.19	0.85	2.6	9.9	0.15	0.62	0.49	nd	nd	0.02	nd	0.05	nd	0.05	nd
156	Base with kick and footring	Greenish	10.1	3.0	1.2	71.2	0.49	0.23	0.78	2.9	8.8	0.14	0.42	0.53	nd	nd	0.02	nd	0.05	nd	0.04	nd
66a	Base with kick and footring	Greenish	10.1	3.1	1.3	71.0	0.47	0.22	0.76	2.9	8.8	0.13	0.42	0.53	nd	nd	0.03	nd	0.04	nd	0.04	nd
67	Handle of hanging lamp with blue trails	Colourless	13.0	3.1	1.5	70.0	0.26	0.23	0.94	2.5	7.5	0.06	0.47	0.33	nd	nd	nd	nd	0.06	nd	0.03	nd
67	Handle of hanging lamp with blue trails	Blue	12.9	3.1	1.5	69.2	0.26	0.22	0.89	2.5	7.7	0.06	0.49	0.73	0.05	nd	0.05	0.04	0.06	nd	0.02	0.24
59a	Neck with blue spiral trails	Colourless	11.6	2.9	1.1	70.2	0.50	0.18	0.69	3.1	8.0	0.10	0.97	0.52	nd	nd	0.02	nd	0.04	nd	0.07	nd
59a	Neck with blue spiral trails	Blue	11.6	2.9	1.1	69.3	0.44	0.19	0.68	3.0	8.0	0.11	0.92	0.99	0.05	nd	0.21	0.11	0.05	nd	0.07	0.14
65a	Rim of hanging lamp with blue trails	Colourless	13.2	4.0	1.1	67.5	0.50	0.26	0.88	2.6	8.6	0.12	0.52	0.61	nd	nd	nd	nd	0.06	nd	0.04	nd
65a	Rim of hanging lamp with blue trails	Blue	13.3	3.2	1.1	68.2	0.38	0.21	0.88	2.5	6.9	0.11	0.54	1.6	0.10	nd	0.32	0.14	0.05	0.01	0.05	0.35
347	Rim of hanging lamp with blue trails	Colourless	12.9	3.1	1.6	69.8	0.24	0.19	0.91	2.6	7.6	0.07	0.53	0.39	nd	nd	nd	nd	0.06	nd	0.03	nd
347	Rim of hanging lamp with blue trails	Blue	12.8	3.1	1.6	68.2	0.27	0.19	0.87	2.6	7.7	0.07	0.53	1.0	0.24	0.01	0.23	0.19	0.07	0.03	0.02	0.37
681	Handle of hanging lamp	Colourless	13.0	3.1	1.6	69.8	0.23	0.17	0.89	2.6	7.6	0.06	0.53	0.39	nd	nd	nd	nd	0.06	nd	0.03	nd
681	Handle of hanging lamp	Blue	13.0	3.1	1.5	69.2	0.24	0.19	0.87	2.5	7.6	0.06	0.55	0.58	0.07	nd	0.08	0.04	0.06	nd	0.02	0.19
680	Window – painted	Pinkish	12.6	3.6	1.5	67.9	0.42	0.25	0.80	3.4	8.4	0.07	0.71	0.33	nd	nd	nd	nd	0.05	nd	0.03	nd
570	Window	Colourless	12.4	3.7	1.4	68.0	0.43	0.28	0.78	3.5	8.4	0.05	0.65	0.30	nd	nd	0.01	nd	0.05	nd	0.04	nd
651	Window – painted	Colourless	12.4	3.5	1.5	68.1	0.40	0.23	0.76	3.4	8.5	0.06	0.71	0.32	nd	nd	nd	nd	0.05	nd	0.03	nd
609	Window	Colourless	14.6	3.5	1.5	68.3	0.24	0.26	0.90	2.3	7.4	0.06	0.60	0.30	nd	nd	0.01	nd	0.03	nd	0.03	0.08
648	Window – painted	Colourless	14.7	3.5	1.4	68.4	0.22	0.26	0.94	2.2	7.3	0.06	0.62	0.33	nd	nd	0.01	nd	0.03	nd	0.02	0.06
674	Window – painted	Colourless	14.8	3.5	1.4	68.4	0.22	0.24	0.89	2.2	7.3	0.06	0.59	0.30	nd	nd	0.01	nd	0.04	nd	0.02	0.05
658	Window – painted	Greenish	15.0	3.6	1.4	67.8	0.25	0.24	1.0	2.2	7.4	0.05	0.63	0.32	nd	nd	nd	nd	0.05	nd	0.02	0.05
326	Window – painted	Yellowish	19.0	3.9	1.2	62.4	0.31	0.32	0.94	2.5	9.2	0.05	0.07	0.27	nd	nd	nd	nd	0.03	nd	0.01	nd
663	Window	Blue	16.6	3.2	1.3	64.4	0.33	0.33	1.0	2.7	8.5	0.05	0.31	0.68	0.14	nd	0.16	0.13	0.04	0.01	0.03	0.16
676	Window	Blue	12.3	3.2	0.44	69.4	0.28	0.24	0.93	1.7	9.2	0.15	0.42	0.87	0.13	nd	0.20	0.24	0.04	0.01	0.02	0.21
627	Window	Green	15.0	3.4	0.97	63.2	0.32	0.23	0.76	2.6	8.0	0.07	0.65	1.1	nd	nd	3.4	nd	0.06	0.20	0.01	0.16
671	Window	Green	15.0	3.5	0.98	63.0	0.31	0.22	0.79	2.5	7.9	0.07	0.67	1.1	nd	nd	3.5	nd	0.05	0.20	0.01	0.22
614	Window	Purple	13.4	2.9	1.0	69.8	0.46	0.24	0.89	2.5	6.8	0.10	1.3	0.45	nd	nd	0.04	0.02	0.03	nd	0.09	nd
679	Window	Purple	13.3	3.0	0.97	70.0	0.46	0.25	0.89	2.5	6.7	0.10	1.4	0.44	nd	nd	0.02	nd	0.04	nd	0.08	nd

nd= not detected

contain traces of lead (PbO), zinc (ZnO) and copper (CuO), as well as somewhat elevated iron contents. Small traces of tin (SnO_2) were found in four of the seven blues. Analyses of inclusions in one of the blue glasses (the blue trail on 28.99.65a), show them to consist mainly of iron, cobalt and zinc, with small amounts of tin, antimony (Sb_2O_3) and copper, and traces of lead, nickel (NiO), and arsenic (As_2O_3), although the amounts of antimony, nickel and arsenic present in the glass overall are less than the WDS minimum detection limits. These inclusions appear to be remnants of cobalt-containing ore which did not fully dissolve in the glass. A scanning electron microscope image of a sample of this glass (FIG. 3) reveals several particles suspended in a bright streak in the glass matrix. The bright streak contains several percent of lead oxide, although the overall percentage in the glass is less than 0.4%, and only a trace of lead was found in the particles themselves, suggesting that the lead might have been added separately to the glass with the cobalt, possibly in the form of a cobalt-rich frit. In addition, the ratio of copper to cobalt is much higher in the overall glass than in the particles, indicating that it too was a separate addition to the blue glass, although the small percentages of copper found in the blues would not appear to have much effect on the colour.

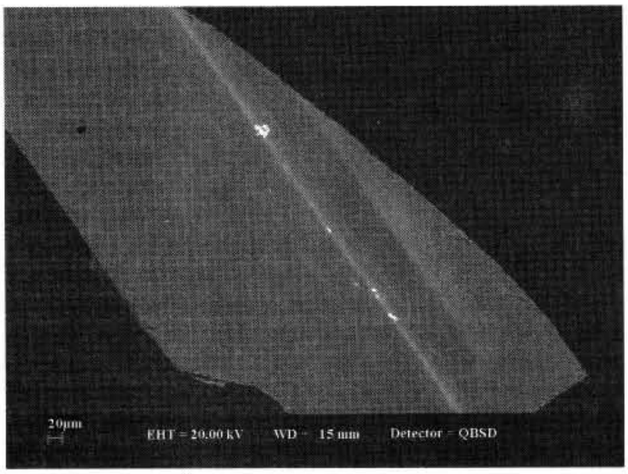

FIG. 3. Scanning electron micrograph of a cross-sectioned sample of the blue glass trail from fragment 28.99.65a (original magnification 300X)

The two green glass samples analysed are coloured by the addition of copper oxide (CuO), which can produce a range of colours from aqua blue to green, depending on the oxidizing conditions and the other elements present in the glass. Iron oxide is also somewhat elevated in these glasses, probably intentionally added to help shift the colour more towards the green end of the spectrum. Small amounts of tin and lead oxides are present in the green glasses, possibly due to the use of a bronze or leaded bronze alloy as the copper source. In contrast to the small amounts of cobalt oxide found in the blues, more than 3% of copper oxide was used to colour the green glasses. The two green glass samples analysed are essentially identical in composition, and appear to have come from the same source, if not the same batch of glass.

The red enamel on the small fragment of gilded and enamelled vessel glass (28.99.327) consists mainly of silica, lead and iron, and appears to be similar to the high lead red enamels found on two Islamic enamelled glass fragments from the British Museum (Freestone and Stapleton 1998, 123–5).

Discussion

Comparison of the compositions of the Montfort glass samples with published results of contemporary soda-based plant ash glasses from the Levant and Europe reveals significant similarities and differences. Although relatively few analyses of glass from the nearby glassmaking site at Tyre have been published (Freestone 2002), these show comparable levels of most of the major components, such as magnesia and potash. Whereas the alumina contents in most of the Tyre glasses average somewhat higher than those from Montfort, one of the glass samples from Tyre contains less than 1% of alumina, as do several of the Montfort samples. Two blue glasses from Tyre are distinguished from the others by somewhat lower magnesia contents, in about a 1:1 ratio to potash, which was also true of a few of the Montfort glasses (such as 28.99.66b and 28.99.327).

Glasses from several medieval Islamic sites also exhibit compositional similarities to the glass from Montfort. Finds from the glassmaking site at Raqqa in northern Syria, dated from the late 8th to early 9th through the 11th century, have been grouped into several different compositional types. One of these groups, designated type 1, based on summaries of the data, appears to have a similar overall composition to the Montfort glass (Henderson and McLoughlin 2003, 146–7). Also like most of the Montfort glass, the alumina levels average slightly lower than the glass from Tyre. Plant-ash glasses from Fustat in Egypt, dated from the 9th to the 13th century, are also similar in composition to the glass from Montfort, with somewhat lower mean alumina and soda levels than the glass from Tyre (Brill 1999, vol. 1, 87–8, vol. 2, 168–70). Like some of the Montfort glasses (such as 28.99.69a and 28.99.101), the Fustat plant ash glasses have an average soda to lime ratio of almost exactly 1:1, lower than most other reported Islamic glasses.

Comparison of the Montfort glass with data reported from a large assemblage of cullet from the Serçe Liman wreck dated to *c*. AD 1025 (Brill, 1999, vol. 1, 89–92, vol. 2, 178–87) shows several differences in composition. The Serçe Liman glasses are for the most part also plant ash based and some contain high percentages of magnesia and low levels of alumina like the Montfort glasses. However, the majority have lower levels of magnesia and higher levels of alumina than the Montfort glass, like the two blue glasses from Tyre noted earlier. Similarly, glass from Banias, in modern Israel, dated from the 11th to the 13th century, contains somewhat lower magnesia values than the Montfort glasses, although the alumina values are rather low, similar to many of the Montfort samples (Freestone *et al*. 2000, table 2).

Although potash-lime glasses are usually associated with medieval European glass production, soda-based plant ash glasses were also produced, particularly in northern Italy and France (Pause 2000; Foy 2001; Uboldi and Verità 2003). These glasses generally contain higher levels of potash, alumina and phosphorus than either Venetian or

Islamic glasses, probably due to the use of more impure silica sources and a different type of plant ash. Analyses of Venetian *vitrum blanchum* glass have shown that it is very similar to Islamic glass, and historical documents attest to the use of plant ash imported from the Levant in Venetian glassmaking from at least the mid 13th century (Verità 1985). Comparative studies of 13th and 14th-century enamelled Venetian and Islamic glasses show compositional similarities among these two groups (Freestone and Bimson 1995; Verità 1995; Freestone and Stapleton 1998). While the Montfort glass is also very similar to these two groups, the average lime content is closer to that of the Islamic than to the Venetian glasses.

Conclusions

Comparison of the compositions of a representative sampling of glass objects and windows excavated at the Crusader castle at Montfort with glass from a number of medieval Islamic and European sites suggests that the glass used at Montfort was produced locally. However, the limited amount of comparative material from other Crusader sites precludes the identification of a precise location of the glass manufacture, and the possible use of Venetian glass, although unlikely, can not be entirely dismissed. Preliminary analyses of a few samples of chunk glass from the furnace at Somelaria from the collection of the late Dr Gladys Weinberg revealed close similarities with the glass from Montfort and Tyre. Future work will seek to increase the available data of Crusader glass by analysing more samples of the Montfort fragments as well as samples from other sites, such as Acre, where it will be interesting to compare the glass from similar vessel types, as well as the unworked chunk glass, which might shed more light on the sources of raw glass used by the medieval glassmakers of the Levant as well as possible connections with the Venetian glass industry.

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FRAGMENTS OF COLOURED GLASS WITH APPLIED DECORATION FOUND IN SINGAPORE

BRIGITTE BORELL

The remains of ancient Singapore are buried today under the modern town, that is under the colonial centre of 19th-century Singapore. In Malay literary tradition Temasek/Singapore is portrayed as the Malay capital, prior to the founding of Malacca around the year 1400. Whereas this may be a slightly exaggerated view, Singapore in the 14th century is best understood as a trading port cum residence of the local ruler. The existence of a settlement and port of some significance at Temasek/Singapore is attested also by Chinese and Javanese written sources of the 14th century. The founding of Malacca by the last ruler of Temasek/Singapore marks the beginning of the decline of Singapore (Borell 2001).

Situated at the southern end of the Strait of Malacca, the great thoroughfare between the Indian Ocean and the South China Sea, part of the so-called Silk Road of the Sea, ancient Singapore flourished for a period of not much more than 100 years, roughly speaking from *c.* 1300 to *c.* 1400. From archaeological finds it is clear that ancient Temasek/Singapore was well integrated with the international trade network of the time. Chinese ceramics constitute the largest component in the ceramic assemblage; only few pieces of Vietnamese and Thai glazed ceramics have been recovered, besides the local low-fired earthenware and some fine earthenware probably imported from Thailand. In addition other artefacts have been found, among them a number of Chinese coins, and in one of the downtown sites a coin from Sri Lanka with a date in the late 13th century (Borell 2000).

The dating of the cultural layers at the three Temasek/Singapore archaeological sites is based mainly on datable finds of Chinese ceramics. The site on Fort Canning Hill appears to have been occupied for the shortest period of time according to Chinese ceramics of the middle and late Yuan Dynasty, i.e. from *c.* 1300 to 1360/70 – all other signs of occupation on the hill (top layer) deriving from the 19th and 20th centuries. At the two downtown sites, occupation indicated by Chinese ceramics covers a longer period: one site from the 13th (late Song and early Yuan) to the late 14th/early 15th century (early Ming) and the other from the late 13th to the mid 15th century (Miksic 2000a; 2000b).

Most of the glass has been found in archaeological excavations at Fort Canning Hill, the ceremonial and political centre of ancient Singapore. It came from the north-east slope of the hill in an undisturbed layer containing 14th-century artefacts (Miksic 1989; 1995, 255, map 4). In general, the glass finds can be assigned to four categories – beads, vessels, bangles and dribbles and drops characteristic of glassworking (Borell 2001, 47–50).

The majority of the vessel fragments are from blown vessels. Only a few fragments of opaque white glass with polychrome decoration are made in a different technique – probably by the core-forming method – and can be reconstructed as miniature jarlets, their shape imitating the Chinese ceramic jarlets dated to the Yuan dynasty (Borell 2003).

DESCRIPTION

Here I am focusing on a small group of blown glass vessels of an unusual shape which have some features in common. Only small fragments survived, generally one rim fragment representing one vessel. They can be reconstructed as small vessels, about 100mm in diameter at the rim. The glass is extremely thin-walled, measuring about 1mm in thickness or even less, and has numerous small bubbles. Glass colours are translucent dark blue or purple with some additions of clear glass to form the rim. The decoration consists of applied threads of opaque glass. With regard to their technique the fragments display superb craftsmanship. This is true also for the quality of the glass itself – even when found in the layer of sandy loam on the hill it was in excellent condition.

1 FTC 10913/9962/XI. Three joining rim fragments of a vessel made of translucent purple glass with a slightly curved wall. The inverted rim is not made of the purple glass of the body. Instead, some clear glass with an olive-green tinge has been added and shaped into a rim horizontally protruding towards the interior thus forming two concentric bulges separated by a rounded groove between them. Several threads of opaque yellow glass have been added as decoration: three on the upper part of the purple wall, and two on the clear glass of the rim (on top of the two bulges). Rim diameter *c.* 90mm, wall thickness *c.* 1mm and less (COLOUR PLATE 48, FIGS 1.1, 2.1).

2 FTC 24314. Rim fragment of a vessel made of translucent purple glass. The rounded exterior part of the rim was made by folding the glass over. Then some clear glass with an olive-green tinge was added on the inner side to form the inward protruding part of the rim. Threads of opaque white glass were added as decoration: one on the clear glass on the innermost protuberance of the rim, the other on the rounded part of the rim made of the purple glass. Rim diameter *c.* 8mm, wall thickness *c.* 1mm (COLOUR PLATE 49, FIGS 1.2, 2.2).

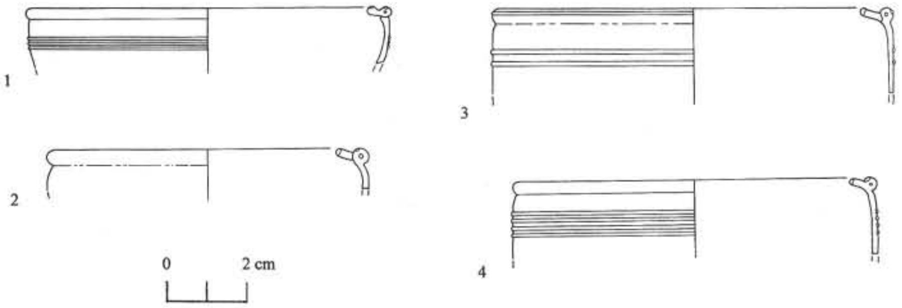

FIG. 1 Glass from Fort Canning Hill, Singapore.

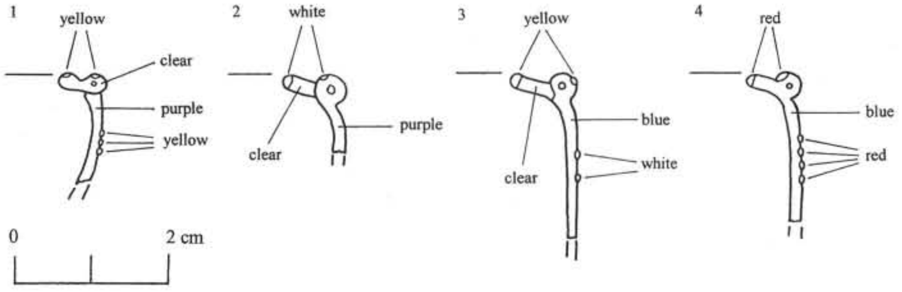

FIG. 2 Colour details of FIG. 1

3 FTC 19350 Rim fragment of a vessel made of translucent dark blue glass, the wall rather straight with a slight indentation just below the rounded rim formed by the folded over end of the wall. On the inside of the rounded rim some clear glass with a green tinge has been added to form the inward protruding part of the rim. The piece has been decorated with two threads of opaque yellow glass applied on the rim, and two threads of opaque white glass on the wall below the rim. Rim diameter *c.* 100mm, wall thickness 1mm (COLOUR PLATE 50 left, COLOUR PLATE 51 left, FIGS 1.3, 2.3).

In this case a maximum of four different colours were used on the same piece. The other two fragments previously described have three different colours and the next fragment has only two different colours.

4 FTC 4327 Rim fragment of translucent dark blue glass. The profile is very similar to no. 3 with a straight wall and a slightly offset rim with a bulge on the outside and protruding towards the interior, only in this case with the difference that wall and rim are made from the same translucent dark blue glass. Decoration consists of applied threads of opaque red glass: two on the rim, and four on the wall below the rim. Rim diameter *c.* 90mm; wall thickness 1mm (COLOUR PLATE 50 right, COLOUR PLATE 51 right, FIGS 1.4, 2.4).

What type of vessel was it and what was its purpose? Because of the particular shape of the rim, use as a drinking vessel can be excluded. Was it intended to hold liquids at all? A rim turning inward could be intended to prevent spilling, but the liquid would have to be poured out by other means; usually one would expect such a rim to be combined with a pouring device, for instance some sort of spout. Among the surviving fragments there are none indicating a spout or anything similar. Therefore, it seems more likely to suggest a use for substances other than liquids. One might ask whether the interior protrusion of the rim – measuring *c.* 7 to 8mm across – was meant to support a lid. Some fragments have rather straight walls so they might be reconstructed in an approximately cylindrical shape. In this case the shape should be reconstructed as round boxes rather than bowls. It seems reasonable to suggest a use for storing some pastey or solid material – certainly lightweight to judge from the thin walls of the glass containers.

So far no base fragments can be ascribed to any of these vessels; no further clues are thus available for the reconstruction of their shapes. The strange fact that no more fragments from wall or base have survived is explained when we consider the situation in which the fragments were found. Nearly all the glass was concentrated in a rather limited area on the hill. Among the glass were also some distorted vessel glass fragments, as well as dribbles and drops of glass suggesting that some glassworking activity took place at the site. Qualitative XRF analyses of some examples of the glass – mainly focusing on trace elements – allowed different groups to be distinguished; for instance, the driblets of glass, the bangles of simple shape and some of the vessel glass fragments were grouped together. This led to the conclusion that broken glass vessels, brought there from somewhere else, were melted down for the manufacture of simple bangles (Miksic *et al.* 1994; Miksic 1995; Miksic *et al.* 1996). Therefore, judging from the situation in which it was found, the imported vessel glass can be regarded as scrap glass being used for recycling.

The question is still open whether the glass was already broken and imported as scrap glass; or whether the glass vessels were imported originally because they were valued on their own as a commodity; or whether they were simply the containers for some precious goods that would be the real merchandise? The answer we cannot say for certain but, whatever the answer, glassworking on the site can only have been carried out on a small scale. It is most unlikely that the blown glass vessels, which are of a superior technique and quality, would have been manufactured there. They must have been brought to Singapore from somewhere else. To my knowledge, no finds of glass of this kind are reported from other sites in south-east Asia. Where could they have come from?

So far I have not found a close parallel for the shape of these receptacles anywhere which would allow a precise attribution to a well-defined group of glass in its regional and chronological classification. Since the small delicate glass vessels show an excellent craftsmanship they must have been made by experienced glassworkers well versed in dealing with several differently coloured glasses.

The Indian Ocean trade

The colour range of the glass used for the manufacture of this group of vessels resembles that of Islamic glass of the later medieval period (Kolbas 1983). Besides the universal clear glass with a brownish/greenish tinge, the coloured glass in translucent blue and purple, combined with decoration of trailed-on threads in opaque colours – white, yellow, and red – can be compared to the so-called group of marvered glass which seems to have been popular from the late 12th to the 14th century and possibly even into the 15th century (Shindo 1993; Allan 1995; Carboni 2001, 291–3). There is a difference in the colour combinations on the glass from Singapore – for instance opaque red on translucent blue or the combined use of opaque white and opaque yellow – which does not follow the customary colour combinations used for the marvered group.

Finds of imported Islamic glass in south-east Asia would not be uncommon. Islamic glass has been found at several sites there with dates from the 9th century onwards. Some of the earlier glass has been ascribed to the Iranian region, for instance the finds in southern Thailand (Bronson 1996) and Vietnam (Shindo 2000). From the locations of the sites it is evident that the glass reached its destination via maritime routes. At Barus (Lobu Tua) on the west coast of Sumatra, a site dating from the end of the 9th century to *c.* 1100, glass from the Iranian region has been identified, for instance a flask of the bichrome variety, made of translucent dark blue and clear glass; as well as glass from the Syrian or Egyptian region, for instance marvered glass of the early period (Guillot and Wibisono 1998). In the case of Pengkalan Bujang on the west coast of the Malay Peninsula, a site dated mainly to the 12th, 13th and the beginning of the 14th century, some of the glass found has been compared to finds at the Red Sea port of Quseir, dated to the 13th and 14th century, i.e. the Mamluk period (Lamb 1965; Whitcomb 1983, 105). The glass lamp found at Pengkalan Bujang might also be ascribed to the Syrian region (Lamb 1966, pl. 1; Liu 1987, 19 illus.).

It seems some Islamic glass reached Singapore. Among the glass fragments found in the same 14th-century archaeological context on Fort Canning Hill, there are two fragments made of translucent dark blue glass with opaque white threads, marvered and combed like the so-called group of marvered glass (Borell 2001, 47–8). They come from two different vessels. The shape of the original vessel cannot be recognized, but it is possible to say that they were not the frequently found kohl flasks as the estimated diameters are much larger. One fragment (Miksic 1995, 259, fig. 4.FTC 1800) has an estimated diameter of at least 70mm, it might have been part of a bottle with a wide body. The other fragment (Miksic 1995, 257, fig. 6) seems to have belonged to a slightly carinated shape, perhaps resembling that of the glass jars found at al-Tur, on the south-western coast of the Sinai Peninsula, in a 14th/15th-century context (Shindo 1993, 301, figs 5, 6).

There is another object from Singapore which also finds parallels among glass of the Mamluk period. It is the fragment of a glass bracelet (Borell 2001, 49, fig. 17). The core is made of translucent greenish glass, encased on the outer side by a layer of opaque yellow with a strip of reddish brown glass along the ridge, studded with prunts of opaque white glass. It is a characteristic type of Islamic bracelet (Shindo 2001, 90, subtype D3) which can be found dispersed over a large area from the Eastern Mediterranean, the Red Sea ports, along the Yemen and Oman coasts to the Makran and to North-west India. Though not always found in a dated context, they occur also in the above-mentioned excavations at al-Tur and at Quseir in contexts dated to the Mamluk period (13th–15th century), i.e. a period partly contemporary with the stratum from Singapore.

If these fragments are rightly identified as products of western Islamic glass they would have reached Singapore via the maritime routes probably from the Red Sea ports across the Indian Ocean and through the Strait of Malacca. Despite the period of the *pax Mongolica* which encouraged the use of the land routes of the Silk Road, it was certainly the maritime Silk Road which took the bulk of the trade.

In the Mamluk period the Indian Ocean trade was largely in Islamic hands, contemporary written sources mention the Karimi merchants as well as Indian Muslim merchants (Meyer 1992, 97–103; Kulke 1998; Haarmann and Zantana1998). Arabic was the *lingua franca* of the maritime trade. Marco Polo in his travelogue (Book 3, chapter 11), describing his journey back in 1292, says about the kingdom of Perlak (Ferlac) in north-east Sumatra that Saracen merchants frequented it with their ships on a regular basis. It is also interesting to note that the reason Marco Polo (Book 1, chapter 1) gives for choosing the sea route from Quanzhou for his return journey was the safety of the maritime trade route compared to the more dangerous and insecure land routes at the time of his return. The Indian Ocean trade conducted by the Muslim merchants flourished until the late 15th century, when the Portuguese arrived on the scene.

Conclusion

The unusual rim profile suggests that the glass vessels discussed here were designed for a special purpose. They might be reconstructed as a kind of box for storing some small items of a solid material; to judge from the shape of the rim they were probably meant to be covered – and possibly sealed – by a lid perhaps even made of some other material. It is very tempting to view them as containers for some precious goods, for instance aromatics, to protect them from the moisture of sea transport. One might think of goods such as frankincense and myrrh which were shipped from South Arabia even to China.

So far, they constitute an unusual group, for which – to my knowledge – precise comparisons from other site-finds are not yet known. Their archaeological context dates from the 14th century. As demonstrated, the chronological range of some other glass from the same context points likewise to a date in this period – late 13th and 14th century.

Since the coloured glasses used for their manufacture are similar to those used for the marvered group of Islamic glass of that time, I suggest that they might in some way be related to coloured glass from the Mamluk period. Possibly this relationship was limited only to the use of the coloured raw glass – judging by its appearance only, this can be no more than a suggestion to be confirmed or contradicted by future analyses. The vessels would have been manufactured in a glass workshop somewhere else, but presumably at a place located along the routes of the Indian Ocean trade.

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COMPOSITION OF CAROLINGIAN GLASS IN EUROPE

K. HANS WEDEPOHL

Large parts of post-Roman Europe were successfully incorporated in the Carolingian Empire under Christian rule. Under the Empire about 600 monasteries were founded; and these aided the preservation of some of the achievements of Roman civilization. The large Roman vessel glass production had used soda-lime glass from a standardized proportion of quartz sand, sodium carbonate (trona of the Egyptian Wadi el Natrun) and lime in the form of shells. This continued to be the major glass type until the last centuries of the 1st millennium AD, though containing slightly less sodium and more calcium than Roman glass had.

Monasteries were the prominent glass consumers during the Carolingian period. We have investigated window panes and vessel glass from excavations at the sites of three famous monasteries: Fulda, Lorsch and Corvey which were founded in 744, 764 and 822 respectively. Near the palace of Charlemagne at Paderborn, built in 776, there are the remains of a glass workshop containing raw glass, crucible fragments and tesserae as well as finished products. In Pannonia, west of Lake Balaton, we have sampled fragments of coloured window panes from a 50m long pilgrim's church founded at Zalavar/Mosaburg between 855 and 870. The results of our chemical investigation of nearly 70 Carolingian glass fragments are mainly based on electron microprobe analyses. They are partly published (Paderborn by Wedepohl *et al.* 1997, 44; Corvey by Stephan *et al.* 1997, 708; Lorsch by Sanke *et al.* 2002, 65–6; Zalavar by Szöke *et al.* 2004) and partly prepared for publication (Fulda by Kind *et al.*). In the present paper we compare the results from the listed sites with those from the literature to produce some generalizations about Carolingian glass.

A large proportion of the window panes from these churches, monasteries etc were coloured, shaped by use of pincers and framed in lead cames. Green colours are the

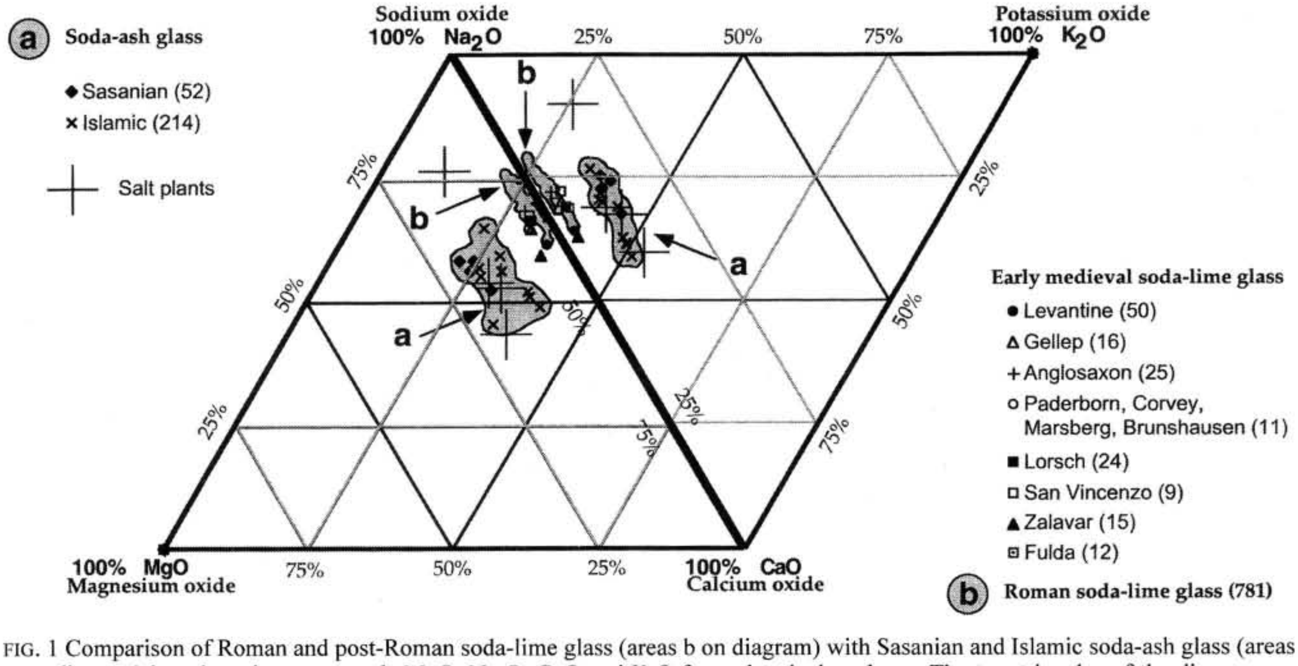

FIG. 1 Comparison of Roman and post-Roman soda-lime glass (areas b on diagram) with Sasanian and Islamic soda-ash glass (areas a on diagram) based on the compounds MgO, Na_2O, CaO and K_2O from chemical analyses. The two triangles of the diagram are constructed from an extrapolation of each of the three-element groups to a sum of 100%

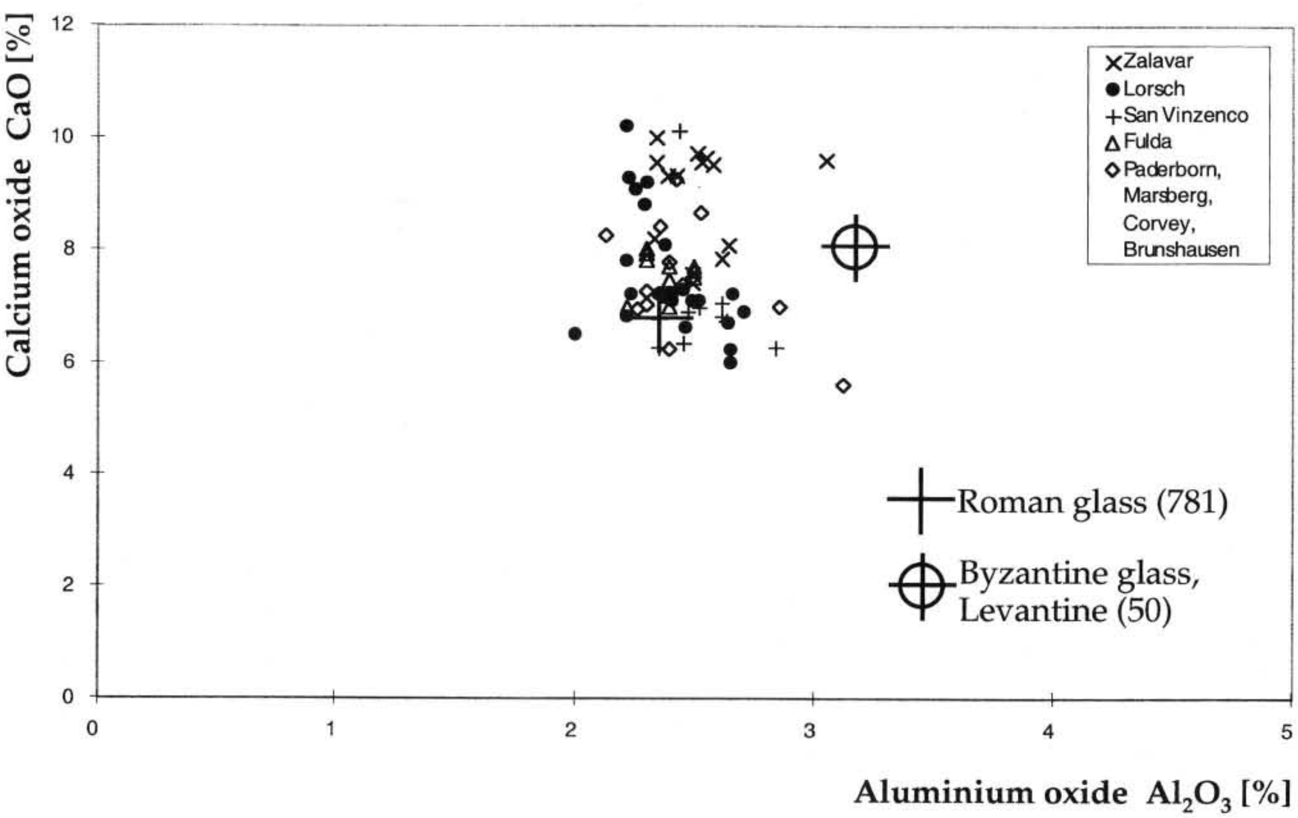

FIG. 2 Relation between calcium oxide and aluminium oxide in Carolingian glass in comparison with Roman and Byzantine glass, the latter from Israel according to Freestone *et al.* (2000)

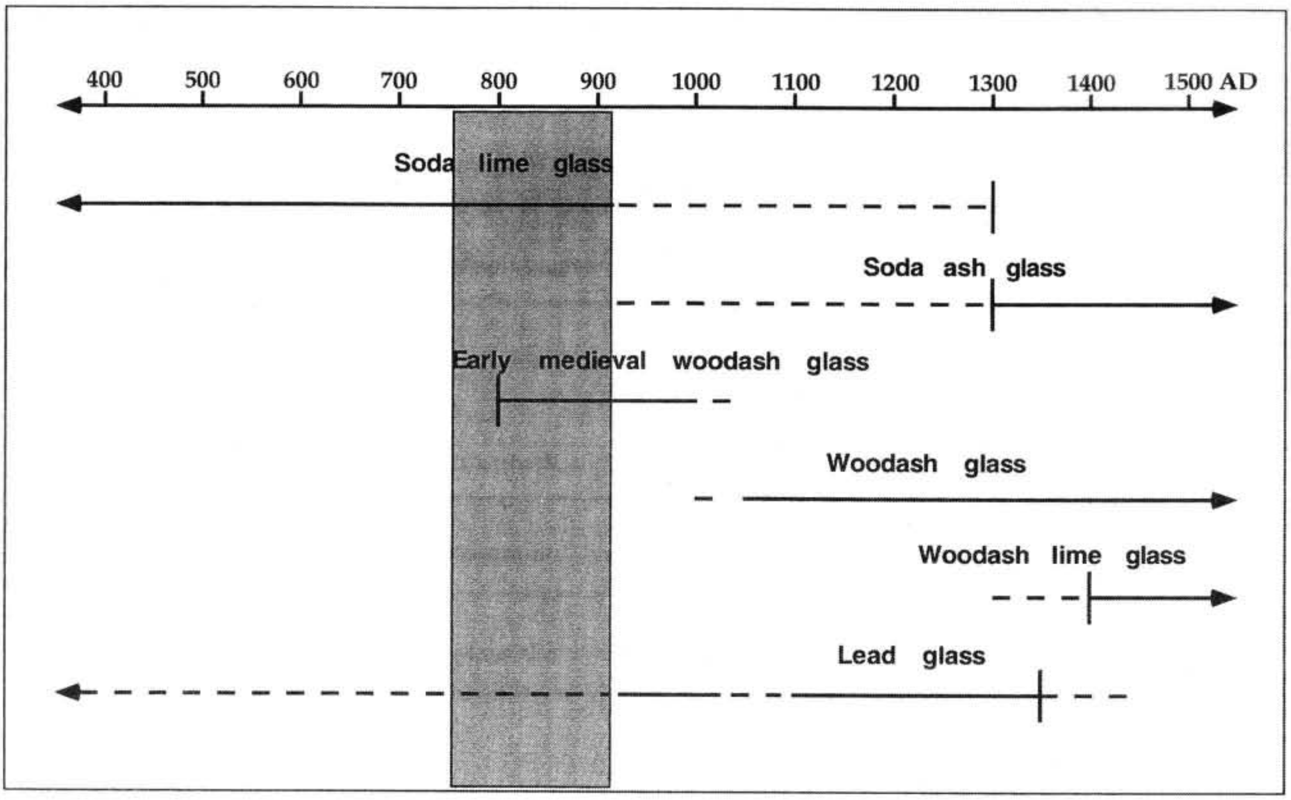

FIG. 3 The time scale of major medieval glass compositions with the Carolingian period in grey

most abundant ones, blues are common and reds are rare. For the characterization of soda-lime and soda-ash glass of the 1st millenium AD we use the diagram of FIG. 1. The compounds Na_2O+CaO+MgO=100% and Na_2O+CaO+K_2O=100% are plotted in two neighbouring triangles. In this diagram the plots of Roman and post-Roman soda-lime glass and of Sasanian plus Islamic soda-ash glass are separated through their MgO and K_2O concentrations. We also observe that the post-Roman glass has a tendency to lower Na_2O and higher CaO concentrations relative to Roman soda-lime glass.

A major problem concerns the origin of the post-Roman soda-lime raw glass, whether it was from a West-European source, or was from Levantine imports. For a chemical characterization of the former glass we used our data, and for the composition of Levantine glass of Byzantine age (6th to 8th century) the data reported by Freestone *et al.* (2000, 77–8) on 70 samples from Bet Eli'ezer, Apollonia and Dor in Israel. We have plotted the individual data on European Carolingian glass and the average concentrations of Roman and Levantine glasses in a CaO-Al_2O_3 diagram (FIG. 2) for comparison. Freestone *et al.* (2000, 82) have presented the individual plots of glass from Apollonia, Bet Eli'ezer and Dor in a comparable CaO-Al_2O_3 diagram in their figure 7. The latter trend from high CaO/low Al_2O_3 to low CaO/high Al_2O_3 as our Carolingian glass does. A remarkable difference between the two groups, however, is the distinctly higher Al_2O_3 concentration in Levantine glass; this excludes the possibility that there were major raw glass imports from the Near-east to Europe during the Carolingian period. Roman glass is comparable in Al_2O_3 to Carolingian glass, which indicates the use of similar sources of quartz sand during both periods.

In our FIG. 2 low-CaO Carolingian glasses seem to change over to high-CaO species without distinct grouping. In a detailed inspection we can discriminate between a high-CaO group with more than 8.5% CaO and a low-CaO group with less calcium. The majority of glasses of the low-CaO group contain 0.1 to 0.9% Sb_2O_3 and the high-CaO glasses have no antimony which is detectable with the electron microprobe. Antimony has been introduced into the low-CaO glasses by blending their melt with Roman tesserae to get green and blue colours. Crucibles from an interrupted blending process with incompletely melted tesserae were observed by Dell'Acqua (1997, 36). Divalent copper and lead oxide were the colouring substances from the tesserae. If high-CaO glasses are green they are coloured from iron introduced by the quartz sand. At Zalavar we observed on high-CaO glass fragments pictures of human heads and arms as well as lettering painted by silver stain and copper red.

The diagram of FIG. 3 indicates that the Carolingian period was a time of major changes in glass compositions in Europe and the Near-east. Soda-lime glass faded out to be replaced by soda-ash and wood-ash glass. A large consumption of trona coincided with a decreasing production in Egypt, so that the Islamic glasshouses had to change to soda-ash glass and the Carolingian raw glass factories to invent wood-ash glass. The latter invention connected with a change from sodium to potassium-rich glass, required almost 200°C higher melting temperatures and large amounts of beech logs. Wood contains not more than 0.1% K_2O. All the three early raw materials for glass, which were beach and desert plant ash, trona and wood ash, have been primarily used as detergents. Early wood-ash glass was excavated at Paderborn, Lorsch, Fulda, Corvey and a few additional sites in Germany, France, England and Norway with the oldest materials dating around 800 AD.

The experimental stage in the invention of wood-ash glass can be recognized in the relatively large variation of

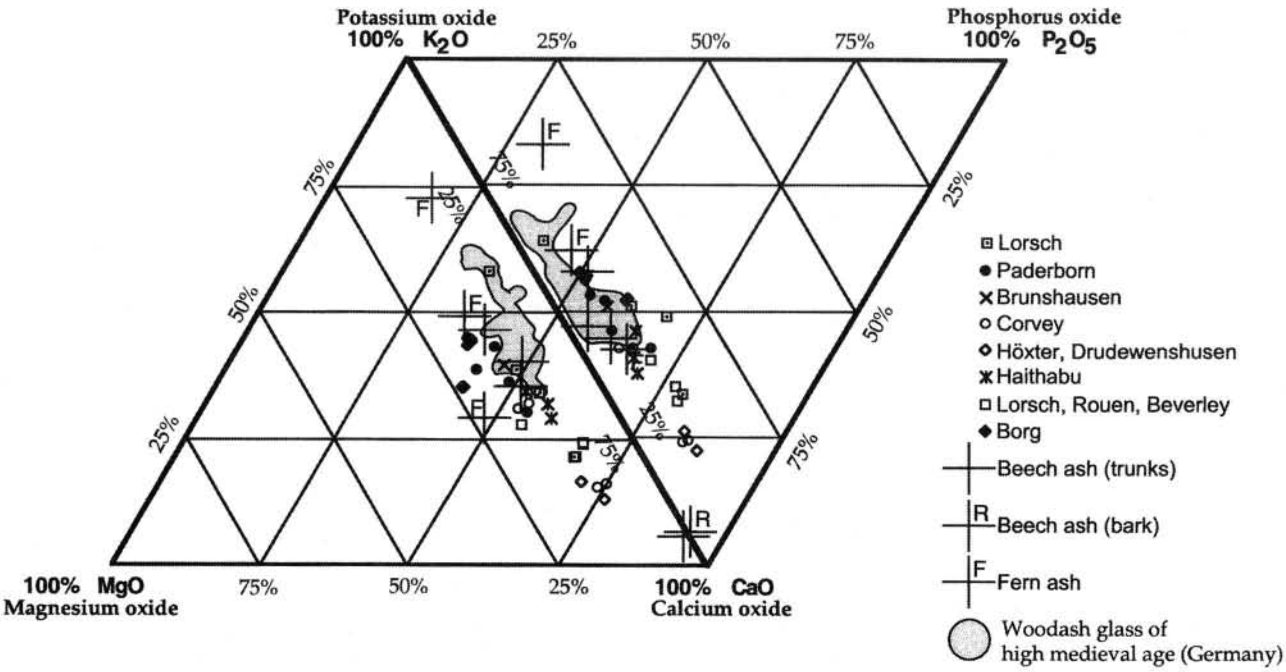

FIG. 4 Comparison of early medieval wood-ash glass (plots) with high medieval wood-ash glass (grey areas) based on the compounds MgO, K_2O, CaO and P_2O_5 from chemical analyses. The two triangles of the diagram are constructed from an extrapolation of each of the three-element groups to a sum of 100%

the compositions. This variation is observable in the MgO-K_2O-CaO-P_2O_5 diagram of FIG. 4. The CaO/K_2O ratio scatters in 43 early medieval wood-ash glasses, reported by Wedepohl (2003, 181–3), from 0.6 to 5.85 with a majority larger than 1.0. The ash of beech trunks has a ratio only slightly higher than 1.0. But the CaO/K_2O ratio increases up to more than 10 with the proportion of bark in the wood. In countries poor in woodland, fern ash might have partly replaced wood ash. Fern ash is characterized by relatively high MgO and P_2O_5 concentrations (Wedepohl 2003, 184). Glasshouses experienced in the production of soda glass from trona plus lime might have added some lime to their experimental wood-ash melts. The low concentration of potassium in the early starting compositions was partly compensated by the addition of soda glass cullet and/or less than 2.5% NaCl. We expect that the early wood-ash raw glass was produced in the western part of the Carolingian empire which had the oldest tradition in glassmaking, and also a lower amount of woodland and hence an impetus to use fern ash.

Wood-ash glass is softer and less resistant against weathering than soda glass. These poorer qualities caused the introduction of soda wood-ash glass blends. We detected such glasses, which mostly contain higher proportions of the soda fraction, as minor glass fragments in the excavations of Lorsch and Fulda.

Glasshouses or their commodities have been excavated at Paderborn, Fulda and Zalavar. They were located at Paderborn and Zalavar close to the buildings in which their window panes have been installed. These glasshouses apparently imported raw glass (probably from the western part of the Carolingian empire) to colour this by blending its melts with green or blue tesserae. Green was the fashionable colour of this period.

All data required for FIGS. 1, 2 and 4 are listed by Wedepohl (2003, 174–222).

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ANGLIAN GLASS FROM RECENT AND PREVIOUS EXCAVATIONS IN THE AREA OF WHITBY ABBEY, NORTH YORKSHIRE

SARAH JENNINGS

Whitby Abbey occupies a prominent position on top of the East Cliff to the east of the town of Whitby. The first abbey at Whitby was founded by King Oswey of Northumbria after the battle of Winwead in 655. It was a double establishment of men and women set up under the aegis of the first Abbess, Hild, in 657, and developed an early reputation for scholarship and also became important as a royal burial place. In 867 the abbey was destroyed by the Danes and archaeological evidence suggests that the site was then largely, if not totally, abandoned. Around 1078 the monastery was re-established as a Benedictine house and the medieval abbey, whose ruins are visible today, was constructed over this second establishment around the 1220s. Although the structural remains of the first Anglian abbey have never been found they are presumed to be underneath the two, later, medieval churches.

There have been two major episodes of archaeological investigations in and around Whitby Abbey (COLOUR PLATE 52). The first of these cleared large areas to the north of the ruins of the medieval abbey in the 1920s, the second undertook work on the headland outside the monastic area, from 1993 to 2002. During the excavations of the 1920s a variety of objects was recovered which demonstrate the richness and wealth of the first abbey during the Anglian period (7th to 9th century AD) and the later abbeys of the medieval period.

Amongst the finds recovered in the 1920s were two small glass plaques made from coloured twisted canes fused to a clear glass backing (COLOUR PLATE 53). These and their possible place of manufacture are the subject of this paper. The plaques are not identical in shape or colour, neither were they made in the same way. One was cut from a vessel wall, the other was purpose-made. In both of the Whitby plaques the pieces of cane are alternately aligned.

The purpose-made square plaque (Whitby Museum Acc No W506) has canes with one or more thin coloured trails twisted and stretched until they were thin – *c.* 1.5mm in diameter – producing a polychrome spiral. These were then cut to the desired length and laid on a same-size base of transparent glass less than 1mm thick. The whole was then reheated until the different elements fused together, although the canes remained separate unlike those on the rectangular plaque that have fused to the body of the vessel (FIG. 1). When cold the edges and corners of the base were filed; the sides and the base of the piece are slightly bowed, but the edges are sharp. The plaque is slightly weathered and the different-coloured glasses have decayed to varying degrees so the colours are not always clear. It utilizes two different-coloured canes on a very pale olive-green base.

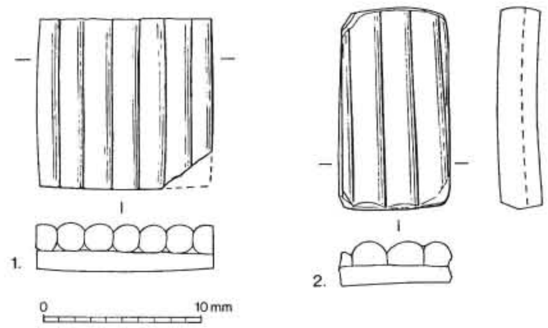

FIG. 1 Plaques; scale 2:1 © English Heritage

The main bodies of the canes are translucent and the trail(s) are opaque, one has a yellowish-brown base and the other blue green. Both have apparently white trails though these are now somewhat discoloured and appear darker against the transparent background (COLOUR PLATE 53). The overall size of the plaque is 11 x 10.5mm and seven pieces of cane were used, four yellowish-brown and three blue/green.

The rectangular plaque (Whitby Museum Acc No W507) was cut from the wall of a vessel and uses just one type of cane, blue green with white and yellow trails, and the plain base appears to be the same colour as the main body of the canes (COLOUR PLATE 53). It comprises three complete canes set at a slight angle to the longer sides and the two opposing corners have small slivers of partial canes. The corners and edges are much more rounded and the back is lightly curved and fire-polished. The edges have been filed to a slight curve. The canes are completely fused together and to the base (FIG. 1).

At the time of publication these were thought to be ornamental settings, possibly inlays from book covers (Peers and Radford 1943, 72).

In October 2002 English Heritage Centre for Archaeology excavated an area on the north cliff at Whitby near to the ruins of the medieval abbey (COLOUR PLATE 52). This was a small part of a much larger programme of work to investigate the archaeology being lost due to extensive cliff erosion. The finds show that this area of the headland was occupied in the 8th– 9th century (the Anglian period), was semi-industrial in nature, and was abandoned sometime in the 9th century. It was part of a large lay community located outside the boundaries of the first abbey, but which supported the monastic establishment. Amongst the material recovered were the waste products from glass, iron and lead working,

The glass items from the excavation of this area were, with one exception, all retrieved as a result of wet sieving.

TABLE 1 ANALYSIS OF THE GLASS SURFACE; bd=below detection limit; Bl=blue, Wh=white, Br=brown, Gr=green, Ye=yellow

Sample	Colour	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	SnO_2	CaO	TiO_2	MnO	Fe_2O_3	CuO	ZnO	PbO
Rod 1	Bl	8.8	0.4	3.4	71.2	0.5	0.4	8.5	0.2	0.1	1.1	5.2	0.1	0.2
(bl/wh)	Wh (+ some bl)	5.7	0.3	4.1	71.0	0.8	2.7	8.7	0.3	0.3	1.8	3.3	0.1	1.0
Chip	Bl	11.9	0.4	3.4	71.6	0.6	0.3	6.3	0.1	bd	2.1	2.8	0.1	0.4
Chip	Br	12.3	0.5	3.6	75.8	0.6	0.1	6.2	0.1	bd	0.8	0.0	bd	bd
Rod 2	Wh	10.7	0.2	3.2	66.2	1.7	4.0	7.0	0.2	bd	0.8	0.1	bd	6.0
(wh + bl)	Bl	11.4	0.5	3.7	73.7	1.0	0.1	6.3	0.1	bd	1.5	1.5	bd	0.2
Plaque 506	Gr (base) rpt	4.8	0.4	6.1	73.6	2.2	0.1	9.3	0.3	0.3	1.7	0.7	0.1	0.5
	Gr (base)	4.3	0.2	4.3	72.3	1.6	0.1	11.9	0.4	0.3	2.7	1.0	0.1	0.9
	Br (twist)	3.6	0.5	7.9	71.5	2.8	0.2	10.4	0.3	0.5	1.9	0.1	0.1	0.3
	Bl (twist)	9.5	0.4	4.6	71.7	1.3	0.2	7.4	0.1	bd	1.1	3.3	0.2	0.2
	Bl (twist) rpt	6.2	0.3	5.9	71.3	1.9	0.3	8.4	0.2	bd	1.3	3.6	0.2	0.2
	?Wh (twist on br)	3.0	1.0	8.3	39.7	5.4	2.5	10.3	0.8	0.8	4.9	0.3	0.2	22.9
	?Wh (twist on bl)	5.5	1.3	9.5	48.2	5.1	2.0	9.0	0.7	0.9	3.0	1.0	0.2	15.2
Plaque 507	Bl (twist)	2.8	0.8	4.2	80.0	0.9	0.4	2.5	0.4	bd	1.7	5.8	0.1	0.3
	Bl(twist) rpt	1.6	0.6	4.4	79.2	1.0	0.5	2.9	0.5	bd	2.0	6.9	0.1	0.3
	Bl	1.0	0.4	4.2	80.7	1.0	0.4	2.8	0.5	bd	2.0	6.7	0.1	0.3
	Bl (back)	1.3	0.6	4.3	78.9	1.2	0.5	3.0	0.5	0.1	2.2	7.0	0.1	0.3
	Ye (twist)	1.0	1.0	9.3	31.0	2.8	3.0	1.3	0.9	bd	3.9	0.4	0.1	45.4
	Wh (twist)	6.8	1.1	5.1	69.1	1.3	3.8	6.6	0.4	1.9	2.7	0.9	0.1	0.3

They include the end of a twisted cane in opaque white glass with a fine transparent blue-green trail, and a small length of a twisted blue-green cane with three fine white trails (COLOUR PLATE 54). The marks of tongs used to hold the white cane as it was twisted and stretched are clearly visible in the wider end, the other end has been snapped off. The two ends of the small cane, although straight, are also broken. An irregular cabochon-shaped lump, a trail and a number of small pieces or chips of blue green, yellow, green and reddish-brown glass were also found (COLOUR PLATE 55). All of these and the white cane are either working waste or raw glass and, as such, represent the debris from manufacturing. The small cane is probably one finished element of a plaque.

This is not the only glass from either the 1920s excavations or the recent work on the headland. Two other high-quality settings were found, one with a thick gold inlaid design of two interlaced loops set in a frame (Peers and Radford 1943, 55, 72, no. 2, pl. 29d), the other a cast oval setting with the bust of a youth. This was almost certainly imported from mainland Europe (*ibid*, 55, pl. 28b). Both areas have yielded pieces of vessel and window glass (*ibid*, 72–3, fig. 22, nos 1, 4; Jennings forthcoming).

The appearance of the small twisted cane is very similar in colour, size and form to those in the finished plaques (COLOUR PLATE 56). The end of the opaque white cane is the one part that could not be used and would have been discarded, and both were found with pottery dating to the Anglian period. This suggests that these plaques and other ornamental fittings were made at Whitby sometime in the 8th or 9th century. Although there is no evidence for either making glass or the manufacturing of glass vessels, these pieces are evidence for the fabrication of small decorative items. As the analyses reported below make clear, the glass has a composition that is typical of the period, but unfortunately lacks any distinctive characteristics that categorically link the working waste with the finished plaques. The presence of waste glass is just one of the factors which demonstrate the clear division in the material culture of the settlement between the area providing support for the monastic community with its remains of industrial processes, and the area around the Abbey which is redolent of wealth and status and where the completed objects were used.

POSTSCRIPT

Since the poster presentation in September 2003 two additional small canes from the area have been brought to my attention. A tiny piece of a cane 6mm long from the excavations at Kirkdale Anglo-Saxon Minster, North Yorkshire, looks similar to the Whitby ones. It has alternating opaque white and yellow strands on a clear green base and is approximately 3mm in diameter (Rahtz and Watts 1997, 421–2). The other from Thearne, East Yorkshire, appears to have blue and opaque white trails around a darker blue core. It is about the same length as the Whitby ones but like the Kirkdale piece is rather thicker, with a diameter of approximately 3mm. (I am indebted to Hilary Cool and Jennifer Price for drawing my attention to these.)

ANALYSIS OF THE GLASS *Sarah Paynter*

The analysis was non-destructive and semi-quantitative, using X-ray fluorescence spectrometry (XRF). All of the glasses appear to be soda-lime-silicate glasses typical of the period (TABLE 1). These glasses would have been fluxed predominantly by the alkali soda, but because the surfaces of the glasses are weathered, the concentrations of soda detected are considerably less than would have been present originally. The depletion of soda is worse for the display objects than for the objects recently excavated. The source of the alkali fluxes was probably a mineral type rather than plant ashes, as plant ashes give rise to characteristically higher levels of magnesium and potassium, and only small amounts of magnesium were detected in these glasses. Higher levels of potassium than typical were detected in

TABLE 2 COLORANTS USED IN THE PLAQUES, CANES AND WASTE GLASS

Sample	Colour	Main colorant
Rod 1 (blue/	Blue	Copper oxide
white)	White (+contam)	Tin oxide
Chip	Blue	Copper oxide
Chip	Brown	Iron oxide
Rod 2 (white	White	Tin oxide
+ blue)	Blue	Copper oxide
Plaque 506	Green / blue (back)	Copper oxide
	Brown (twist)	Iron and manganese oxides
	Blue (twist)	Copper oxide
	White? (twist on brown)	Tin oxide?
	White? (twist on blue)	Tin oxide?
Plaque 507	Blue (twist)	Copper oxide
	Blue (back)	Copper oxide
	Yellow (twist)	Lead stannate
	White (twist)	Tin oxide

some of these glasses. This was probably due to the combined effects of weathering, which, as noted, was more severe on the display objects, and also to the difficulty in resolving some of the X-rays characteristic of tin from those produced by potassium, as they have similar energies.

The blue-green glasses were coloured by copper oxide (TABLE 2). Small amounts of zinc, lead and tin were commonly detected in these glasses as well, thought to have entered the glass unintentionally with the copper oxide. The levels of zinc and tin varied, with only the blue glass on plaque 506 containing noticeable amounts of zinc, but most samples containing small amounts of lead and tin.

Manganese was present in small amounts in most of the glasses. However it was only present in larger amounts in white (on one of the excavated rods and both plaques, although the original colour of the weathered twist decoration on plaque 506 – white or yellow – is uncertain), brown (on plaque 506) and pale blue-green glass (back of plaque 506). It appears to have been added as a decolouriser. The only certain example of yellow glass (on plaque 507) contained no manganese.

The opaque white glasses were opacified by tin oxide but some (one of the excavated rods and the twist decoration on plaque 506, assuming that this was originally white) also contained several weight percent of lead oxide. The opaque yellow glass was opacified and coloured by yellow lead stannate and so contained high concentrations of lead as well as tin oxides. None of the glasses contained antimony. The chip of Whitby brown glass was distinct from the other glasses in that it did not contain manganese or lead oxides.

When interpreting the analytical results the influence of the probable heterogeneity of the glass, and the fact that weathered surfaces were analysed, must be noted. The analyses have shown that the colorants used in all of these glass samples are typical of the period and so generally similar in the excavated glass and in the plaques. However the analyses have not found any unique characteristics of the Whitby glass, compared to glass from other sites of the same date, that would show the excavated working waste was necessarily linked to the production of the plaques.

ACKNOWLEDGEMENTS

I am very grateful to Whitby Literary and Philosophical Society for allowing me to study their two plaques and for lending them for analysis, and to colleagues in the Centre for Archaeology – Dr Sarah Paynter for undertaking the analyses and John Vallender and Vincent Griffin for preparing the illustrations. Photographs: © English Heritage.

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ARCHAEOMAGNETIC DATING OF MEDIEVAL AND TUDOR GLASSMAKING SITES IN STAFFORDSHIRE, ENGLAND

CHRISTOPHER WELCH AND PAUL LINFORD

INTRODUCTION

Glassmaking had begun in Staffordshire by the early years of the 14th century. Before 1615 the industry was based entirely on the use of wood as fuel and until the reign of Elizabeth it was confined to an area in the east of the county about 10km across within which were two concentrations of glassmaking sites. To the south, glassmaking took place on the manor of Wolseley, and a site there at Little Birches was the subject of an excavation in 1991–1992. This revealed evidence for three furnaces, one belonging to the mid 16th century, a second of a similar date, and another dating from the 13th or 14th century. The output of the later furnaces was clear crown window glass; the earlier site yielded virtually no glass at all (Welch 1997).

Following excavation at Wolseley, investigation turned to the northern and larger concentration of glassmaking sites in Bagot's Park, north of the village of Abbots Bromley. Until the 1960s the Park had been an area of scrub and ancient woodland, but it was reclaimed for arable farming and during the process a number of sites were located. David Crossley excavated one of these sites (site 4) in 1966 and found that the main output of the furnace was, again, white crown glass (Crossley 1967).

After 30 or more years of ploughing the glassmaking sites in the Park exist as little more than spreads of production debris, identifiable after cultivation. Nevertheless, sufficient thermoremanent magnetisation remains beneath the ploughsoil for the original location of the furnace to be detectable by geophysical techniques, and a programme of archaeomagnetic surveys was carried out by Dr Ruth Murdie of Keele University which led to the identification of 15 furnace locations. Together with one site destroyed completely in the 1960s (site 7), and two other sites (11a and 16) known by surface debris spreads only (and assuming that these three sites had one furnace each), it is now known that there were 18 furnaces in use over the whole period of glassmaking in the Park (FIG. 1; the numbering of sites follows that originally used by Crossley with later additions; his original sites 1, 2, 5, 10 and 14 cannot now be found).

The geophysical surveys had identified the precise locations of the furnace remains and indicated that material with significant thermoremanent magnetisation survived at each site. This raised the possibility of dating the last firing of each furnace using archaeomagnetic analysis, at which point English Heritage's Centre for Archaeology became involved. By 2002, 14 furnace locations had been excavated and subjected to the technique; a fifteenth (site 4) had been dated during Crossley's excavation in 1966.

THE DATES

The dates determined from the 14 furnace locations investigated in 2000–2002, together with that from site 4, excavated in 1966, are represented in FIGURE 2 (for a detailed technical discussion of the results see Linford 2001; Linford and Welch 2001; 2002). The broader section of each range bar represents the date range for the last firing at a confidence of 68%; the narrower is the range at 95%. The dating technique can yield alternative dates and where this is the case the most likely date is indicated in heavier tone. The earliest date is that for furnace 11b, which seems to have been in operation in the second half of the 13th century. There is an alternative date in the 15th century but this latter is thought less likely as the site has yielded some fragments of pottery of the earlier period. Another furnace, 15a, is of the same period, and there then follows a gap until a point in the late 14th century when 15b was in use (although the long 95% error bar should be noted). It is also worth noting that 15b is a near neighbour of 15a on the ground (FIG. 1).

There then follows a long sequence of furnaces from the late 14th century up to perhaps 1550, and that century and a half sees a sequence of 13 furnaces in use. There may have been gaps in the sequence which the resolution of the technique cannot identify, but with a new furnace appearing on average every eleven or twelve years it is reasonable to view this as a long phase of regular, if not continuous, production.

Furnace 13c has given the latest archaeomagnetic date. However, it has already been noted that there are two sites (11a and 16) where furnace remains could not be accurately located, but these can be identified and dated from surface material. Both are characterized by large quantities of glass, where the others have little on the surface, and that glass is of a hard and resistant type that is usually associated with the period of glassmaking following the arrival of glassmakers from France in the mid to late 16th century (Kenyon 1967, 42–3). Pottery from these sites supports a late 16th-century date. The glass found also suggests much of the production was of vessels, unlike the excavated site at Wolseley and Crossley's site 4. The period of glassmaking by immigrants from Lorraine in Bagot's Park can be defined with some confidence: in June 1585 an agreement was signed between Richard Bagot and Ambrose Hensey by

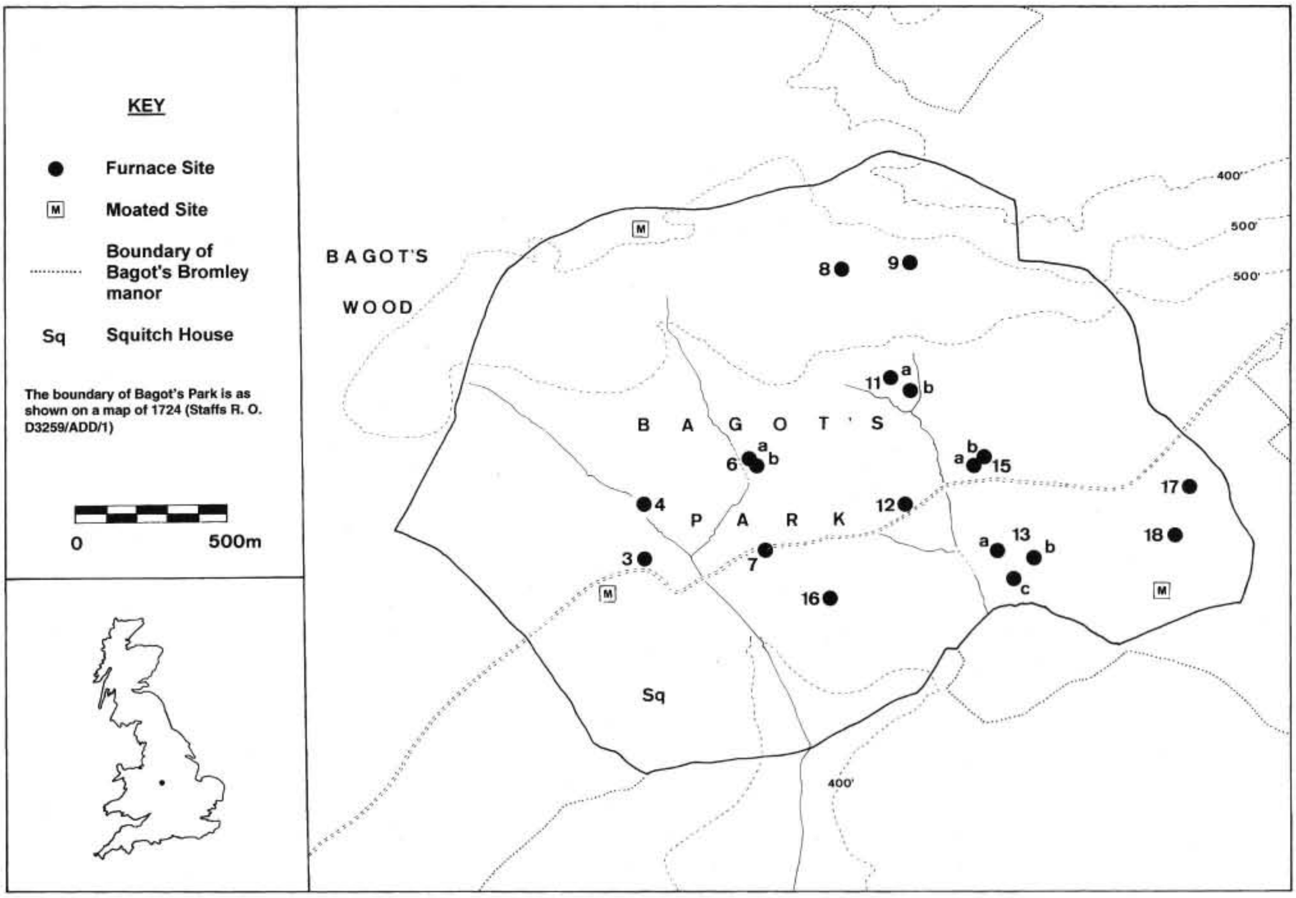

FIG. 1 Bagot's Park and furnace locations

which Hensey might make glass in the Park, and glassmaking ended there for ever in June 1615 when glassmaking with wood fuel was forbidden by the crown (Horridge 1955). Furnace13c spans the period from 1525 to 1565 at the 95% confidence level, leaving at least a 20-year gap between its last firing and the date of the Hensey agreement.

It is possibly coincidence that the two sites (11a and 16) where no furnace location could be detected by geophysical techniques also happen to be the only two in the Park that are of the post-1585 period. However, it might also be conjectured that some technical detail relating to the design of the later furnaces has resulted in an absence of detectable thermoremanent magnetisation in the subsoil.

No record was made of site 7 when it was destroyed in the 1960s, but the suggestion that it was associated with a brick building might suggest a 16th-century date (Crossley 1967, 49).

In summary, there appear to be three broad phases of glassmaking at Bagot's Park: an early phase with a few sites, ending in around 1300, a middle phase with many sites and perhaps continuous production from the last few years of the 14th century until the middle of the 16th, and a late phase associated with the Lorrainers lasting 30 years from 1585.

Discussion

While comparison of the locations shown on FIGURE 1 with the dates given on FIGURE 2 shows no obvious pattern of movement within the Park, it can be seen that where furnaces are near neighbours geographically (6a and 6b; 11a and 11b; 15a and 15b; the group 13a–c) they appear chronologically distinct, albeit with some overlap at the higher level of confidence. The most obvious explanation for this is that the glassmakers are returning to the same location after a period of time, perhaps after a particular section of woodland has regenerated.

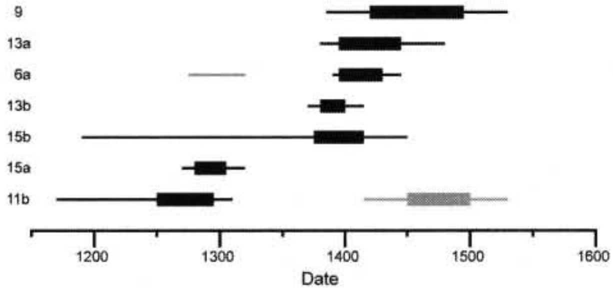

FIG. 2 Archaeomagnetic date ranges of furnaces. The broader section of each range bar represents the date range for the last firing at a confidence of 68%; the narrower is the range at 95%.

The distribution of furnace use over time seen in the Park can be supplemented by evidence for glassmaking elsewhere in this part of Staffordshire. At Wolseley, furnace 4 may have belonged to the early phase, although the dating, which was based on associated pottery, was not precise (Welch 1997, 53). Furnace 1 and the associated furnace 2 certainly belonged to the middle phase (contemporary with 13c, and thus late within the phase), and the fragmentary remains of furnace 3 seemed to be of a similar period, although the assumption made at the time that it was probably contemporary might now be questioned in view of the results from similar neighbouring sites in Bagot's Park (Welch 1997, 11, 16).

Direct documentary evidence adds a few more furnaces to the middle phase. Two rentals from the 1470s indicate that there was one in operation at Wolseley then, and this might be associated with the remains at Cattail Pool which lie 1km away from the Little Birches site excavated in 1991–1992. A further furnace is known to have been in production around 1530 in 'Assheleyhey', near Colton, between Wolseley and Bagot's Park (Welch 1997, 29–32). Place-name evidence suggests the location of two more furnaces of the late, Lorrainer, phase near Bagot's Park; and there is debris at Cattail Pool that seems to come from a furnace of this period, but there is no documentary evidence for this (Crossley 1967, 48; Welch 1997, 31).

The above evidence confirms that the general pattern seen at Bagot's Park is repeated over the whole area of glassmaking in this part of Staffordshire. In total there are perhaps three sites belonging to the early phase, but four can be added to the 13 of the middle phase, emphasizing the impression of continuous production through the 15th century and into the first half of the 16th. In the later, 'immigrant', phase there are probably four and perhaps five sites in this area.

These patterns can be considered in a national context. There are three specific references known which relate to the sale of glass from Staffordshire in the period 1300–1615, all in the 15th century and all relating to the sale of window glass. Glass was sold to York Minster in 1418 by a glassmaker from Rugeley, and again in 1478 by a glassmaker from Abbots Bromley. Glass for the church of the Holy Trinity at Tattershall, Lincolnshire, was bought from Staffordshire in 1480, and this must have come from the Rugeley/Abbots Bromley area (Welch 1997, 2, 37; 2003).

The apparent gap around the middle of the 14th century is intriguing. Marks notes the general lack of large-scale glazing schemes in the period 1350–1380 (1993, 166). In 1366 glass was brought to Nottingham Castle from London, when it might be expected that it would have been obtained from a source much closer in Staffordshire, but this certainly does not prove the absence of an industry there (Salzman 1928, 190). Glass was sought in Staffordshire in 1349 for St Stephen's Chapel at Westminster, and a glassmaker came from the county to run a furnace in the Weald in 1380, which must imply that there was an industry in the area at this time. Perhaps the apparent gap between the early and middle phase is local to Bagot's Park itself and other sites from the 14th century remain in the area to be discovered and dated (Kenyon 1967, 25, 31). An example might be the undated site found at Lount Farm, which lies between the main concentrations at Bagot's Park and Wolseley (Welch 1997, 32).

Furnace 1 at Wolseley, sites 4 and 13 in Bagot's Park and the site at 'Assheleyhey' can all be reasonably said to have been in use in the 1530s and 1540s. The cessation in glassmaking after about 1550 is thus particularly striking and seems to represent a sudden end to a thriving industry rather than a dwindling of activity, but it may again be possible that other sites remain to be discovered and to bridge the gap.

Conclusion

Further documentary research may alter the general pattern outlined above. Even if it does, the evidence for the high level of activity in the middle phase from the late 14th century to around 1550 would remain to suggest that at this period Staffordshire was supplying a large amount of glass to the market. This is also the period when documentary evidence for glass production in the main area of glassmaking in England, in the Weald on the Surrey/Sussex border, is particularly scarce (Kenyon 1967, 29). The archaeological evidence from Wolseley and from Crossley's excavation of site 4 clearly shows that the main output of these sites was crown window glass, and this is supported by the few references to actual sales, which are all related to church glazing. This was also the period when the Perpendicular style predominated in England, with its emphasis on large areas of glass; Marks comments on Tattershall that it was 'primarily a glass-house' (Marks 1979, 138). If the rather sudden end of the middle phase is a real, and wider, phenomenon perhaps it can most readily be explained by the Reformation. After the 1530s wealth was redistributed from the church to the crown and laity on a massive scale, bringing to an end a thriving market for window glass, and the statement by Thomas Charnock in 1557 that glassmakers were scant in the land is well known (Platt 1994, 16). The market only reappeared towards the end of the 16th century, and then it was the laity who provided the demand, and the immigrant glassmakers the supply.

Further work

Documentary research will now continue in order to firm up the picture emerging from the Staffordshire glass industry. Some of the sites in Bagot's Park have been fieldwalked and initial results from this are promising; it is hoped to move to a full programme of analysis in the future and the programme of dating has now provided a framework within which this can take place.

Acknowledgements

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HIGH MEDIEVAL GLASS PRODUCTION IN THE CENTRAL GERMAN LOW MOUNTAIN RANGES

Udo Recker

In grateful memory of Claus Chwalczyk (†) – forestry expert and authority on the Reinhardswald

Introduction

The archaeological exploration of medieval and later glassworks in Europe has increased during the last two decades. In Germany most of the research work was concentrated on well-known production areas in the Southwest or, for example, in Spessart (Krimm 1982; Loibl 1996), Kaufunger Wald (König and Stephan 1987; Sippel 1987; 2001), Bramwald (Schröder and Schröder 1982; Stephan 1990a; 1990b; 1998; Stephan *et al.* 1993), Solling, Hils (Leiber 1990/91; 1994) and adjoining woodlands in Lower Saxony (Bloss 1977; Schröder and Schröder 1982; Stephan 1990b). In future new technological evidence can be expected from glassworks in the Bavarian Fichtel Gebirge (P. Steppuhn and G. Zeh pers. comm., Autumn 2003).

On the initiative of the Archaeological Board of Hesse and a number of interested volunteers, large-scale surveys of the woodlands in Northern and Central Hesse were carried out in the 1990s. On this basis at least two new 'glass landscapes' could be postulated in the Reinhardswald (Buthmann and Zickgraf 2003; Henne 2001; Recker 2002a; 2003a; 2003b; 2003c) and Taunus (Berg 2000; Schmenkel 2003; Steppuhn 2001; 2002; 2003a; 2003b, Wächtershäuser 2003). In 2000 the Kommission für Archäologische Landesforschung in Hessen (KAL) incorporated glass research in Hesse into a long-term interdisciplinary research program on 'Economic Archaeology in the German Low Mountain Ranges' (Recker 2002b, 215).

This paper is restricted to new aspects of the high medieval glass production in the north Hessian Reinhardswald.

FIG. 1 Germany and Hesse with the location of Gieselwerder

The Reinhardswald

At present the Reinhardswald covers an area of nearly 60km^2 (Bonnemann 1984; Chwalczyk 2000; Jäger 1951; Koch 1998; Rapp 2002; Schenk 1996). A diversified cultural landscape with a wide range of vestiges of medieval and later economic activities is well preserved in its northern part. Deserted medieval villages, extensive field systems, traces of open digging, carbonising furnaces and charcoal works, shaft and smelting furnaces as well as ironworks and more than 50 glassworks (Henne 2001) give a general idea of pre-industrial economic processes in the area.

Scientific analysis of archaeological finds as well as written sources from the Middle Ages can help us to answer at least some of our questions. They help us to gather information on the selection of raw materials, give us an insight into its processing as well as firing and melting techniques. With regard to medieval written sources we have to mention Theophilus Presbyter's famous *Schedula diversarum artium* (Brepohl 1999) in the first place. It was written around 1122/23 in the imperial abbey of Helmarshausen which is located at the north-western edge of the Reinhardswald. In volume two a comprehensive description of the contemporary manufacturing process of glass is given, which underlies major parts of our knowledge of high medieval glass manufacture up today.

The archaeological part of the Reinhardswald project was concentrated on a glassworks site called Heiderkopf next to the village of Gieselwerder (FIG. 1). Apart from archaeological remains, historical records were studied as well as all kinds of interactions, interdependences and dynamics resulting from economic activity at the site. The non-archaeological part of the project is concentrated on the close relationship between three central points: natural resources, the environment and society. It is aimed at a diachronic account reflecting all the elements, general structures and specific frameworks of economic activity in the Reinhardswald.

FIG. 2 The glassworks from the south; © Landesamt für Denkmalpflege Hessen, Archäologische und Paläontologische Denkmalpflege

The exploration of the Reinhardswald region is conducted by KAL, the Archaeological Board of Hesse, the University of Bonn – Department of Geography, Division Historical Geography, and the University of Würzburg – Department of Mineralogy.

THE HEIDERKOPF SITE

Topography and Archaeology

The Heiderkopf glassworks (FIGS 2, 3) was located on the south of a plateau on a steep slope. It was linked to the local road system by a footpath that passed the Reinhardswald in a north–south direction. The bank of the Weser river could be reached via a path leading west–east that crossed the north–south communication a few kilometres south of the plateau. The plateau and parts of the adjoining steep slope were investigated by means of a geomagnetic survey, which showed that the glassworks had a maximum extent of 90m². A smelting furnace was located in the middle of the production site and three anomalies lying to its north-west and west could be identified as rubble and clay pits. A fourth pit was discovered in front of the flue. South-east of the furnace a large number of local sandstones had been piled up. Their size corresponded to that of the stones used in the inner structure of the furnace. Following the slope downhill a number of rubbish heaps could be made out south-west of the glassworks covering an area of about 180m². The western part of the rubbish heaps had been destroyed by a modern forest path. The necessary water supply was guaranteed by a nearby spring that even today is periodically water bearing.

Most striking was an oval shaped – *c*. 7x6m – large accumulation of local sandstones that once had formed the glass furnace. Its dome and the front of the flue had

FIG. 3 The glassworks from the east; © Landesamt für Denkmalpflege Hessen, Archäologische und Paläontologische Denkmalpflege

collapsed, but the foundation, parts of the inner and outer masonry, the smelting chamber as well as the back part of the flue with a vault were well preserved.

The furnace had been built on a layer of light grey unfired clay of non-local origin. The same clay was found in one of the pits south-west of the furnace. The foundation and the outer masonry (FIG. 4) had been constructed with large – *c*. 0.7x0.4m – local sandstones whereas distinctly smaller sized stones – *c*. 0.25x0.25m – had been used for the erection of the inner structures of the furnace. The walls had been preserved up to a maximum height of 0.8m.

FIG. 4 Foundation, outer masonry (front) and part of collapsed flue (rear) of the glass furnace; © Landesamt für Denkmalpflege Hessen, Archäologische und Paläontologische Denkmalpflege

FIG. 5 Unidentified vitrified compound and slag within the smelting chamber; © Landesamt für Denkmalpflege Hessen, Archäologische und Paläontologische Denkmalpflege

The glass furnace was aligned to the direction of the wind. Its flue had a clear height of 0.4m and was covered by a vault that was well-preserved in its rear part. Ash had been temporarily stored in an oval-shaped, 2x1.6m, working pit in front of the opening of the flue. It contained about 1 cubic metre of ashes from the last firing.

The smelting chamber was *c.* 1x0.5m, had no bench and had been covered by a dome originally. The stones of the inner walls showed clear signs of heat damage; they were vitrified and completely covered with glass. At two points the walls had obviously been repaired. Parts of the dome walls were found lying within the smelting chamber. The smelting chamber's filling consisted of an unidentified vitrified compound and slag (FIG. 5). Questions concerning the existence of a chimney or openings in the outer walls cannot be answered.

At the back of the furnace a small store room had been built, that was accessible from the outside only (FIG. 6). Its inner surface covered only 0.35m^2 with a floor made of tamped loam. Comparable features are known from several glassworks sites (e.g. Boss and Wamser 1984, 157, fig. 111; Leiber 1990/91, 521, fig. 5; 1994, 18, fig. 2; Stephan 1990a, 132, figs 4–7, 23, 24; Steppuhn 2003b, 189).

The number of finds was rather small. Only a few drops of glass, pieces of glass flux, a small quantity of glass sinter, one fragment of a crucible and some earthenware potsherds of two baggy pots (Kugeltopf) and a jug/bottle were found. In all probability the pottery is of local origin and had been produced in the nearby villages, now deserted, of Bensdorf or Thonhausen next to Gottsbüren in the 13th century (*cf.* Desel 1978; Leinweber 1982; Stephan 2000, 236).

Production Engineering, Trade and Environment

One of the most striking features of the Heiderkopf excavation is surely that the glassworks had only one furnace. It is very clear that the operation of a 'one-furnace-glassworks' has far-reaching consequences with regard to medieval glass-production procedures in the Reinhardswald. Because of the lack of any working furnace and/or annealing oven, as well as the structural characteristics of the glass-smelting furnace, the most sensible conclusion we can come to is that only raw glass had been produced there. This is why we have to think of a differentiated production system resulting in a spatial separation between the fabrication of raw glass and its processing to vessel glass or flat glass wares. Research on this matter is still in progress in the Reinhardswald, but we have evidences for such a way of production engineering in the Bohemian Forest (Cerná 2003).

FIG. 6 Smelting chamber and small store room at the back of the furnace; © Landesamt für Denkmalpflege Hessen, Archäologische und Paläontologische Denkmalpflege

The length of time a glassworks was in use in the Reinhardswald cannot be answered in general. Three variables are significant: the structural quality of the furnace, a sufficient supply of firewood and the availability of all required raw materials. The extensive consumption of wood made it necessary to shift the glassworks from one forest district to another. Historical geographical research on the Reinhardswald (Jäger 1951; Schenk 1996) shows that the wooded area shrank in the 13th century. Only the growing number of deserted villages and restrictions of the rights of users by the local aristocracy led to an increase of woodland in the early 14th century. According to secondary literature (e.g. Bonnemann 1984) a glassworks moved from one district to another in a 10–15 year rhythm. Based on written sources of the 15th–18th century we know that the Reinhardswald glassworks changed site within a period of approximately seven years (Dix and Sauer 2001). We do not have comparable data for the 13th/14th century yet, but what is clear is that the Heiderkopf glassworks had been in use for a much shorter period than this.

Prospects

Future research work will be concentrated on the interrelations between the exploitation of natural resources, the environment and society (Recker 2002b, 214). As already noted one aim should be to take into account all aspects of economic activity in the Reinhardswald, and to explore the resulting interactions. In addition we have to examine the relative importance of the natural landscape and the social structures in these economic activities. Thus the Heiderkopf glassworks can be used as a peg on which to hang questions concerning the human management of resources and the interaction of environment and society.

Conclusions

The research projects in the Reinhardswald and in the Taunus show that in regard to high medieval glass production a lot of research work remains to be done. One aspect of this is that the scientific analyses of the glass finds and the pottery remain to be completed. After three years of intensive research work we still can answer only some of the questions raised.

The excavations and accompanying studies gave us an insight into new structural aspects of high medieval glassworks. Most remarkable is the 'one-furnace-glassworks' and the spatial separation between the fabrication of raw glass and its processing. It is worth stating at this point that this interpretation stands in clear contradiction to traditional opinions. Consequently the future aims of the glass research projects in Hesse are to capture more basic data at different places within the research areas, to document their effect on the environment and to uncover their repercussions on the society. In doing so it should be possible to get a representative impression and depiction of essential aspects of the economic systems related to glassworks and their products.

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ARCHAEOLOGICAL VESSEL GLASS OF THE LATE MEDIEVAL AND EARLY MODERN PERIODS IN THE FORMER DUCHY OF BRABANT: AN INTERDISCIPLINARY APPROACH

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This project, started in 2002, aims to define a comprehensive classification for the archaeological vessel glass of the former Duchy of Brabant for the period 1400–1700. All types of vessels have been selected from urban, rural and high-status sites including beakers, goblets and bowls and utilitarian equipment for storage, distillation and personal care. Though limited in its geographical, chronological and topical scope, the project presented in this paper aims at determining the appropriateness of a methodological approach within an interpretative framework. However, the results have to be considered as being of a preliminary nature: more quantitative and qualitative post-excavation analysis in combination with other historical and scientific data is required to provide further elucidation.

PROBLEMS AND OUTLOOKS

The presence of several glassmaking traditions, rooted in different geographical areas, is shown by the archaeological glass finds of Brabant; an area which functions both as a distribution network on the consumer side and as a crossroads for transfer of labour, form, design and composition on the production side. Although, by its sheer nature the archaeological record is incomplete, scattered and fragmented, it documents the silent processes of production, their technological developments, distribution and use. When applied to glass production the record shows that technological and manufacturing problems, such as furnace technology, combustible use, and standards of accuracy relating to the establishment of an efficient and stable glass composition, were dealt with and solved by numerous glass producers. This could possibly explain the wide compositional diversity in this crucial period, of the 15th to 17th century, when a rural industry with more functional characteristics was gradually converted into an urban one which belonged more in the world of luxury goods.

For these reasons, this study focuses on the cumulative effects of the 'continuum of innovation' (Mathias 1972, 73), rather than on attributing the documented technological changes to one prime region/producer or another. Therefore, a contextualized and integrated approach is needed and a variety of economic, social, historical, pictorial and archaeological sources have to be used to assess fully the importance of the production, distribution and use of vessel glass.

The former Duchy of Brabant, with its central geographical position, possessed an important number of urban centres each with a dominant function: commercial (Antwerp, s'Hertogenbosch, Bergen, Op Zoom, Leuven), political and judicial (Brussels, Mechelen) and military (Breda). This highly urbanized region, with access from important sea ports such as Bruges and Antwerp, created the optimal conditions for the development of trade and distribution through its dense network of international, inter-regional and local trade routes, both fluvial and terrestrial (COLOUR PLATE 57).

The well-known trade routes linking Brabant to the important German cities and fairs such as Cologne and Frankfurt, were used for the importation of glass from the late 14th century onwards. The green forest glass vessels account for between 60–65% of most 16th-century glass assemblages throughout the whole region (COLOUR PLATE 58.a–d; Caluwé 2000; 2001; forthcoming a–d; Gevaert *et al.* 2003). The wrythen beakers and the prunted beakers are the most dominant types, showing the largest variety and diversity in quality, decoration and execution.

Glass was also being imported from France, such as Fontenoy-le-Château, a glass production area in the Vosges. The Brabantine archaeological glass reflects these French imports both in types and in the compositions used (COLOUR PLATE 59.a–b; De Raedt 2001, 76).

Apart from French and German imports, glass was produced in the rural forest furnaces of Brabant and nearby regions, and historical records studied by Hudig (1923, 12) mention at least 20 urban glass furnaces in the early modern period, of which the earliest are Antwerp, Middelburg and Amsterdam, followed by Liege, Brussels, 's-Hertogenbosch, Gent and Namur and many other smaller cities. The first contract for Antwerp *façon-de-Venise* production dates from 1537 and ample evidence exists during the 16th and the 17th century for large scale production managed by Italian emigrants marrying into Antwerp families and establishing an international reputation (Caluwé 2000; Veeckman and Dumortier 2002).

THE ARCHAEOLOGICAL EVIDENCE

The 14th and 15th-century glass imports in the trade centres of coastal Flanders near Bruges are clearly shown in the amount and frequency of the archaeological evidence which have been recently studied (COLOUR PLATE 60; Caluwé 2001; Gevaert *et al.* 2003). These have revealed an early, and continuous, distribution of a diversified range of glass vessel types, found in urban and religious surroundings but also their wider use in lower social strata and more rural contexts. For the first half of the 15th century throughout Flanders and Zeeland, the green, forest glass, wrythen-ribbed types are the most prevalent. The Italian (from Sluis, Zeeland) and French (from Vrouwenpolder, Zeeland) imports are characterized by a high technical level, a well executed finish, good quality metal and refined decoration. The Italian provenance and a probable sodic composition is evidently demonstrated by the parallels found in the Northern Italian production areas (Mendera 2002).

In the later 15th to 17th centuries, in Brabant, the majority of the green forest glass vessels consisted mostly of more current types in everyday use, such as the prunted beaker and the wrythen-ribbed beaker. The range of the Antwerp Steen (COLOUR PLATE 61) is representative of the total range of forest-glass vessels found throughout the whole region. The typological difference between the prunted beakers (*berkemeiers*, COLOUR PLATE 58.d) and the low drinking cups (*magelein,* COLOUR PLATE 58.b) seems to coincide with a remarkable difference in quality and technology. The low cup, often found in larger numbers in inn surroundings or religious communities in the early 16th century (Henkes 1994, 54–5; Aalst – Caluwé forthcoming a; Dendermonde Abbey of Zwijveke – Stroobants and Balthau 1991) is definitely a less well finished, widespread mass product. Its compositional similarity with the *roemers*, as shown by De Raedt (2001, 72–3) is remarkable and could be indicative of technological developments such as a change in the use of combustibles, or changing furnace or heating techniques, as was the case in the Weald region of England (Kenyon 1967). In general, the Antwerp prunted beakers show a higher frequency and a larger typological variety, often combined with a high level of technological execution. The analytical work on the composition, done by De Raedt (2001, 76), suggests that these potasso-calcic vessels could be produced using a mixed-alkali source of calcium, possibly a mixture of beech ash and potassium-rich fern ash, coinciding with the typical composition for the west of France. The probable provenance could be the Beaulwelz furnace, located in Brabant, near the French border.

The contemporary appreciation of the *berkemeier* and *roemer* is shown by the use of these beakers as official gifts by cities and towns, and by the use of metal and gilded mountings. The occurrence of colourless *berkemeier*s such as in 's-Hertogenbosch (COLOUR PLATE 62) and Antwerp, where a *berkemeier* analysed by Van der Wee (1987) proved to be produced in a soda glass, and their frequent depiction on still lives in rich surroundings, all point to the luxury nature of these vessels. Recent iconographical research (Caluwé 2000; 2001) reveals a frequent and very realistic depiction of glass vessels in the 15th century, in religious scenes, in high-culture contexts and on high-quality paintings commissioned by urban, religious and secular high-status groups. In contrast in the 16th century with the development of genre painting, and of the still life in particular, the vessels are increasingly emphasized as a compositional element, to catch the light and even more to illustrate the craftsmanship of the painter. This makes the interpretation of the pictorial record problematic as it may reflect not only cultural and social changes in attitude towards the material objects and their use but also their representation.

The most popular form, in colourless and *façon-de-Venise* glass, is the cylindrical beaker (COLOUR PLATE 63.A–C) as it constitutes the most frequent type of vessel found throughout the region. In particular, the 16th-century type, with lightly everted rim, modelled after silver or pewter counterparts, occurs in all different glass types, both with applied, mould-blown and marvered *lattimo* decoration. The fact that diversity seems to be increasingly expressed through the choice of the type of decoration, rather than through vessel form or design could indicate a growing tendency towards a form of standardisation in the production mode. This is evident for mould-blown vessels, implying inherently a certain degree of uniformity. In an attempt to document this occurrence further, the cylindrical beakers were grouped, irrespective of colour, decoration or glass composition, on the basis of their base diameters – an advantage of this was that bases are indicative and frequently found fragments in the archaeological record. Three groups were differentiated by 15mm intervals, ranging from 35mm to more than 65mm base diameter (Caluwé 2000). The dominant group, F2 (50–65mm), accounts for 66% of the cylindrical beakers of the Antwerp Steen, while groups F1 (35–50mm) and F3 (>65mm) are less important in quantitative terms. This result is also reflected in other glass assemblages of the period throughout the region (Caluwé forthcoming a; forthcoming d). It would suggest a possible degree of standardisation of the production process, as it seems attempts were made to obtain an element of uniformity with regard to both vessel design and capacity. The use of a mould can also be seen as a form of simplifying the vessel-formation process because it reduces the number of manipulations required and the time needed for the formation per vessel, and is thereby most probably more time and cost effective.

This search for more effective production modes coincides with an increasing number of complex forms built up by joining several parts of the vessel with preformed mereses and/or stems on a separate foot, which occur in the archaeological record from the late 16th century onwards. These compound vessels (COLOUR PLATE 64.a–c) are very conspicuous objects, produced in all sorts of glass and colours; but are always distinct high-quality products.

Although these complex forms added to the stem develop out of the former pedestal types (COLOUR PLATE 59.a–b) frequently found in both the German and French traditions, the influence of Venetian technology and design stimulated a general tendency towards more complex and elaborate forms, which evolve chronologically (COLOUR PLATE 65). The quantification, frequency, distribution and dating of the different types of compound stems functions as a standard to measure the transfer of technology and the degree of interaction between the distinct glass traditions throughout the whole of Europe as shown for the Netherlands (Henkes 1994, 200–1), France (Velde 2002), England (Willmott 2002) and Germany (Steppuhn 2003).

Glass objects were also increasingly used for purposes other than drinking or storage, extending also to serving and presentation (COLOUR PLATE 66.a–b). From the early

17th century onwards low pedestal bowls in opaque white glass, used for the presentation of sweets, occur in Antwerp, Middleburg, s'Hertogenbosch and Breda (Caluwé forthcoming c).

As table manners developed during the 16th and 17th centuries, so did the way the table was laid, and the use of the objects at the table. In general a tendency towards increasing individualisation of the object used, and a specialisation and serialisation of the range of objects, can be noted. Certain forms became related to certain types of drinks, as the range of these expanded. The introduction of warm drinks, such as spiced wine, drunk in porcelain *candeelscoppen* cited in Dutch cargo lists from the early 17th century onwards (Van der Pijl-Ketel 1982, 30), coffee, tea and chocolate (from the second half of the 17th century – Laan 2002) and their impact on drinking habits cannot be underestimated. The inappropriateness of contemporary glass vessels for warm liquids made glass producers look for other niches in the table and drinking ware market.

This increasing specialisation is reflected by the very specific vessel types used for toasting and social games played at the table, for which purpose all sorts of forms such as bells, horns, boots and canons were in use (COLOUR PLATE 67 – *Drinkuyt,* goblet without a foot). The occurrence of these vessels, on high-ranking military sites such as Breda, 's-Hertogenbosch and Middelburg, Flanders, demonstrates the perceived value they had in certain gender-related contexts.

Another social and even more symbolic use of vessel glass is shown by the pedestal beakers (COLOUR PLATE 68.a–b) occurring on several sites in Antwerp, Middelburg and s'-Hertogenbosch. They are very often found as a pair, two very similar vessels with comparable dimensions, decoration and overall appearance. Their use for drinking games is well known, but they were also popular as betrothal and wedding presents, often in conjunction with Werra or yellow slipware dishes (Laan 1994, 102; Steppuhn 2003, 108).

Diversity in glass compositions

The growing tendency towards a standardised production is also noticeable in the technological changes applied in search of a stable glass composition. The compositions of 130 16th and 17th-century *façon-de-Venise* vessels from Antwerp excavations were analysed in order to separate the genuine Venetian imported glass and the locally manufactured objects (De Raedt 2001). The majority of the samples were categorized as local production, although with three different compositional groups – 16th-century *façon-de-Venise* (FDV), 17th-century *Antwerp cristallo* (AC), and a mixed alkali group (MA). Related to this latter group are the vessels in potash glass (PA; De Raedt 2001, 129). A remarkable technological development is noticeable through a change in the type of ashes used as an alkali. Thus, all the 16th-century FDV objects have glass compositions suggesting that unpurified natron-rich ash was used as a flux, probably in the form of Spanish *barrila*. In contrast, the 17th-century AC and MA compositions, though based on the same, purified natron-rich ash are now mixed with purified potassium-rich fern ash in different proportions. These proportions and the various mixtures vary with the quality and complexity of the vessels (De Raedt 2001, 129).

In general, when comparing Antwerp composition to compositions from Venice, Tuscany, Amsterdam, London, Breda and Maastricht similarities are found suggesting that 16th and 17th-century recipes and practices were shared.

Conclusions

The archaeological finds reflect the importance and the central role of the former Duchy of Brabant as a distributive network and crossroads for spreading methods of production and use of vessel glass. Although the prominence of the green forest potash glass and the increasing quantities of colourless and *façon-de-Venise* soda and mixed alkali glasses are evident, their different provenances are less noticeable. In order to compete with foreign markets and imports several technological changes occurred simultaneously and interactively, both in the vessel formation process and in the glass composition, suggesting a growing tendency towards a more efficient and cost-effective production. Thus the diversified use of moulds, the changing use of raw materials and the development of compound vessels act as significant indicators for the assessment of interaction between the distinct glass traditions. Furthermore, the impact of other material groups such as metal, ceramics and porcelain, on the production, appreciation and the use of glass tableware cannot be underestimated. Only further quantitative and comparative analyses of data from artefactual, historical, pictorial and archaeometrical sources can further elucidate the provenance, distribution and use of vessel glass in the study region in the period between 1400 and 1700.

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ARCHAEOLOGY OF GLASS: MEDIEVAL AND RENAISSANCE PRODUCTION IN ITALY. CHARACTERIZATION AND CLASSIFICATION OF PRODUCTION INDICATORS: AN INTERDISCIPLINARY APPROACH

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Introduction

This contribution stems from the difficulties archaeologists have in producing a macroscopic classification and interpretation of various kinds of production indicators found in glassmaking and glassworking sites. Some indicators are well known and easily recognizable – furnaces, crucibles, tools, moiles, cuttings, trails etc – and can be placed exactly in the production cycle. However, the origin and role or function of others is more difficult to recognize and explain. For example what are the different stages of frit and what is the significance of some kinds of production waste such as scums, heterogeneous masses etc? Is it possible to recognize relicts of raw materials in some indicators? An interdisciplinary approach, bringing together archaeologists, petrologists and chemists, can clarify some of these questions. As all indicators contain intrinsic information, they can be characterized, classified and placed in the production cycle when explored by scientific analysis. Here we present some examples of this approach tried out on production indicators found in Liguria and Tuscany (FIG. 1) where glass was made and worked (Casellato *et al.* 2003a; 2003b; Giannichedda *et al.* 2000; Messiga and Riccardi 2001).

FIG. 1 Location of the districts of Liguria and Tuscany

Macroscopic classification of production indicators

A relevant quantity of different indicators is an important element in identifying past glassmaking or working, as demonstrated in the glass-production sites excavated in Gargassa (Liguria) and Gambassi (Tuscany) (FIGS 2–4). A few isolated glass drops are not sufficient to prove glass production, because they could derive from other production activities. Macroscopic classification of the indicators was made by considering their morphology and archaeological context; they consisted mainly of vitreous and heterogeneous materials of different shape and volume.

The indicators are closely related to the principal steps of the glass-production cycle recognizable in glassmaking and glassworking.

Glassmaking consists of:

Step 1. Fritting raw material. Different kinds of heterogeneous masses are possible indicators of this process.

Step 2. Frit melting and refining of the batch. This may generate:

- drops and drips (possibly from tests for fluidity);
- vitreous masses in opaque or transparent glass;
- scums – partly vitrified irregular masses;
- slags – partly vitrified irregular masses;
- cullet – scrap glass used for recycling.

Glassworking consists of:

Step 3. Modelling the molten glass into artefacts produces similar indicators to those of step 2 as well as others of a different kind:

- drops and drips;
- vitreous masses in opaque or transparent glass;
- cuttings – fragments of glass released during the working of artefacts;
- moiles – conical-shaped glass masses left on the blowing pipe;
- tweezer marks – glass masses with signs of tweezers;

Step 4. When annealing the artefacts only broken glass, usable for recycling, is generated.

In this contribution we present examples of indicator characterization belonging to the first and second steps.

Archaeology of glass in Liguria

Glass production in Liguria is attested by documents (Calegari and Moreno 1975) and archaeological research

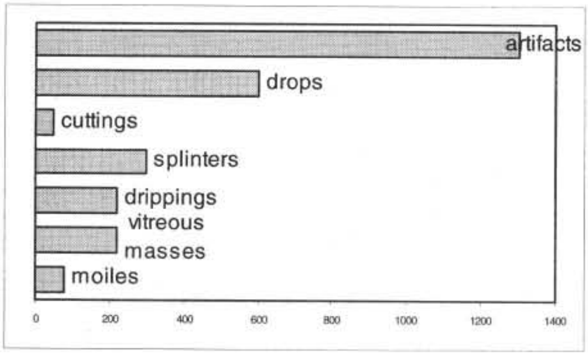

FIG. 2 Production indicators at Gargassa

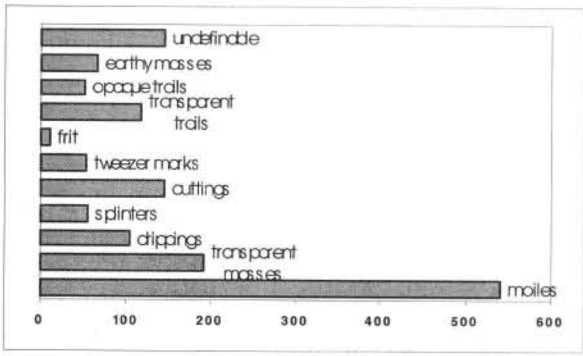

FIG. 3 Production indicators at Gambassi

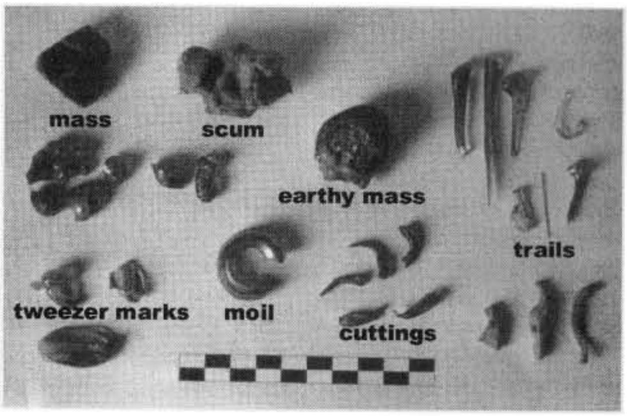

FIG. 4 Production indicator categories

(Fossati and Mannoni 1975; Giannichedda 1997; Lerma 2003).

In the central part of the region (district of Genoa and Savona) 20 production sites active between the 13th and 17th century have been identified. These data are not equally distributed and the Stura Valley can be considered the most important based on the number and distribution of glasshouses and the quantity of archaeological finds. Here, in the so-called 'Oltregiogo' between Genoa and northern Liguria, at least ten medieval glasshouses – 13th to 15th century – have been identified.

One of the glasshouses, located in the Gargassa Valley (Rossiglione – GE), was explored by ISCUM members in 1997 and 1998. The excavation revealed a stratigraphy rich in indicators of glass production related to furnace activity. It was not possible to excavate the furnace as it was located under an unsafe building, but finds indicated glassworking activity in the mid 13th century (Giannichedda 1997, 47). The Gargassa site yielded nearly 3000 production indicators belonging to different categories (FIGS 2, 4). At Gargassa the high number of artefacts, in comparison with other categories of production indicators, indicates a large recycling of broken glass (cullet).

Scientific characterization

Scientific analysis of archaeological glass needs an analytical strategy combining micro-textural and chemical investigations because there are a large number of chemical data available on glass compositions but only a few on its microtexture. Thus the analytic strategy includes different observation grades. Samples have been thin-sectioned (and C-coated for SEM-EDS), then analysed for micro-textural data under optical (OM) and scanning electron microscopes (SEM). This method allows us to analyse the same microtextures under optical and electronic microscopy, allowing the identification of micro textures through the distribution of medium atomic number differences in back-scattered electron (BSE) images. Spot data were necessary for *in situ* chemical analysis of phases related to particular microtextures. An electron microprobe (EMP) was used to perform *in situ* microanalyses. This was a JEOL JXA 840A electron analyser equipped with three wavelength-dispersive spectrometers (WDS) (TAP, PET, LIF analysing crystals) and one Si(Li) energy dispersive spectrometer (Be-window). Analytical conditions were 20kV accelerating voltage and 20nA. Spot size was 5mm. Counting time was 20 seconds for all elements except Mn and Fe (40 seconds). Data collected by the WDS were processed with the TASK correction program. Mineral phases were used as standards. Estimated precision was about 3% for major and 10% for minor elements, respectively.

When we are able to use an analytical strategy combining micro-structure observations with spot analyses of phases related to significant micro-textures, we can reconstruct a sequence of events that, exceptionally, can cover the whole history of the artefact. FIGURE 5 is an exhaustive example of a sequence of processes undergone by an artefact over a long period – from melting to burial within an archaeological deposit. In the sample from the Gargassa site a relic of the batch material (Ba-feldspar), partially reacted and melted, is evident. The cleavage planes are evidence of its crystalline nature. The compositional zoning in adjacent glass, tested by different grey shades, represent a steady state of the melting process dominated by diffusion of some components from the solid phase. During cooling the glassy transition only partially occurred and diopside crystallized. The artefact within the archaeological sediment experienced weathering reactions, such as alkali-depletion along fractures from surface to the inner parts (small irregular breaks and production of black alteration).

ARCHAEOLOGY OF GLASS IN TUSCANY

Glass production is attested throughout Tuscany (Pisa, Florence, Gambassi, Siena, Arezzo, Lucca, Pistoia, Prato, Volterra etc) from the early 13th century by documents and archaeological research (Mendera 2002). The first

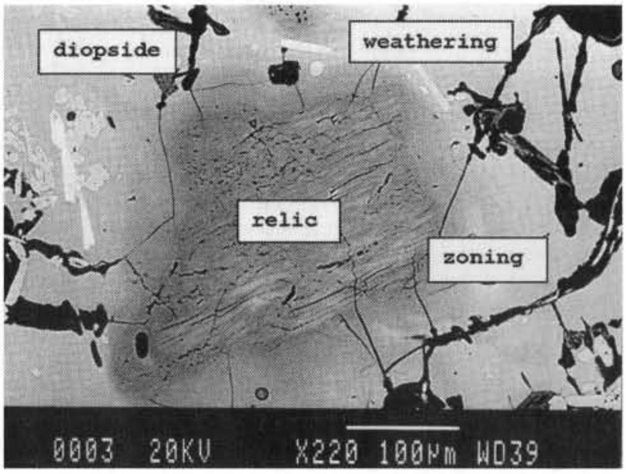

FIG. 5 Microstructure of an opaque glass mass from Gargassa

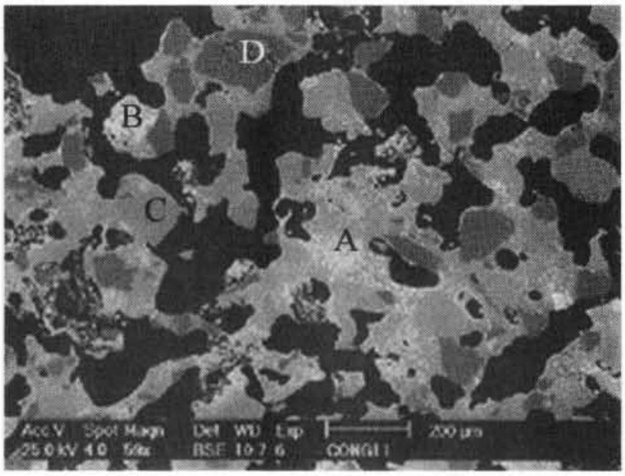

FIG. 6 BSE view of a thin section of a partially fused sandy conglomerate from Gambassi

glasshouses were located outside the villages beside woodland, but from the second half of the 14th century they lay also within villages and cities. Making and working glass for common use was particularly important in the Elsa Valley. Field archaeology, undertaken in the 1980s by the Department of Archaeology of the University of Siena, plotted 29 glass-producing sites there. In two of these, at Germagnana and S. Cristina near Gambassi (district of Florence), extensive excavations were carried out in the 1980s and 1990s, and altogether six medieval furnaces were found where green glass – beakers, bottles and flasks – was made and worked (Mendera 1993).

Excavations in the central square in Gambassi testify that glass was produced inside the city walls from the end of the 14th century until at least the 16th century. The circular Renaissance-period furnace, where over 1500 production indicators (FIGS 3, 4) were found, is well conserved. The high number of moiles, cuttings and drips demonstrates that in this furnace artefacts were modelled, but heterogeneous masses indicate that glass was also made. Besides green glass (flasks, bottles lamps), blue (cups), yellow (beakers) and greyish (goblets and little bottles) glass was worked (Mendera 1999).

Scientific characterization

Heterogeneous masses and sampled sands from the Elsa Valley

Comparison of heterogeneous samples with sands from nearby sand quarries allows us to propose that these sands were used for glassmaking in the Gambassi furnace.

Observation by optical microscopy of a partially fused sandy conglomerate found at the Gambassi site, revealed the sample to be composed of white and yellow-ochre grains. BSE investigations (FIG. 6) show white spots (B) extremely rich in Fe and Si and (A) containing in addition Ca. The most extensively present grey phase (C) has a feldspar composition, being rich in Si and Al. Finally well-defined dark grey crystals (D), mainly composed of Si, correspond to quartz, ascertained by a parallel XRD investigation which proved its presence as well as anorthoclase ($(Na,K,Ca)AlSi_3O_8$), diopside and calcite.

The presence of quartz indicates that its complete transformation did not occur during the glass-production process. Consequently an appropriate physico-chemical investigation of this find can give suitable parameters to be correlated with the raw materials used. The presence of calcite (≈5%) suggests its intentional addition (in Step 1) as a pre-treatment of the batch material.

Thermo-gravimetric measurements prove a 5% weight loss; a first weight loss (≈0.5%) in the range 500–600°C and the remaining weight loss (4.5%) in the range 640–770°C. This thermo-gravimetric behaviour is due to the decomposition of all the calcium and magnesium carbonates present in the sample, particularly calcite.

Mineralogical investigations were primarily carried out to identify the phases present in the sampled sands. Generally the identified phases are quartz, phyllosilicates, feldspars and calcite, their variable amount depending on the sampling place, as shown by a semi-quantitative XRD analysis.

The properties of the sand samples from the La Casina and La Casina La Cava quarries are closely related to those of the archaeological sample, although they show a higher phyllosilicate content. A washing of the sands can be proposed in order to remove these phyllosilicates and improve their physico-chemical properties, in view of the vitrifying process verified for the La Casina and La Casina La Cava sands.

Glass masses

Glass masses are finds of variable dimensions, with a relevant homogeneity and transparency. Their shape shows that they do not belong to vitreous production waste or to finished objects. Generally the glasses from the Gambassi site have a 1–2% Mn content that may justify an intentional addition of MnO_2 as decolourizer; the vitrifying material and the most used fluxes, in fact, show an Mn content less than 0.5%. Thus, without an intentional addition of MnO_2, the Mn content of the Gambassi glasses should be about 0.5%.

A vitrified heterogeneous sample showed under optical microscopy observation a yellow-green thin section, partially translucent and partially opaque. BSE investigations proved two morphologically different crystalline phases inside a vitreous bulk: one is needle-shaped while the other has an irregular form, both being mainly constituted by Ca and Si in a 2:3 ratio, with a manganese content of 1.5%. They are due to a crystallization process during the cooling of the material.

The mean SEM-EDS analysis showed a lower Ca (7.8%), a higher K (6.3%) and Mn (2.7%) content with respect to the mean composition of the Gambassi glasses. A rounded grain (≈300mm) was detected, its composition being MnO 85.2, SiO_2 10.3, Al_2O_3 2.0, CaO 1.1, Na_2O 1.1 and K_2O 0.3 %. The Mössbauer spectrum testifies the presence of a tetrahedral iron (III) (78%), a tetrahedral iron (II) (18%) and an octahedral iron (II) (4%); thus the iron is prevalently oxidized in this sample which is consequently yellow. The mean manganese percentage and the identification of manganese-rich grains, allow the classification of this sample as a slag generated at the beginning of the fusion and refining stage of the glass batch (Step 2) when the MnO_2 addition occurs.

Conclusions

With this interdisciplinary approach on production indicators we are trying to find answers to questions concerning medieval and Renaissance glass technology – raw materials, fritting, temperatures, use of cullets etc. Scientific studies corroborated or corrected the macroscopic classification of production indicators worked out by the archaeologists. Different kinds of scientific analyses on vitreous and heterogeneous samples allowed an initial characterization and classification of the indicators, and their placing within the first and second steps of the production cycle. It has been demonstrated that vitreous artefacts contain relicts of raw material and recycled glass cullet. Collaboration and discussion between archaeologists and scientists is thus shown to be fundamental for the comprehension and interpretation of the data. Continuing the project, it will be possible, in the second stage, to standardize terms, making it possible to bring together archaeological and archaeometrical publications.

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LA VERRERIE DANS LES ANCIENS PAYS-BAS: BILAN DES TROUVAILLES ARCHÉOLOGIQUES À BRUXELLES (XIVE – XVIIE S.)

CHANTAL FONTAINE

INTRODUCTION

Jusqu'il y a peu, les verreries de Bruxelles faisaient essentiellement parler d'elles par le biais de textes d'archives (Houdoy 1873; Schuermans 1889; Fettweis 1989). Loin d'être négligeables, ces sources donnent un éclairage de première main sur les conditions d'octroi, le renouvellement des privilèges, le type de production, les difficultés à faire respecter certaines décisions, etc. Ces documents ont aussi permis d'établir une filiation des détenteurs du monopole pour la fabrication des verres fins (cristal et cristallin) à Bruxelles, depuis 1622 et jusqu'à la fin du XVII^e s. (TABLE 1). Ces données théoriques peuvent aujourd'hui être illustrées grâce aux découvertes archéologiques.

LES DÉCOUVERTES ARCHÉOLOGIQUES

En réalité, Bruxelles n'est pas absente du paysage verrier européen. De nombreux verres y ont été exhumés. A une exception près (trouvaille rue Notre-Seigneur), ils ont tous été trouvés dans le centre historique de la capitale, circonscrit par la première enceinte datée du XII^e s. Qu'il s'agisse de découvertes anciennes fortuites, restées inédites jusqu'il y a peu, ou de verres issus de fouilles récentes, publiés ou pas, toutes ces trouvailles méritent d'être répertoriées et mises à jour afin de constituer une base de recherche pour les études futures. C'est dans cette optique-là que nous avons rassemblé toutes les informations dont nous disposons pour la période du XIV^e au XVII^e s.

A notre connaissance, la plus ancienne trouvaille de verres à Bruxelles remonte à un peu plus d'un siècle, vers 1897, dans l'ancien quartier Saint-Roch (actuellement Place de l'Albertine) (FIG. 1.1). L'étude récente de cette trouvaille a permis de dénombrer une soixantaine de récipients s'échelonnant de la fin du XIV^e s. au XVII^e s.: restes d'un gobelet à côtes torses, d'un maigelein simple et d'un maigelein sur pied, d'une quinzaine de maigelbechers, de verres biconiques à pieds refoulés, de gobelets à pastillage dont un beau *Stangenglas*, un calice à jambe à bouton tréflé et un beau fragment de coupe émaillée décoré de fleurs de lys (Fontaine 1997, 225–40).

Peu après, au cours de l'automne-hiver 1905–6, rue de la Grande-Ile (FIG. 1.2), les fragments de trois beaux verres 'façon de Venise' furent extraits du comblement du fossé de la première enceinte, d'après ce que l'on peut déduire de la relation des faits (Cabuy et Demeter 1997, 48–52, nos 35, 36, 37).

Bien plus tard, en 1968, en vue de la construction du métro et à l'extrémité orientale de la place Sainte-Catherine vers les rues de Laeken et de la Vierge-Noire (FIG. 1.3), cinq verres de la fin du XVI^e et du XVII^e s. furent fortuitement mis au jour. Parmi ceux-ci, un très beau calice côtelé à jambe à mufles de lion, un fragment de coupe en verre craquelé avec applique à tête d'homme barbu, dite

TABLE 1 FILIATION DES VERRIERS À BRUXELLES AU XVIIE SIÈCLE – VERRIERS DÉTENTEURS D'UN OCTROI POUR LA FABRICATION DE 'VERRES FINS' (CRISTAL ET CRISTALLIN); SYNTHÈSE ÉTABLIE D'APRÈS HOUDOY 1873, 19–73; SCHUERMANS 1889, 218–46; CHAMBON 1955, 103–20 ET FETTWEIS 1989

Anthoine Miotti	(octroi du 27 avril 1622 et nouvel octroi du 7 janvier 1623, accordé par Philippe IV)
Francisco del Bueno	(à partir du 23 octobre 1623)
Jean-Baptiste Van Lemens	(à partir du 4 décembre 1629)
Gilles Colinet	(à partir du 25 septembre 1640)
Francesco Savonetti	(peu de temps)
Jean Savonetti	(à partir du 29 novembre 1642)
Francesco Savonetti	(à partir du 22 décembre 1653)
Jean-Baptiste Van Lemens	(à partir du 26 octobre 1657)
associé à Henry Bonhomme	(à partir du 27 octobre 1657)
Henry et Léonard Bonhomme	(à partir du 20 juillet 1658)
Léonard Bonhomme	(jusqu'à sa mort en février 1668)
Ode de Glen (veuve de L. Bonhomme) avec son fils Léonard II Bonhomme	(poursuit sous le nom de son mari: nouvelle autorisation le 1^er janvier 1674, jusqu'au 31 décembre 1683)
Jacomo Mols	(à partir du 9 octobre 1681 jusqu'à sa mort, avant le 22 mars 1714)

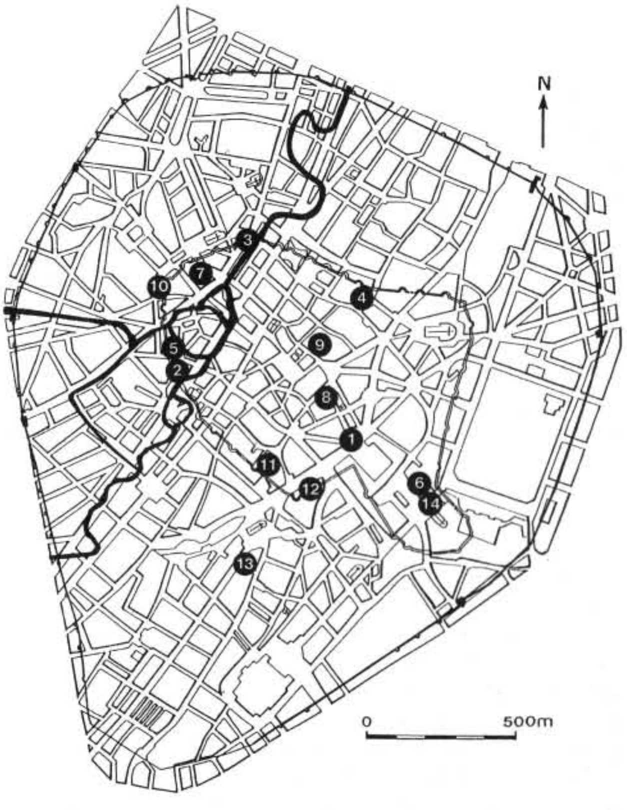

FIG. 1 Bruxelles: localisation des sites. 1 Place de l'Albertine, ancien quartier Saint-Roch; 2 Rue de la Grande-Ile; 3 Place Sainte-Catherine; 4 Rue Montagne-aux-Herbes-Potagères; 5 Eglise Notre-Dame des Riches-Claires; 6 Ancienne Cour d'Hoogstraeten; 7 Rue Sainte-Catherine; 8 Rue de la Madeleine; 9 Rue d'Une Personne; 10 Rue du Vieux-Marché-aux-Grains; 11 Rue de Dinant; 12 Boulevard de l'Empereur; 13 Rue Notre-Seigneur; 14 Place Royale

'de Neptune', disposée tête-bêche, et un gobelet filigrané *a fili* et *a retorti* (Cabuy et Demeter 1997, 92–3, no. 53; Fontaine-Hodiamont 2003, 256–62).

Une quinzaine d'années plus tard, à l'angle de la rue d'Assaut et de la rue Montagne-aux-Herbes-Potagères (FIG. 1.4), les restes d'un petit calice à tige creuse, daté de la fin du XIV^e s., furent minutieusement recueillis et confiés à l'IRPA pour restauration (Fontaine-Hodiamont et de Henau 1984/85). La fosse aurait aussi livré des verres du XVI^e s.: 'fragments de berkemeiers, aiguières et un peu de verre façon de Venise', sans autre précision (Cabuy et Demeter 1997, 107, no. 64; Jurion-de Waha 1984a; 1984b, 117).

Puis, en 1989, ce sont les ruines de l'église Notre-Dame des Riches-Claires (FIG. 1.5) détruite par un incendie, qui firent l'objet d'une fouille systématique. Quelques beaux spécimens en verre furent recensés, dont trois fonds de coupe côtelée appartenant à des calices à tige du XIV^e s. et une bouquetière à la vénitienne (De Poorter 1995, 61, 85–86, 99–100, 117–18, 130, 132, 139, 154, 169; Fontaine-Hodiamont 1994/95).

C'est en 1991 que les fouilles de l'ancienne Cour d'Hoogstraeten (FIG. 1.6) jouxtant la Place Royale, révélèrent l'existence d'une soixantaine de verres datant de la première moitié du XVI^e s. à la première moitié du XVII^e s. (Van Eenhooge 1995/96; Fontaine-Hodiamont et Dehertogh 2003, 253–6). Ici la verrerie de luxe, d'une rare qualité d'exécution (verres filigranés *a retorti* et *a reticello*, calices à jambe à mufles de lion, jambes à serpent) côtoie de la gobeleterie plus commune, des flacons et des bouteilles (COLOUR PLATE 69).

En 1992, c'est le quartier Sainte-Catherine qui fut exploré (FIG. 1.7). De nombreux gobelets aux décors variés et des berkemeiers du XVII^e s. (au total 60 exemplaires, tous incomplets) trouvés à l'emplacement même d'une ancienne brasserie et rassemblés dans une cuve en bois, vinrent ainsi enrichir le patrimoine verrier bruxellois. Non loin de là, furent aussi découverts quelques fragments d'autres gobelets, deux fragments de la partie inférieure d'un *Stangenglas*, rehaussée de filets bleus, remontant à la première moitié du XVI^e s. ainsi qu'un mascaron à tête d'homme barbu, doré, dite 'de Neptune' de la fin du XVI^e s. (Fontaine et Degré 1995; Fontaine-Hodiamont 1994/95).

Par la suite, en 1993, un calice à jambe en fuseau 'façon de Venise', ainsi que des restes de deux autres verres, tous du XVII^e s., furent découverts fortuitement rue de la Madeleine (FIG. 1.8) (De Poorter et Demeter 1997, 79 et 81).

Le site de la rue d'Une Personne (FIG. 1.9) fit l'objet de deux campagnes de fouilles, en 1992 et 1994. Deux fûts à pastillages avec base dentelée et quelques menus fragments de bouteilles des XVI^e/XVII^e s. y furent trouvés (Diekmann 1997, 49–50).

En 1995, des sondages archéologiques furent réalisés à l'angle de la rue du Vieux-Marché-aux-Grains et de la rue des Chartreux (FIG. 1.10). A cette occasion, une quantité impressionnante de fragments de verre du XVII^e s. fut extraite d'un puits recoupé par une tranchée. Sur les 95 individus recensés et pour la plupart malheureusement incomplets, 58 peuvent être qualifiés de 'façons de Venise' trahissant une recherche de pureté de matière proche du fameux *cristallo* (Fontaine 2001a, 153–72). La trouvaille interpelle par la très grande variété des formes: verres à jambe (à serpent, à anneau, à balustre), gobelets cylindriques (à paroi lisse, sur pied, à paroi ondulée, à résille, à gouttes), gobelets tronconiques, berkemeiers dont certains à piédouche surélevé du type '*spun-stem, tall type*' (Henkes and Henderson 1998), roemers à framboises ou à pastillage, bouteilles communes, bouteilles 'à eau de Spa' et fioles (COLOUR PLATE 70).

Toujours pour 1995, il faut mentionner les fouilles rue de Dinant (FIG. 1.11). Là encore, une belle moisson de tessons de verres sortit de terre. Le tri et la restauration mirent en évidence un petit cor de chasse à décor plumé, quelques spécimens rares de verres à jambe à la vénitienne et un bel échantillonnage de gobelets du XVII^e s. (COLOUR PLATE 71; Fontaine 2001b).

En 1996, une fouille de sauvetage put être effectuée boulevard de l'Empereur, au pied d'une tour de la première enceinte (FIG. 1.12). Plusieurs intéressants fragments de verres furent exhumés à cette occasion, dont un gobelet filigrané *a fili* blancs et bleus, datable de la deuxième moitié du XVI^e/premier quart du XVII^e s., ainsi que des morceaux d'une cruche moulée en *lattimo*, du XVII^e s. (Fontaine 2001c, 355–8).

Pour 1996, il faut encore signaler la découverte de 'verres du XVI^e s.', sans autre précision, lors de la fouille de deux fosses rue Notre-Seigneur (FIG. 1.13; Bonenfant et Fourny 1996).

Si les fouilles évoquées ci-dessus ne sont pas toutes des fouilles de sauvetage, elles présentent malgré tout un caractère ponctuel. Les seules campagnes de fouilles programmées avec une certaine régularité et qui ont fourni un matériel verrier appréciable, se situent en plein cœur de Bruxelles, Place Royale (FIG. 1.14). Elles ont pour objectif, l'étude de l'ancien palais de Charles Quint. Ces fouilles, menées par la Société Royale d'Archéologie de Bruxelles (dir. Prof. P.-P. Bonenfant) ont été entamées en 1995 et se poursuivent encore en 2003. Nous remercions Madame Nathalie Danis, responsable de l'ASBL *Palais de Charles Quint* qui, depuis peu, gère l'entièreté de ce site archéologique, pour l'accès qu'elle nous a donné au récent inventaire du matériel verrier. Cet inventaire illustre le contenu des 56 caisses dans lesquelles sont entreposés les verres (25 caisses de bouteilles du XVIIe s., plusieurs cols de bouteilles 'à eau de Spa', des dizaines de jambes à la vénitienne, des fragments filigranés, des restes de flacons et gobelets, etc). Provenant d'une citerne de l'*Aula Magna* et de remblais comblant diverses fosses, cet abondant matériel verrier n'est pas encore publié mais une trentaine de verres est accessible au public, depuis 1999, dans les derniers vestiges souterrains de la chapelle du vieux Palais de Bruxelles sur le Coudenberg. A côté d'une superbe bouteille biconique quasi intacte, de fûts de berkemeiers, de petits roemers et de fioles, on peut y découvrir quelques beaux témoins de la verrerie de luxe, tels des jambes à mufles de lion dorées, une 'tête de Neptune' également dorée, des jambes à ailettes et à fuseau, les restes d'une flûte à paroi gaufrée et deux panses de bouquetière à la vénitienne, tous des verres des XVIe et XVIIe s.

Le problème de l'attribution

Il est évidemment bien tentant d'attribuer une origine bruxelloise à tous les verres évoqués ci-dessus. Pourtant, compte tenu de certaines informations, il serait imprudent de considérer que tous les verres trouvés à Bruxelles y aient été fabriqués. Tout d'abord, la fabrication et la vente des verres communs ne semblent pas avoir toujours fait l'objet d'un monopole à Bruxelles. Ce n'est que quand Van Lemens reprit la verrerie de Miotti, en 1629, qu'il sollicita le privilège de faire aussi à Bruxelles 'des autres voires qui simplement s'appellent voires ou *vetro* en italien ...' (Houdoy 1873, 23). Il en fut de même pour Jean Savonetti à qui, par contre, fut accordé un monopole absolu et très explicite, interdisant l'entrée pour 'toutes sortes de verre de quelque pays ou composition que ce soit, nonobstant qu'ils seroient de cendres ou d'autres matériaux même les gros allemans, sans en excepter, aussi les verres en cristal de Venise' (Houdoy 1873, 28). Francesco Savonetti hérita des mêmes droits, y compris pour la fabrication des 'reumers, gros verre, bouteille à eauwe de Spa' (Houdoy 1873, 29).

Quant aux verres 'façon de Venise', ce n'est qu'en 1623 que Philippe IV en accorda, à Anthoine Miotti, le privilège exclusif (= monopole) pour la fabrication et la vente à Bruxelles. Précédemment, au XVIe s. et au tout début du XVIIe s., les verres à la vénitienne devaient sans doute arriver d'Anvers ou de Beauwelz, les centres les plus proches de Bruxelles autorisés à écouler leurs verres fins dans les Pays-Bas. Ce fut bel et bien ce même monopole exclusif pour la fabrication et la vente qui fut octroyé aux successeurs de Miotti. Mais nombreux furent les litiges qui opposèrent les détenteurs du monopole de Bruxelles aux verriers extérieurs: les infiltrations frauduleuses de verres fins 'façon de Venise' étaient fréquentes (Houdoy 1873; Schuermans 1889).

Il se peut donc que certains verres sortis du sous-sol bruxellois soient, par exemple, des productions de Gilles Colinet, verrier de Barbançon, avec qui Van Lemens et Jean Savonetti eurent plusieurs démêlés quand il ne détenait pas le monopole pour Bruxelles. Il pourrait aussi y avoir des productions de Nicolas Colinet, également de Barbançon et beau-frère de Gilles, avec qui les frères Henri et Léonard Bonhomme étaient en conflit pour non-respect du monopole. Le sous-sol de la capitale pourrait encore avoir livré des verres fabriqués par les Bonhomme, dits 'verres bruxellois', mais qui seraient en réalité des produits importés de leurs fournaises liégeoises, comme cela leur a été reproché, précisément par Nicolas Colinet. On sait aussi qu'en 1676, un certain Jean de Colnet, verrier de Gilly, fut autorisé à débiter ses gros verres, bouteilles et fioles, dans tous les Pays-Bas, au détriment de Léonard Bonhomme, maître de la fournaise de Bruxelles (Schuermans 1889, 236).

Tout compte fait, il est relativement plus aisé de cerner les productions dites vénitiennes. Des analyses de composition ont été effectuées sur de la verrerie fine provenant de plusieurs sites bruxellois, mentionnés ci-dessus. Les résultats ont mis en évidence que la plupart des verres étaient bien des 'façons de Venise', imitant les produits vénitiens, car leur composition s'écartait trop de celles des verres fabriqués à Venise. Seules les compositions de la *tazza* filigranée *a reticello* et du verre à pied filigrané *a fili* et *a retorti*, trouvés dans l'ancienne Cour d'Hoogstraeten, ainsi qu'une jambe à anneaux trouvée rue de Dinant se rapprochent des productions vénitiennes en *vitrum blanchum* (Wouters 2002; Fontaine 2002, 415–20; Fontaine 2001b, 226–7).

Un lien entre Londres et Bruxelles

En recherchant des pièces de référence pour l'étude des verres bruxellois, des coïncidences nous sont apparues de plus en plus troublantes. A cinq reprises à présent, des verres exhumés à Bruxelles et datables de la première moitié du XVIIe s., trouvent des parallèles à Londres, dans la trouvaille de Gracechurch Street (Oswald and Phillips 1949) qui, en 1940, livra plus de deux cents verres rassemblés dans une cave, probablement l'entrepôt d'un magasin, jouxtant l'ancienne église Gracechurch. Le contexte archéologique de la découverte londonienne situe le matériel dans les années 1600–1666. Le *terminus ante quem* est donné par l'incendie qui ravagea l'église et l'entrepôt en 1666.

Les verres en question sont les suivants:

1 Un calice à jambe à chaînettes (rue de Dinant, COLOUR PLATE 71, à droite = Gracechurch no. VIII)

2 Une flûte à jambe à serpent (rue de Dinant = Gracechurch no. VII, à gauche)

3 Une jambe à bouton côtelé (rue de Dinant = Gracechurch no. VI, à droite) (Pour les 3 verres trouvés rue de Dinant, voir Fontaine 2001b, 229-30, respectivement IRPA 3, 5, 7)

4 Petit verre à jambe et pied refoulé (quartier Sainte-Catherine = Gracechurch no. XI, à gauche) (Fontaine et Degré 1995, 155, no. 48)

5 Fragment de coupe émaillée à fleurs de lys (Place de l'Albertine = Gracechurch no. X) (Fontaine 1997, 233, 235, fig. 257)

Au moment de sa découverte, la version anglaise du calice à jambe à chaînettes n'est pas passée inaperçue: 'this lovely piece of glass ... this fantastic stem ...'. L'hypothèse d'une production londonienne était clairement envisagée: d'inspiration vénitienne, produite par la verrerie Mansell et peut-être même façonnée par les mains de Paolo Mazzola (Oswald and Phillips 1949, 33). Cette jambe, alors unique en son genre, suscita vraiment l'admiration.

A priori, il paraît peu vraisemblable que nos verres bruxellois soient directement issus d'une verrerie londonienne. Et pourtant un fil conducteur relie ces deux villes: il s'agit d'Anthoine Miotti. Depuis juillet 1606, ce capitaine vénitien apparenté sans doute aux Miotto, verriers renommés de Murano, dirigeait la verrerie de Middelburg aux Pays-Bas. En 1619, il rejoint la verrerie londonienne de Robert Mansell où il est présenté comme 'one of the ablest and most knowing for the Guidance of a Glasswork in Christendom' (Thorpe 1949, 121–4). Par la suite, il retourne sur le continent et, le 7 janvier 1623, obtient de Philippe IV l'octroi pour la fabrication de verres fins à Bruxelles, alors capitale des Pays-Bas.

Le privilège qui lui est accordé pour Bruxelles le présente

> 'muny des qualités, expérience et inventions, convenables pour faire par deça les verres, vases, couppes et tasses de fin cristal de Venise, de toutes sortes de couleurs à boires vins et bières; de la même bontè, perfection, matière, comme se font au dit Venise et de la quintacensia de la barilla et du soda parfaict et real et non contrefaict ...' (Houdoy 1873, 54–5).

Evidemment, rien ne prouve que ces verres fortement apparentés aient été fabriqués par Miotti dans les villes où il a séjourné, d'autant plus que son activité à Bruxelles semble avoir été assez réduite dans le temps. Pourtant, à l'heure actuelle, c'est bien la seule piste qui semble relier Londres à Bruxelles.

En conclusion, il est clair qu'au XVIIe s. des verriers chevronnés ont voyagé d'une verrerie à l'autre, emportant leur tour de main, leur savoir-faire, telle une signature. Pour pousser davantage cette recherche, il faudrait interroger les archives relatives aux verreries de Londres et de Bruxelles: elles recèlent peut-être encore quelques secrets concernant le transit des verriers. En règle générale, les archives mériteraient certainement d'être explorées dans ce sens afin de jeter des ponts entre les différents centres de production des 'façons de Venise', qui sont jusqu'à présent étudiés de manière fort isolée.

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MEDIEVAL AND POST-MEDIEVAL GLASS FROM RUA DA JUDIARIA, ALMADA, PORTUGAL

TERESA MEDICI

The town of Almada is located on the River Tagus opposite Lisbon (FIG.1). Excavations at Almada have revealed continuous occupation from the late Neolithic, through Bronze Age, Iron Age, Roman epoch and Islamic to medieval periods. The site at Rua da Judiaria is located in the old part of the town (*Almada Velha*), and was excavated between 1992 and 1994 by a team from the *Museu Municipal de Almada* (*MMA*). It yielded an important medieval and post-medieval record. The site is now part of the museum and is open to the public.

FIG. 1 Location of the town of Almada

The first phases of occupation at the site are represented by 26 pits carved in the bedrock during the Islamic period. They were probably used from the 12th to the 15th century, and then sealed in the 15th century, when the area was restructured for the building of new dwellings. These were short-lived, as they were abandoned during the 16th century, when the whole area began to function as a courtyard which was subsequently covered with a large deposit of 16th to 20th-century rubbish.

The excavations revealed an important group of finds, featuring Chinese, Italian, Spanish and Portuguese pottery, glass objects, coins, etc, indicating that Almada was closely linked to European countries and Portugal's overseas colonies (Barros 2000).

THE GLASS OBJECTS

About 600 fragments of glass objects were collected at Rua da Judiaria from pits and rubbish deposits. Here I present an overview of the glass found in contexts dated to the 15th–17/18th century. Since the complete results of the excavations are still unpublished, the chronological framework used here is based upon the report submitted by the field director, Mr Luís Barros (*MMA*).

Most of the vessels are free-blown; some of them have mould-blown decoration and pontil marks. The fragments are mainly made of colourless transparent glass, sometimes with a blue, green or yellow tinge. Another prevalent colour is green, in shades ranging from blue green, light green and dark green to olive green. A few fragments are light blue, yellow, purple or red. Opaque black or white glasses are also present. In some cases, it is not possible to determine the colour and quality of the glass due to weathering and corrosion.

CATALOGUE

Fifteenth-century contexts

- beakers with applied pinched threads (FIG. 2.1, light green, and FIG. 2.2, colourless);
- cylindrical beakers with a mould-blown pattern of ribs (FIG. 2.3, colourless; others: pale blue);
- a goblet with mould-blown pattern of ribs and applied frill in opaque dark blue glass (FIG. 2.4, light yellow);
- a goblet with a mould-blown pattern of ribs and applied spiralling blue trails (FIG. 2.5, colourless with yellow tinge);
- a goblet with badly preserved enamelled or painted decoration, perhaps gilded (FIG. 2.6, green);
- a cup of a goblet with a mould-blown pattern of diagonal ribs (FIG. 2.7, colourless);
- various fragments of pushed-in bases of goblets, free-blown or with a mould-blown pattern of ribs (FIG. 2.8, colourless; other: colourless, colourless with yellow tinge, yellow);
- a beaker or cup of a goblet with opaque white diagonal trails applied to the surface (FIG. 2.9, colourless with blue tinge);
- a beaker or bowl with tubular rim folded outside and mould-blown pattern of vertical ribs (FIG. 2.10, colourless);
- bowls or plates with rounded or turned-over splayed rim (FIG. 3.11–12, colourless; FIG. 3.13, green; other: light green);
- a bowl or plate with rim rounded on inside (FIG. 3.14, opaque white);
- a small jar with truncated-conical neck (FIG. 3.15, yellow);
- bottles with cut rim underlined by an applied trail (FIG. 3.16, colourless; other: grey), with polished splayed rim (FIG. 3.17, blue green), with deeply kicked base (FIG. 3.18, colourless; others: light green, light blue, colourless with yellow tinge);

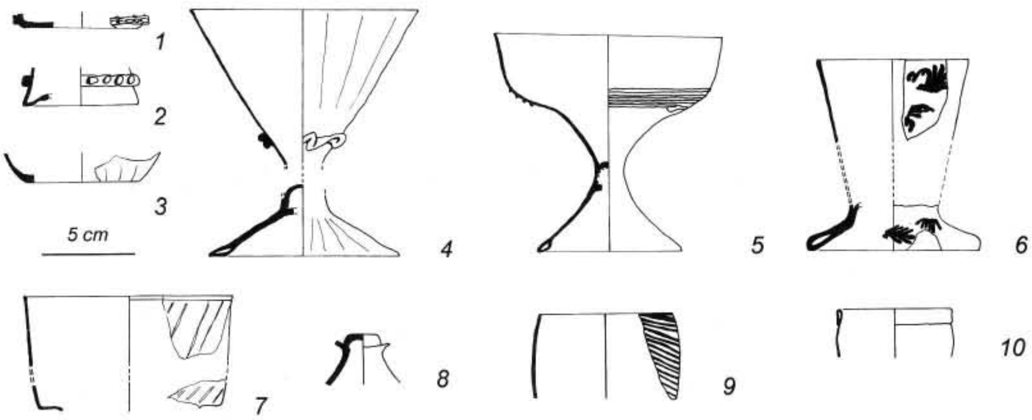

FIG. 2 Glass vessels from 15th-century contexts at Rua da Judiaria; scale 1:4

• a vessel probably with two handles, mould-blown pattern of vertical ribs on the body, applied trail at the base of the cylindrical neck (FIG. 3.19, light yellow).

Sixteenth-century contexts

• beakers or small bottles with pricked base, always made with light green glass (FIG. 4.20);

• pushed-in bases of goblets, with tubular base ring (FIG. 4.21, colourless with green tinge), and mould-blown pattern of ribs (FIG. 4.22, green);

• a wide variety of wine glass stems (FIGS 4.23, 25, colourless; FIGS 4.24, 26, dark green);

• a beaker or cup of a wine glass with rounded rim (FIG. 4.27, yellow);

• beakers or bowls with the rim folded on the outside (FIG. 4.28, olive green), or with applied horizontal trail (FIG. 4.29, dark yellow);

• bottles with kicked base (FIG. 4.30, light green; others: colourless with yellow green tinge, light green, olive green), with rim underlined by an applied trail (FIG. 4.31, colourless with yellow tinge; others: blue green; FIG. 4.32[1], dark green), with pushed-in base and tubular base ring (FIG. 4.33, olive green; others: light green);

• urinals (FIG. 4.34, green; others: colourless or colourless with green tinge; FIG. 4.35, green);

the diagnostic function of the green objects is uncertain, because the colour can make it difficult to observe the urine.

Seventeenth/18th-century contexts

• cylindrical beakers or cups of wine glass (FIG. 5.36, colourless; others: colourless with a green or blue tinge);

• cylindrical beakers or small bottles (FIG. 5.37, colourless; others: colourless with a yellow tinge, light green, green, olive green);

• a cylindrical beaker decorated with pincer-work (FIG. 5.38, colourless);

• various bases of goblets (FIG. 5.39, pushed-in, colourless; FIG. 5.40, light green; others: colourless; FIG. 5.41, colourless);

• a wide variety of wine-glass stems (FIG. 5.42–3, colourless; FIG. 5.44, olive-green; FIG. 5.45, colourless; FIG. 5.46, colourless with a green tinge); no. 46 is composed of a moulded hollow knop, decorated with two lion masks;

• bowls with turned-over splayed rim, plain (FIG. 5.47–9, olive green; others: colourless, colourless with a green tinge, light green) or with mould-blown pattern of ribs (FIG. 5.50, green; others: colourless);

• the pear-shaped neck of a bottle with globular body (FIG. 6.51, colourless with a yellow tinge);

• bottles with cut rim, underlined by an applied trail, and long cylindrical neck (FIG. 6.52, light blue; other: colourless);

• bottles with splayed rim, plain (FIG. 6.53, yellow) or with a mould-blown pattern of vertical ribs (FIG. 6.54, colourless with green tinge);

• bottles with pricked base, plain (FIG. 6.55, with globular body, light yellow; others: colourless, colourless with blue green or green tinge, light green, olive green; FIG. 6.57, olive green; other: colourless), or with mould-blown pattern of ribs (FIG. 6.56, light yellow; others: colourless, light green, olive green);

• bottles with pushed-in base and tubular base ring (FIG. 6.58, colourless; others: colourless with green tinge, light green, olive green);

• square bottles, always made with dark green glass (FIG. 6.59);

• a small bottle or jar with splayed rim and cylindrical body (FIG. 6.60, light yellow).

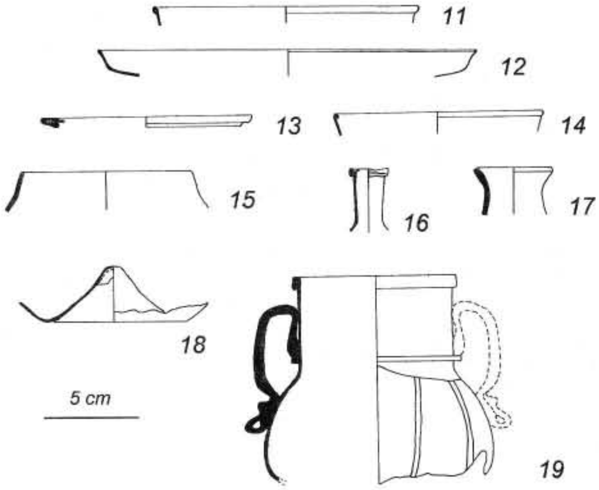

FIG. 3 Glass vessels from 15th-century contexts at Rua da Judiaria; scale 1:4

[1] When it was too late to modify text and figures, I received, from the director of the excavation, the information that the level where FIG. 4.32 was found is now dated to the 17th/18th century.

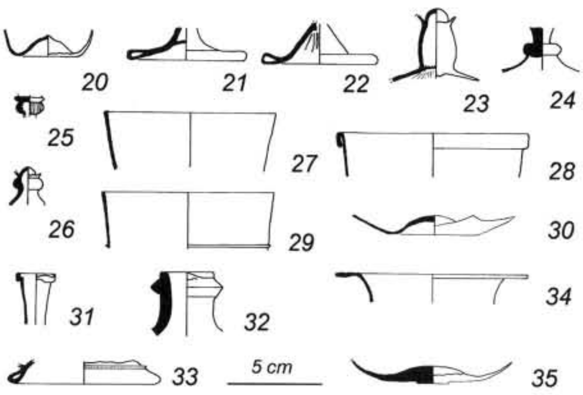

FIG. 4 Glass vessels from 16th-century contexts at Rua da Judiaria; scale 1:4

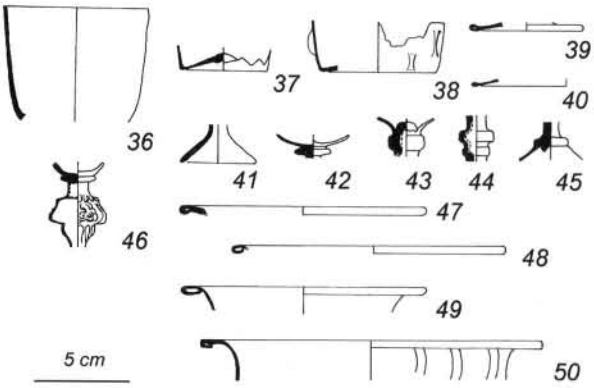

FIG. 5 Glass vessels from 17th/18th-century contexts at Rua da Judiaria; scale 1:4

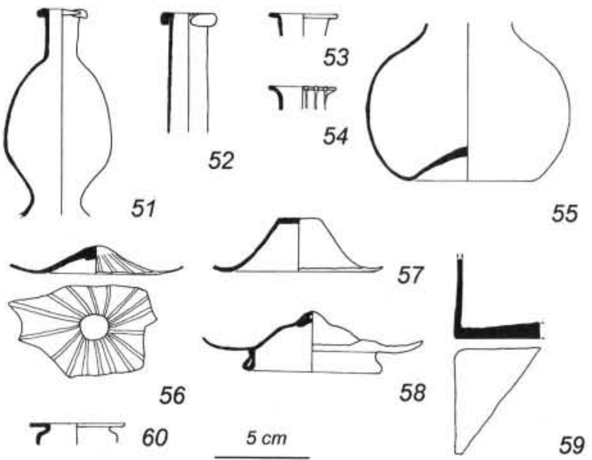

FIG. 6 Glass vessels from 17th/18th-century contexts at Rua da Judiaria; scale 1:4

DISCUSSION

Most of the glass objects from Rua da Judiaria may be compared with finds from other Portuguese sites. However, the presence of new specimens makes this assemblage particularly interesting.

The 15th-century contexts yielded a group of glasses that are most typical of European production of this period, such as the cylindrical beaker with mould-blown decoration (FIG. 2.3), the goblets with pushed-in base (FIG. 2.4–6), the bottles with kicked base (FIG. 3.18), and the decoration with opaque white diagonal trails applied on the surface (FIG. 2.9). All of these types are known from other Portuguese sites dated from the 16th century onwards, and found at Sintra (Ferreira 2003), Coimbra (Ferreira 1993), Lisbon (Ferreira 1997) and Tomar (Ferreira 1994).

However, the decoration with blue trails, appearing here on two goblets (FIG. 2.4–5), has never been described before in Portugal, as well as the painted (gilded?) goblet (FIG. 2.6). The production of colourless cups, goblets and bottles, with blue applied decoration, is known in southern France, from the end of the 13th century to the very beginning of the 16th century (see for example Foy 1985, 46–52), and in Italy, at the Monte Lecco factory, between the end of the 14th and the beginning of the 15th century (Fossati and Mannoni 1975, 62). The blue frill in particular seems to bear some relation to bottles and goblets from the 13th to the 16th century in Italy. Whitehouse (1981, 168–9) reported a group of objects coming from central Italy and Sicily. We can now add more finds from northern Italy: Liguria (a goblet in the *Museo del Priamàr,* Savona, dated to the mid 13th–15th century – Ventura 2001, 420, pl.187 no. 1471, and a bottle from Genoa, dated to the beginning of the 15th century – Andrews 1977, 169, no 19, pl. xxxi); Piedmont (two bottles from Varallo, late 16th century – Pettenati 1996, 414–15, figs 17, 18 – and a goblet in the *Museo Civico di Arte Antica,* Turin, dated to the end of the 15th/16th centuries – Pettenati *et al.* 1987, 414, no. 5, fig. 8); Friuli (two bottles dated to the 13th/14th centuries – Testori 1992, no. 14, no. 16, pl. 9).

The different types of bowls or plates (FIG. 3.11–15) are already known in Portugal (e.g. at Tomar, dating to the 17th/beginning of the 18th century – Ferreira 1994, 122, no. 15, 125, no. 43). Particularly no. 15, as well as the vessel in FIG. 3.19, may be compared with unpublished objects from Coimbra, dating from the 16th century onwards (M. Ferreira pers. comm.).

The more recent contexts offer a similar situation, showing a typical complex of glasses from the 16th to 17/18th century, which is well-known in Portugal and Europe: wine glasses featuring various types of stems reflecting the Venetian style; globular and square bottles; and cups (Ferreira 1989; 1993; 1994; 1997; 2003). Whereas the stem with lion masks (FIG. 5.46), very common in *façon de Venice* production, was unknown in Portugal previously, it is worth noting the presence of some glass that could belong to Portuguese production, such as the *cabaça* (FIG. 6.51), a bottle with pear-shaped neck and globular body deriving from the Islamic tradition and still produced in the *Real Fábrica de Vidros* in Coina during the 18th century (Ferreira 2000, pl. i, fig. 1; Custódio 2002, 27–8, figs 5, 6). The beaker with pincer-work (FIG. 5.38) and the bowl with mould-blown decoration (FIG. 5.50) also find their best comparison at Lisbon and Coimbra (M. Ferreira pers. comm.).

FINAL REMARKS

The glass assemblage from Rua da Judiaria represents a variety of objects that span at least four centuries of glassmaking.

The group of glasses attributed to 15th-century contexts allows us to predate the presence in Portugal of types hitherto known from 16th-century sites in Lisbon, Coimbra, Sintra and Tomar.

The assemblage as a whole shows either the early importation of objects from abroad (probably Italy) or the local reproduction of exotic models. Some objects, analysed from a formal point of view, may indicate local production. Unfortunately, the lack of archaeological data referring to glass factories prior to the 18th century biases our knowledge of Portuguese glass production before the creation of the Royal Factories at Coina and Marinha Grande (Custódio 2002, 43–57).

Finally, it is worth noting that the use of glass vessels in Almada is related to the presence of social classes such as merchants, jewellers, nobles etc. This also corroborates other archaeological and historical data (Barros 2000, 36–37).

Acknowledgements

I am very grateful to Manuela Ferreira for her useful suggestions and for kindly providing unpublished information about Portuguese glass that she is currently studying. I also thank the *Museu Municipal de Almada* for allowing me to study the glass finds of Rua da Judiaria and Simone Lerma for the bibliographic suggestion about the glass from Savona. I am finally indebted to Simon Davis and Diego Angelucci for reviewing my English.

Inventory of finds

Key: SL (*silos*) = pit; SD (*sondagem*) = sondages; c. (*camada*) = layer

Fifteenth-century contexts

1 cat. no. 15; SL 4, c. 1
2 cat. no. 158; SD 7/2, c. 3
3 cat. no. 16; SL 4, c. 1
4 MAH 2708 RJ 323, cat. no. 99; SD 8/2 *caixa de esgoto*
5 MAH 2820 RJ 324, MAH 9415 RJ 1343; SD 8/2 *caixa de esgoto*
6 MAH 9324 RJ 1256; SL 8, c. 3
7 cat. no. 176; SD 7/2, c. 3
8 cat. no. 77; SD 6/4, c. 4
9 MAH 9416 RJ 1344; SD 1, c. 5 and SD 10 (restored from 5 fragments)
10 cat. no. 139; SD 6/2, c. 5
11 cat. no. 441; SD 1, c. 5
12 cat. no. 51; SL 22
13 cat. no. 252, SD 1, c. 5 and SD 5, c. 3 (restored from 5 fragments)
14 cat. no. 171; SD 7/2, c. 3
15 cat. no. 433; SD 1, c. 5
16 cat. no. 395; SD 1, c. 5
17 cat. no. 410; SD 1, c. 5
18 cat. no. 52; SL 22
19 MAH 9329 RJ 1261; SD 1 c. 5 and SD 5 c. 3 (restored from many fragments)

Sixteenth-century contexts

20 cat. no. 331; SD 5, c. 5
21 MAH 9432 RJ 1352, cat. 265; SD 5, c. 5 and SD 10 (restored from 3 fragments)
22 cat. no. 259; SD 4, c. 6 and SD 5 c. 3 (restored from 2 fragments)
23 cat. no. 133; SD 6/2, c. 3
24 cat. no. 377; SD 4, c. 5
25 cat. no. 417; SD 4, c. 5
26 cat. no. 382; SD 4, c. 5
27 cat. no. 431; SD 4, c. 5
28 cat. no. 440; SD 4, c. 6
29 cat. no. 439; SD 4, c. 5
30 cat. no. 372; SD 4, c. 5
31 cat. no. 396; SD 4, c. 4
32 cat. no. 91; SD 2, c. 2
33 cat. no. 313; SD 4, c. 5
34 cat. no. 251; SD 4, c. 5
35 cat. no. 373; SD 4, c. 5

Seventeenth/18th-century contexts

36 cat. no. 412, SD 4 c. 3
37 cat. no. 335; SD 10
38 MAH 9429 RJ 1350, cat. no. 415; SD 4, c. 4
39 cat. no. 260; SD 1, c. 4
40 cat. no. 262; SD 5, c. 4
41 cat. no. 109; SD 8/2, c. 4
42 cat. no. 416; SD 10
43 cat. no. 381; SD 5, c. 4
44 cat. no. 380; SD 5, c. 3
45 cat. no. 378; SD 4, c. 3
46 cat. no. 376; SD 4, c. 4
47 cat. no. 254; SD 5, c. 3
48 cat. no. 258; SD 5, c. 3 and SD 10 (2 fragments)
49 cat. no. 266; SD 5, c. 3 and SD 10 (restored from 2 fragments)
50 cat. no. 250; SD 4, c. 4, SD 5, c. 3 and SD 10 (restored from many fragments)
51 MAH 2706 RJ 322; SD 5, c. 3
52 MAH 9433 RJ 1354, cat. no. 393; SD 5, c. 3
53 cat. no. 408; SD 10
54 cat. no. 409; SD 4, c. 3
55 MAH 9328 RJ 1260, cat. no. 392; SD 5, c. 3
56 cat.no. 364; SD1, c. 4
57 cat. no. 371; SD 4, c. 3
58 cat. no. 312; SD 5, c. 4
59 cat. no. 108; SD 8/2, c. 3
60 cat. no. 435; SD 5, c. 4

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ABRISS EINER TYPOLOGIE DER MITTELALTERLICHEN GLASIMPORTE AUS BRNO/BRÜNN, MÄHREN, TSCHECHISCHE REPUBLIK

HEDVIKA SEDLÁCKOVÁ

Brünn liegt an der aus dem Süden ins Baltikum führenden Handelsverbindung in einem Gebiet, das seit der Vorzeit dicht besiedelt ist. Die Entstehung der mittelalterlichen Stadt wird allgemein um 1220 vermutet. Als Regierungssitz des Markgrafen war die Stadt das Wirtschafts-, Verwaltungs- und politische Zentrum der Markgrafschaft Mähren, die zum Bestandteil der Böhmischen Krone gehörte.

Seit der ersten Hälfte der 80er Jahre des 20. Jahrhunderts führt man im Stadtzentrum archäologische Grabungen durch, die eine große Menge sowohl Hohl- als auch Fensterglas zu Tage förderten. Die Mehrheit der Funde stammt aus Abfallgruben. Ihre Datierung ist in einigen Fällen durch Münzfunde gesichert. Bis 2003 wurden Glasbestände aus mehr als 70 Objekten bearbeitet, was etwa zwei Drittel des Gesamtmaterials ausmacht. Das Brünner Glas wurde schon seit 1990 sporadisch publiziert, wegen des Materialumfangs jedoch nur einige ausgewählte Exemplare (Himmelová 1990a; Himmelová 1991; Cerná Hrsg.1994), seltener auch ganze Materialfunde (Merta und Peška und Sedlácková 2002). Die Grabungen in Brünn wurden von einigen Fachinstitutionen durchgeführt, seit 1995 vor allem von der Gesellschaft Archaia Brno. Die Funde, mit deren Bearbeitung ich beauftragt bin, werden im Städtischen Museum in Brünn deponiert. Nach zweijähriger Arbeit sind die meisten Fundbestände an importiertem Glas aus der Zeit vom 13. Jahrhundert bis in die erste Hälfte des 16. Jahrhunderts dokumentiert. Im Ergebnis ist eine Typologie entstanden, die sich in XI Grundtypen aus sieben aufeinander folgenden Zeitabschnitten strukturiert (COLOUR PLATES 72–3, Abb. 1). Die Übersicht der Glastypen bis 1400 wurde bereits publiziert (Sedlácková 2003). Zur Zeit wird das einheimische Glas bearbeitet.

DER ZEIT BIS 1240

Aus der Zeit bis 1240 sind nur einige Hohlglas-Bruchstücke in der Stadt bekannt. Ein Nuppenbecher mit angesetztem herausgekniffenem Fußring aus sattem braunem Glas konnte gesichert bestimmt werden.

DER ZEIT VON 1240 BIS 1270

Aus der Zeit von 1240 bis 1270 sind aus zehn Fundstellen 48 Gefäße bekannt, die sieben Grundtypen repräsentieren. Es handelt sich dabei um eine Kanne, deren Hals mit Faden und um eine Tafelflasche, deren Hals mit blauem Faden ebenfalls umwickelt ist. Sechs Flaschen mit Fadenrippen sind aus braun oder violett getöntem Glas. Diese Flaschen sind nur dieser Zeit zuzuordnen. Anzutreffen sind auch die ersten Stauchungsringflaschen. Birnenförmige Flaschen sind aus grünem Glas, eine Flasche mit konisch zulaufendem Unterteil ist aus blauem Glas. Durchgehend walzförmige Flaschen sind aus braunem oder violettem Glas. Einige Nuppenbecher sind aus gelblichem oder braunem Glas. Ein überraschender Fund ist auch der Becher mit optischem Dekor aus Punktmuster und Bruchstücke einiger glatter Scheuer aus farblosem Glas. Fensterglas ist nur durch ein Bruchstück belegt. Die (Schmuck-) Ringe sind aus grünem oder gelbem Bleiglas.

DER ZEIT VON 1270 BIS 1350

1270 bis 1350 ist die Periode der reichen Fundbestände mit der größten Anzahl an Typen und Varianten. Die bedeutendsten Funde stammen aus dem Areal der Mecová-Straße, in dem der Markgrafensitz vermutet wird. Neben Kannen mit blauem und farblosem Dekor finden sich auch ähnliche Tafelflaschen. Eine hohe Anzahl an Flaschen mit Stauchungsring ist aus bräunlichem oder violettem, seltener aus farblosem Glas. Nuppenbecher kommen in drei Varianten am häufigsten vor. Bei schneckenförmigen Nuppen wird das Glas in bräunlichem Ton gehalten, die Becher mit spitz ausgezogenen Nuppen und kleineren schneckenförmig abgedrehten Nuppen sind aus farblosem, leicht gräulichem Glas. Belegt sind auch Becher mit Nuppen oder angesetzter Zickzacklinie aus blauem Glas, häufiger kommen jedoch glatte Becher oder Becher mit optischem Dekor aus Punktmuster vor. Völlig einmalig bleiben die mit Emaille und Goldfischen verzierten Becher. Kelchgläser kommen in Varianten mit einer glatten Kuppa oder mit Rippendekor aus Glas in leicht grauem Ton vor. Die Scheuer sind nach Nuppenbechern und Stauchungsringflaschen die dritthäufigste Gruppe mit verschiedensten Formen. Nur ein Scheuer ist glatt aus braunem Glas, weitere Bruchstücke stammen von solchen mit feinen senkrechten Rippen, die aus dünnwandigem farblosem Glas gefertigt waren. Aus dem Areal des vermeintlichen Markgrafensitzes stammen auch einige Gefäße, für die noch keine Analogien gefunden wurden. Es handelt sich um eine Schale mit deutlichen Rippen aus gräulicher Glasmasse und zwei Schalen von identischer Form und identischen Ausmaßen. Eine ist aus blauem Glas mit schrägen Rippen, die zweite aus grauem Glas und glatt.

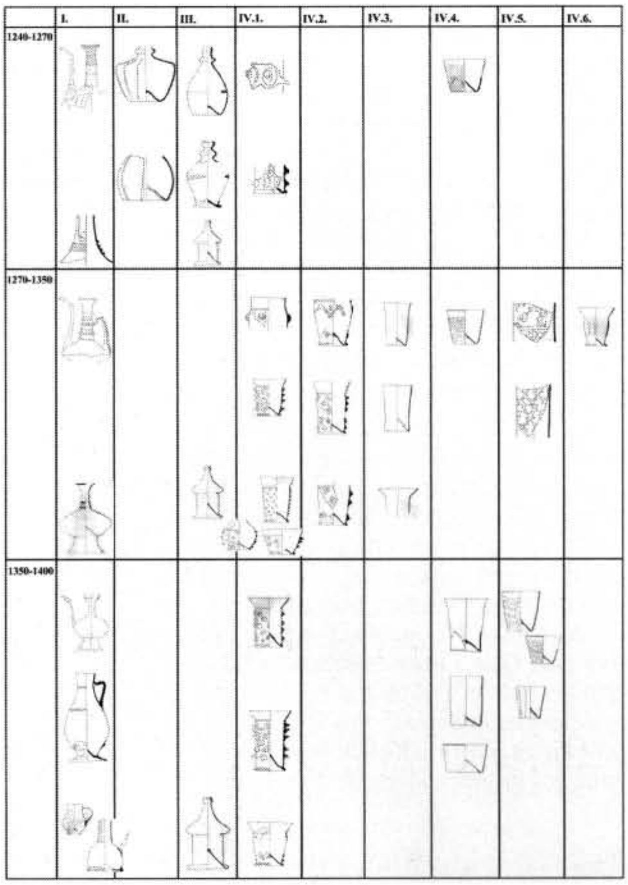

Abb. 1 Glastypen aus Brno/Brunn, Mahren (Tschechische Republik) 1240–1400. I. Schenkgefasse, II. Rippenflaschen, III. Flaschen mit Stauchungsring, IV. Becher – 1. mit Nuppen, 2. mit blauen Glasauflages, 3. glatt, 4. mit optisch geblasenem Dekor, 5. mit gemaltem Dekor, 6. mit den aus Glas aufgesetzten Rippen

Aus derselben Umgebung ist auch Fensterglas bekannt. Es sind mit Schwarzlot verzierte Füllungen aus smaragdgrünem Glas und längsrechteckige Tafeln aus gelbem und leicht violettem Glas. Heimische Herkunft kann man bei einem Becher mit senkrecht gezogenen Tropfen annehmen.

Der Zeit von 1350 bis 1400

In der Periode von 1350 bis 1400 treffen wir neben einer Vielzahl von Formen aus der vorhergegangenen Zeit auch völlig neue an. Einmalig ist die kleine Kanne aus opakem rotem Glas. Zum ersten Mal kommen auch Krüge vor. Tafelflaschen erscheinen in einigen Varianten. Die walzenförmigen Stauchungsringflaschen sind entweder aus extrem dünnwandigem, völlig farblosem Glas oder aus etwas dickerem Glas in gräulichem Ton. Die führende Form bleiben die immer noch in drei Varianten vertretenen Nuppenbecher. Bemerkenswert ist jedoch, dass eine Gruppe mit geringeren Ausmaßen vertreten ist. Verhältnismäßig zahlreich ist eine Gruppe glatter konischer Becher mit feinem optischem Punktdekor und blauen Fäden im Rand oder ohne blauen Fäden mit großem Punktmuster. Eine neue Variante stellen die Becher mit senkrechten Rippen dar. Weiterhin finden sich einige Kelchgläser mit glatter Kuppa. Einmalig ist ein kleiner Kuttrolf aus farblosem Glas. Scheuer treffen wir in zwei Varianten an: mit feinen Rippen aus farbloser dünnwandiger Glasmasse und mit starken Rippen aus dickwandiger, leicht gräulicher Glasmasse. In die Gruppe der Sonderformen gehört eine Pilgerflasche (Pilgrimflasche) aus blaugrünem Glas und ein bauchiges Gefäß (Grappen) mit drei Füßen. Das Gefäß in Hirschform mit Zickzacklinie aus blauem Faden und der kleine fassförmige Becher mit Nuppen im oberen Teil stellen wohl einheimische Produkte aus Glasmasse von minderer Qualität dar. Selten kommen hohe Trinkbecher böhmischen Typs vor.

Der Zeit von 1400 bis 1450

Von 1400 bis 1450 beobachten wir einen deutlichen Rückgang des importierten Glases und eine Verringerung des Formenspektrums. Einheimische Erzeugnisse, vor allem Becher böhmischen Typs, gewinnen deutlich die Oberhand. Importiertes Glas ist lediglich noch durch Flaschen mit trichterförmigem Rand vertreten, der dicht mit blauem Faden umwickelt ist. Becher sind fast immer mit spitzen Nuppen dekoriert, die in einigen Fällen auch aus leicht grünlichem Glas gefertigt sind. Die Becherform ist fassförmig mit niedrigem Rand. Als neue Variante ist ein Nuppenbecher mit einem hohem glattem Oberteil aus farblosem Glas anzuführen. Es bleiben jedoch auch die entweder glatten oder mit optischem Punktdekor versehenen konischen Becher erhalten. Fast vollständig verschwinden die Stauchungsringflaschen und die Scheuer. Flaschen mit schalenförmigem, von blauem Faden umwickeltem Rand sind einheimischen Erzeugnissen zuzuordnen. Als einheimisch kann auch der Nuppenbecher mit polygonaler Kuppa gelten. Fensterglas in Form von Butzenscheiben wird zu einer üblichen Erscheinung.

Der Zeit von 1450 bis 1550

Von 1450 bis 1550 Die Ansicht, dass in dieser Zeit als Folge des Niedergangs der einheimischen Glasproduktion das Hohlglas aus der Ausstattung der Haushalte verschwindet, ist bereits widerlegt (Sedláčková 2000). Aus Brünn sind momentan 24 Objekte bekannt, in denen Glas aus einigen Produktionsstätten vorkommt. In die Gruppe der venezianischen Erzeugnisse gehören ein Becher mit Rippen und Emaildekor, einfache konische Becher mit Rippen sowie Deckel und Bruchstücke der Hohlschäfte von Kelchgläsern. Wohl ebenfalls italienischer Herkunft ist ein hohes Stangenglas mit glockenförmigem Hohlfuß aus blauem Glas. Wahrscheinlich wurden auch weitere Erzeugnisse aus farblosem Glas von dort importiert, glatte konische Becher sind schon aus der Zeit von 1270 bis 1350 bekannt, Becher mit glattem Faden um den Standring. Aus deutschen Glashütten kamen Krautstrünke aus blaugrünem Glas, in einem Fall sogar aus farblosem Glas. Zahlreicher als die Krautstrünke bleiben jedoch die fassförmigen Becher mit spitz ausgezogenen Nuppen aus farblosem Glas;

ein Becher mit Nuppen und hohem glattem Rand stellt einen vereinzelten Fund dar. Die Stangengläser, meist aus blaugrüner Glasmasse, sind nur als Torsi der Unterteile überliefert. Die Gestaltung des Bodens bilden entweder à jour gearbeitete Füße oder Füße aus spiralförmig gewickeltem Faden und Zargen mit deutlich gezwickten Kanten. Ein Exemplar hat Nuppen in Form von kleinen Tierköpfchen. Einige Kuttrolfe sind aus grünem Glas gearbeitet. Eine bemerkenswerte Gruppe bilden weitere Erzeugnisse aus blaugrüner Glasmasse von hoher Qualität, oft mit blauem Faden im Rand. Es sind glatte Becher bzw. Becher mit optischem Punktmuster, Becher mit Rippen bzw. mit Wechseldekor oder auch Becher mit deutlichen, schon in Form geblasenen Rippen. Auf Grund der den Krautstrünken und Stangengläsern ähnlichen Glasmasse kann man bei diesen Erzeugnissen den Ursprung in Deutschland vermuten. In einheimischen Glashütten entstanden wohl aus Glas von minderer Qualität Flaschen mit Rippen und schalenförmigem Rand und Becher mit Rippen. Auch bei den Bechern mit polygonaler Kuppa ist heimische Herkunft anzunehmen. Am meisten sind jedoch hohe Becher vertreten, die in der Tradition der gotischen Becher böhmischen Typs stehen. Es sind Keulenbecher oder schlankere Formen von kleineren Ausmaßen. Das Dekor bei den Keulenbechern bilden sehr kleine Nuppen oder ein gewickelter Faden mit Rädchenmuster, die kleineren Becher sind oft in Form geblasen und dann mit Faden umwickelt. Relativ häufig kommt als Motiv die Zickzacklinie oder Girlande vor. Es ist wahrscheinlich, dass im zweiten Viertel des 16. Jahrhunderts auch Erzeugnisse aus den Tiroler Glashütten in Hall nach Brünn gekommen waren. Sie sind jedoch noch nicht identifiziert.

Schluss

Aus dieser kurzen Übersicht wird deutlich, dass das Hohlglas schon gegen Mitte des 13. Jahrhunderts in Brünn zu einem geläufigen Artikel und festen Bestandteil des Lebensstils geworden war. Bis Ende des 14. Jahrhunderts handelte es sich dabei ausnahmslos um Importe, die schon seit der ersten Hälfte des 14. Jahrhunderts auch in anderen südmährischen Gegenden zu finden sind (Himmelová 1979; 1990a; 1994). Erst im Laufe der ersten Hälfte des 15. Jahrhunderts gewinnen die Erzeugnisse der heimischen Glashütten die Oberhand. Was die Herkunft des importierten Glases anbelangt, so ist klar ersichtlich, dass während des ganzen Mittelalters die Stadt Brünn und ihre Umgebung von italienischen, wenn nicht sogar direkt von den Muraner Glashütten beliefert wurde. Südmähren gehörte seit der Vorzeit in den donauländischen Kulturkreis mit seinen starken wirtschaftlichen und kulturellen Bindungen zu den südlichen Nachbarländern, was auch noch während des ganzen Mittelalters bestimmend blieb. Der Vergleich dieser Funde mit dem Fundmaterial aus dem Südwesten der Slowakei (Hoššo *et al* 2002), aus Niederösterreich (Felgenhauer – Schmiedt 1991; Tarcsay 1999; 2002) Ungarn (Gyurky 1986; 1991; Mester 1997) Slowenien (Lazar 2001) oder direkt aus italienischen Gegenden wie Venedig (Pause 1996), Tarquinia (Baumgartner und Krueger 1988) und anderen (Mendera 2002) zeigt anschaulich die Herkunft dieses Glases von hoher Qualität auf, gibt aber auch Auskunft über den Weg, auf dem es nach Mähren gekommen war. Nur in der Zeit von 1240 bis 1270 wäre es bei einigen Erzeugnissen wohl möglich, die Provenienz auch in alpenländischen Glashütten zu suchen. Ansonsten kommen in dem einige Tausend Exemplare umfassenden Bestand der Brünner Glasfunde kein einziges Bruchstück eines Bechers des Schaffhausener Typs, keine Rippenbecher, Kreuzrippenbecher oder Maigelain vor. Seit der zweiten Hälfte des 15. Jahrhunderts finden sich hier vereinzelt Krautstrünke, Stangengläser und Kuttrolfe bzw. noch weitere Formen aus blaugrünem Glas.

Die Handelsverbindung des Ungarischen Königreiches mit Venedig wurde von 1417 bis 1433 durch das Verbot des Königs Sigismund unterbrochen, was auf ungarischem Gebiet zu einem deutlichen Rückgang des qualitativ hohen Glasbestandes führte. Die Importe wurden erst im letzten Viertel des 15. Jahrhunderts während der Herrschaft des Königs Matthias I. Corvinus in vollem Umfang wieder zugelassen (Gyurky 1986). Eine identische Situation können wir auch in Mähren beobachten: Glas von hoher Qualität wurde im Laufe der ersten Hälfte des 15. Jahrhunderts durch die einheimische Produktion ersetzt und erscheint wieder im letzten Drittel des 15. Jahrhunderts, als Mähren zum Bestandteil des Ungarischen Königreiches wurde. Die Präsenz des Glases spiegelt daher deutlich die aktuelle politische Situation wider.

Die außerordentliche Stellung Brünns wird beim Vergleich mit Glasfunden aus Mittel- und Nordmähren deutlich (Sedlácková 2001). Der Importstrom wurde ausschließlich nach Brünn geleitet. In Olomouc/Olmütz, der zweiten bedeutenden Stadt Mährens, kommt Hohlglas während des ganzen Mittelalters nur in begrenzter Menge vor. In der zweiten Hälfte des 13. bis in die erste Hälfte des 14. Jahrhunderts finden sich hier nur vereinzelt Nuppenbecher, Stauchungsringflaschen und Becherbruchstücke vom Typ Aldrevandin. Ungefähr seit der Mitte des 15. Jahrhunderts ist in Olmütz ein größeres Vorkommen an hohen Bechern böhmischen Typs zu verzeichnen. Gegen Ende des 15. und in der ersten Hälfte des 16. Jahrhunderts trifft man hier auch venezianische und deutsche Ware an, vor allem war jedoch ein spezifischer einheimischer Becher Olmützer Typs verbreitet. Früher als nach Brünn kommen hier jedoch die Erzeugnisse der Tiroler Hütten in Hall an (Sedlácková 2000). In Opava/Troppau (Schlesien) ist importiertes Glas bis zur Hälfte des 15. Jahrhunderts nur durch einige Nuppenbecher und Stauchungsringflaschen repräsentiert. Die Situation ändert sich gegen Ende des 15. bis in die erste Hälfte des 16. Jahrhunderts. Da begegnet man sowohl einheimischen Erzeugnissen als auch Importen aus dem Süden und aus deutschen Glashütten. In westlicher Richtung, in Böhmen, sind recht oft Nuppenbecher und Stauchungsringflaschen anzutreffen. Nur vereinzelt kommen weitere Formen wie Kannen, Tafelflaschen oder Rippenbecher vor (Lehecková 1975; Frýda 1990; Cerná 1992; 2000; Cerná Hrsg. 1994; Krajíc 2000). Die angeführten Beispiele belegen, dass Brünn im Vergleich zu anderen mährischen und böhmischen Städten, was die Ausstattung mit Hohlglas anbelangt, eine völlig außergewöhnliche Stellung innehatte.

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THE SEVENTEENTH AND EIGHTEENTH CENTURIES – STUDIES IN COMPOSITION

THE HERITAGE OF RECIPES EXPORTED BY VENETIAN GLASS MASTERS REVEALED IN A SEVENTEENTH-CENTURY MANUSCRIPT

Cesare Moretti, Carlo Stefano Salerno and Sabina Tommasi Ferroni

Introduction

The problem of glass masters emigrating from Murano to work in the provinces of the Venetian Republic or in foreign countries was a worrying issue for the Venetian authorities and in the 1271 *Capitolare dell'Arte*, rules laid down for the *fioleri* (chapter VIII), we find that a fine was already imposed on expatriate glassworkers and that they were forbidden to return to work in Murano. In one of his articles the historian Luigi Zecchin (1989, 96–101) followed the evolution over the centuries of these laws against the expatriation of the Venetian glass workers. With the same aim of protecting Venetian glass production, in 1285, we find a prohibition on the export without permission from the Venetian territories, of important raw materials such as glass cullet, alum, sand and other materials from which glass is made (*vitrum, alumen, sablonum, seu alia de quibus vitrum fieri debeat*); the chance of obtaining permission was denied in 1315 and the fines were increased through the 14th century.

In a decree of the *Quarantia*, in 1403, the glass masters are warned 'not to work in any place outside Murano, under penalty of a fine of 100 lire and of three months in prison'. The Mariegola of 1441 confirms the above prohibitions and also adds a penalty for the boatmen found transporting the forbidden materials outside the border of the Venetian Republic. In 1468 the glass furnace owners asked the Doge to 'prohibit the export from Venice of *allume catina*, and not to give licence for this, due to the fact that from the *Fontego dei Tedeschi* they export much alum for the false purpose of soap production', and to confirm the prohibition on exporting also 'quartz flints, frit, cullet, *zucconi*, manganese, pots, tools, moulds, or any thing pertinent to the glass production'. They ask also to double the penalties laid down by the previous *Quarantia* for glassworkers going to work outside the provinces of the Venetian Republic. A decree of the senate in the year 1489 fixed a penalty of 500 lire and one year's imprisonment for anyone going to work abroad and exporting the craft to foreign countries, and they could be arrested anywhere in Venetian territory; but at the same time if workers had emigrated to avoid personal debts and decided to return, they would benefit from a two-month delay before coming to an agreement with their creditors.

In the year 1549 the *Consiglio dei Dieci* decreed the public reading in Saint Mark's Square, Rialto and Murano, of the names of the glass masters and furnace owners considered at the time to be abroad, inviting them to return to Murano within eight or four months, depending whether they were outside the dominions of the Republic or not. If they did not come back and were caught and were unable to pay the fine, they 'would be condemned to the galleys for four years'. The list included 25 names; but only one, a certain Bastian Saonetto, seems to have obeyed. Another list of five illegal emigrant workers was read out in 1597, with the further proviso that, if taken, they would be 'condemned to remain chained to the galley oars for five continuous years and to pay a fine of 500 lire'.

As is clear from our summary, the sanctions were truly severe but we do not know if they were also strictly applied nor do we know how many glass masters actually obeyed the invitation to return to Venice. On this argument, Paolo Zecchin (pers. comm.) suggests that the reason why the Darduin manuscript was found in the Venice State Archive is probably because the codex had been in the possession of a glass master who had emigrated and had been obliged to hand it over to the Venetian authority in order to have permission to return to Murano.

Venetian glass masters present in foreign countries

The complete history of the emigration of glass masters has unfortunately still not been written; we do, however, have some interesting information from foreign sources.

For example, information on the Venetian glass workers present in Flanders during the 16th–17th century may be found in a book of Jules Houdoy, published in 1873, and from a series of letters written by H. Schuermans in the years 1882–1893. From these texts we know that in Antwerp one Ambrogio Mongarda was the owner of a furnace around 1580; at his death his widow married (1598–1599) Filippo Gridolfi who succeeded to the direction of the furnace under an exclusive privilege previously granted by Philip II. Another Venetian working at the Mongarda furnace in 1589, Antonio Obizzo, had illegally left the furnace of Donato Brunoro Brisighella at Murano, where he was engaged under contract; he was condemned to four years in the 'galleys' and to the reimbursement of the 107 ducati that he had received as an advance.

Antonio Miotti, a Venetian 'captain' (?), opened a glass furnace in Brussels in 1623 and later in Namur. When Miotti asked Philip IV for authorisation to do so he emphasized that he would produce, at a lower price, glass of the same quality as that produced in Venice, and gave assurances that he would use the same raw materials, in particular the best quality Barilla (soda ashes) from Spain. Stanislav Bormans (1880, 464–91), using information repeated later by D. Van de Casteele (1884, 202–8) and by H. Shuermans (Shuermans 1885), cites a document dated 1629 in which a Venetian master, Gasparo Brunoro, was involved in Namur in a contract with Antonio Miotti's widow, as we shall see later in greater detail.

In 1642 Giovanni Savonetti, banned from Venice with the confiscation of his property because he had introduced his craft in the Low Countries, obtained the exclusive privilege previously granted to the Brussels furnace.

Other information on the presence of Italian glass masters in England may be found in the book by W.A. Thorpe (Thorpe 1949, 114–35). He refers to the presence in 17th-century London of many Venetians working in the Broad Street furnace owned by Sir Robert Mansell, who at the time essentially had the monopoly of glass production. The two glass masters who most interest us are Antonio Miotti, in charge of production in the year 1619, who remained in London until 1623, and Gasparo Brunoro who was engaged for seven years from 1637.

THE MANUSCRIPT

The same Venetian glass master, Gasparo Brunoro, mentioned as present in Namur and London, appears in the title of a manuscript written anonymously in Danzig in 1645 and discovered some years ago in the Casanatense Library in Rome; it is the copy of various notebooks of glass recipes and of other texts. The frontispiece title states that the manuscript was written in Danzig, on 13th January 1645, and the declared subject of the book are the secrets of the many glass masters of crystal and of other literary men. The source of the recipes is not explicitly indicated but it is added that the book, and therefore the recipes it contains, was used and recommended by Gasparo Brunoro, nickname 3 Corone, who was a glass master, an expert in crystal glass and coloured glasses, and a native of Murano, Venice.

Gasparo Brunoro, previously almost unknown to historical researchers, is credited with being the guarantor of the recipes' validity and he could be the owner of the notebooks copied in this manuscript. He is one of the many glassmakers who fled from Murano in violation of the laws of the Venetian Republic, to export their know-how and contribute to the evolution of *façon de Venise* glassmaking technology throughout Europe.

In the year 1628 we find him in Namur (Belgium), a glass worker in the furnace of the Venetian Antonio Miotti. Miotti died the following year 1629. His wife, Cornelia van Horen, made an agreement with Brunoro, by which he engaged to employ her son, Sebastiano Miotti, at the furnace. Evidently Brunoro was charged by the widow to carry on the functioning of the furnace after the death of her husband. But, a few month later, Brunoro and Sebastiano Miotti were prosecuted by law for immoral behaviour and forced to leave Namur. We find Brunoro in London some years later when, in 1638, the Venetian Ambassador wrote to the authorities that a Venetian, Gasparo Brunoro, was in London in the factory of Sir Robert Mansell engaged to work as glass master for seven years (1637–1644). Other Venetians and also some glass masters from the glassmaking centre of Altare in the Monferrato province, were also working in this glass factory.

The manuscript was written in Danzig in the year 1645, so it is likely that Brunoro was there at that time, probably working in a local furnace. Other documents indicate that in the year 1649 he was in Copenhagen and in 1653 he was in Liège standing as godfather in a baptism; he is also mentioned in a list of Venetian glass masters present in Liège in the year 1655. We have no other news of him after that date; we do not know whether he returned to Venice and where he died.

THE IMPORTANCE OF THE MANUSCRIPT

The manuscript contains 256 recipes for the production of different kinds of glass and 36 concerning the preparation and treatment of raw materials for glassmaking; about 100 deal with metallurgy, alchemy, medicine and various other subjects. Examination of this document has highlighted that groups of recipes are common to the Montpellier (Zecchin 1964), anonymous 16th-century (Moretti e Toninato 2001) and Darduin (Zecchin 1986) manuscripts, and to Neri's text. It indicates that a Venetian glass master like Brunoro, working outside Venice, took with him a heritage of recipes covering almost two centuries of Venetian technology. Further regarding the importance of the manuscript, which is due to be published as a monograph annexed to an issue of the Bollettino ICR (*Instituto Centrale per il restauro* – Roma); we would like to emphasize here its demonstration that the so called 'secrets' of Venetian glass masters were in reality often exported and spread in foreign glass environments. On comparing the contents of the manuscript recipes with those in other manuscripts and in Neri's book, we see that 36 recipes are common to recipes in the Darduin manuscript, 52 to the Montpellier manuscript, 36 to the anonymous manuscript and 50 to Neri's book.

The sources of the recipes recorded in the manuscript seem to be entirely Venetian but we must underline that the original sources are never mentioned in the manuscript and the 'masters of Crystal glasses' in the title are never identified. Neri's book, published 33 years before, is completely ignored in the manuscript, although many recipes are the same. We can make the same observation regarding the Darduin manuscript, dated 1644 and hence one year before our manuscript was printed.

Concluding observations

Whatever the practical importance of the recipes once they were transferred to a foreign country and/or sold by the glass master; we may suppose that the engagement of Venetian masters by foreign glass enterprises was more probably motivated by the skills of the masters than by the stock of recipes they had with them. The ability of the glass masters trained in the Murano furnaces was needed to produce *façon de Venise* glass objects in imitation of the Venetian products of recognized excellence. The possession of the recipes to produce the glass was important but we must consider that the recipes were strictly linked with the raw materials originally utilized. If there was no access to a raw material prescribed in the recipe, it was impossible to reproduce the same glass and a similar product had to be used, at times with very different results. We are thinking in particular of *allume catina* ashes (a material imported almost exclusively by Venetians) and of Ticino river flints. In the unavailability of *allume catina* soda ashes, a possible substitute in North Europe was wood ash, rich in potassium, with the consequence that the glass becomes silico-potassic instead of being silico-sodic, and hence markedly different in its physical (viscosity for example) and chemical properties.

We think that more attention should be paid to these aspects of emigration of Venetian masters, and we think that the combined examination of Venetian and foreign documents could give more precise and interesting information on the transfer of artistic and technical know-how from Venice to other countries.

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ENGLISH LEAD CRYSTAL: A CRITICAL ANALYSIS OF THE FORMULATION ATTRIBUTED TO GEORGE RAVENSCROFT – WITH POINTS NOT YET CLEAR ON THE PROCESS FOR THE MANUFACTURE OF 'FLINT' GLASS

Cesare Moretti

Introduction

Much has been written in the last decades on the process followed in England, in the years 1674–1676, to produce lead crystal (Charleston 1968; 1984, 109–30; Watts 1975; 1990; McLeod 1987; Moody 1988; 1989; Francis 2000; Brain 2002). Opinions on the formulation used by George Ravenscroft to manufacture 'flint glass' have been, till now, based on the information reported by Robert Plot (1676) in his history of Oxfordshire. But the process by which Ravenscroft and collaborators might have arrived at the final formulation is not completely clear and presents many obscure and doubtful points.

George Ravenscroft and the development of flint lead crystal

In 1673 Ravenscroft met an Italian glass worker, Seignior Da Costa (Johan or Jean Baptista Da Costa, Master of Barremont), a native of Monferrato (a north-western Italian province where the glassmaking centre of Altare was situated). He set up a partnership with him to produce a new glass, in a glass factory at Savoy, London. Da Costa arrived in England from Eastern Holland, where, in 1665, he had produced glass imitating precious stones in a small glass factory at Nijmegen on the Rhine in partnership with Jean Guillaume Reinier and another Altarese, Johan Odacio Formica (McLeod 1987, 799; Moody 1988; Watts 1990; Francis 2000). The collaboration between Ravenscroft and Da Costa led, in the following year, to the request for a patent by Ravenscroft. In March 1674, he petitioned the King for a patent for the making of 'a sort of crystalline glass resembling rock crystal' (Charleston 1984, 110). This new glass, after a period of experimentation, was intended to contain significant levels of lead oxide – it was a kind of glass that Da Costa would have already experimented with in Nijmegen.

Extant documentation proves that Ravenscroft had contacts with a Venetian glass master, Vincenzo Pompeio, who was in London and intended to work with him (Rendel 1975). We also know that Ravenscroft had kept another Venetian in London for many months with the intention of beginning a glass production with his help. This was Pietro Rossetti, a master craftsman in mirror production; but the more important collaborator, was definitely Da Costa.

Christine McLeod (1986) mentions important information found in the diary of Robert Hooke, the famous scientist, on 29 July 1673 (and so seven or eight months before Ravenscroft applied for the patent). Together with Dr Wren, he visited the Savoy glasshouse where Da Costa was working (McLeod 1987, 799). In his diary Hooke wrote that he saw 'calcined flints as white as flower, Borax, Niter and Tarter with which he made his glass'.

Robert Plot published *The Natural History of Oxfordshire* in 1676. This contains a paragraph dealing with the invention, at Henley on Thames, of a glass made of 'stones or other materials'. Plot says that the new invention was 'lately brought into England by Seignor Da Costa a Monferratese and carried on by one Mr Ravenscroft who has a patent for the sole making of them ...'. All discussions on the development of the recipe of Ravenscroft start from Plot's following paragraph, which is truly ambiguous. The text continues:

> 'The materials they used formerly were the blackest flints calcined and a white Christalline sand adding to each pound of these, as was found by the solution of their whole mixture by the ingenious Dr Ludwell, Fellow of Wadham College, about two ounces of Niter, Tartar and Borax'.

Plot's text is evidently not clear, and McLeod (1987, 798) particularly criticizes the obscure phrase in which Plot suggests crediting the invention to Ludwell.

In the summer of 1674, some of the drinking glasses produced with the new recipe were found to crizzle (a superficial decay) under normal conditions of use. To get to the root of the problem, adjustments in the proportions of the ingredients and trials with new ones were involved (McLeod 1987, 800). At some point during the following year the solution was reached, by chance or with the help of Da Costa, and the surface decay was overcome by adding lead oxide to the recipe. Taking into account his experience in the production of false stones, in whose recipes lead was normally present, Da Costa must have had some familiarity with that material. Watts' opinion (1975, 73, 77) is that when Ravenscroft applied for the patent, he was already using a recipe of this kind: 1lb (i.e. 16oz) of powdered flints and sand, 2oz of minium and 2oz each of nitre, tartar and borax. For the solution of the problem of crizzling, this first addition of minium was not sufficient and had to be progressively increased. Watts suggests the hypothesis that tartar and borax were substituted in successive phases with the same weights of potash, probably also because of problems of cost – for borax was at the time a very expensive material.

Before the invention of flint glass, English glass technology was based on sand and native kelp or potashes for ordinary clear glass: and on sand or flints plus nitre (introduced in glass recipes from the 1630s) and imported

TABLE 1 WE REPORT FOUR RECIPES FOR 'GLASS OF LEAD' FOLLOWING THE ANONYMOUS (15TH–16TH CENTURY) AND NERI (16TH–17TH CENTURY) MANUSCRIPTS (THE COMPOSITION OF COMMON FRIT AND OF 'CRISTALLO' USED IN THE CALCULATIONS IS THE AVERAGE OF THE ANALYSES MADE BY M. VERITÀ –1985). REPORTED ALSO RECIPES FOR 'GLASS FOR BEADS FOR MAGAGNATI' A LEAD GLASS TAKEN FROM A 17TH-CENTURY MANUSCRIPT RECENTLY FOUND IN THE CASANATENSE LIBRARY IN ROME

	Vetro di piombo				*Paste per perle del magagnato* from the Casanatense manuscript					
Source	Anon	Anon	Neri	Neri	Brunoro	Brunoro	Brunoro	Brunoro	Brunoro	Brunoro
Recipe no.	13	50	63a	63b	258	259	260	262	263	265
Date	C15th–16th	C15th–16th	C17th	C17th	1605–1635	1605–1635	1605–1635	1605–1635	1605–1635	march 1635
Raw materials										
Quartz flints	5	5	–	–	3.25	10	4	4	4	45
Common glass frit	30	–	12	–	–	–	–	–	–	–
Crystal glass frit	–	20	–	12	3.25	2	4	6	8	30
Litharge/	10	10	15	15	9	3	10	10	10	150
Minium	45	35	27	27	15.5	15	18	20	22	225
Calculated composition (oxides weight%)										
SiO_2	57.5	56.0	30.5	31.9	36.5	76.7	38.7	42.2	44.8	29.8
MgO	2.4	1.0	1.5	0.8	0.4	0.2	0.4	0.5	0.7	0.2
CaO	6.9	2.9	4.5	2.2	1.0	0.7	1.0	1.5	1.8	0.7
PbO	22.7	28.6	56.5	56.2	57.9	19.7	55.4	50.2	45.4	66.2
Na_2O	8.9	9.8	5.9	7.6	3.6	2.3	3.8	5.2	6.3	2.3
K_2O	1.7	1.6	1.1	1.2	0.6	0.4	0.6	0.4	1.0	0.8
	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

barilla (sodium carbonate) for crystal glass, whose ingredients were much more expensive (McLeod 1987, 781)

THE VENETIAN RECIPES

Because of George Ravenscroft's long residence in Venice and his documented relations with Venetian glass masters (see the above mentioned Vincenzo Pompeio and Pietro Rossetti), we have tried to find if the source of the recipe attributed by Plot to Ravenscroft/Da Costa was by chance a Venetian one.

Recipes for lead-containing glass are already recorded in the 15th century *Trattatelli Toscani*. In the Venetian manuscripts – Montpellier (Zecchin 1964) and Anonymous (Moretti and Toninato 2001) – and in Neri, the so-called *vetro di piombo* (lead glass) is considered a base glass for producing brilliant colours (Moretti and Toninato 1987). According to a recipe in the Anonymous manuscript, this 'lead glass' was made by melting a mix of milled quartz flints and litharge (weight ratio 1:2) in a pot at a moderate temperature. The resulting glass will be clear and golden yellow in colour. In his recipe 63, Neri adds lead calx (litharge) to common frit or to crystal frit, giving the same result as the Anonymous recipe but with a slightly different procedure. Both manuscripts advise paying attention to the possible formation of metallic lead during melting as a consequence of the absence in the recipe of an oxidant like nitre, a material which was apparently unknown in Venice until the late 17th century. *Vetro di piombo* was used in different ratios mixed with frits of common or crystal glass to produce a lead glass and was well known to Venetian glass technicians. It was employed to produce 'pure artifacts' (meaning the production of more brilliant colours than with normal soda-lime glass), particularly to make imitation gems and beads, but it was probably 'too long' to be used for thin blown glass in the Venetian style. Nevertheless in his next recipe, 64, Neri gives instructions on how to utilize this glass for blown articles.

In TABLE 1 we give the recipes for *vetro di piombo* cited in the Anonymous manuscript and in Neri's book. In the same table we have also recorded the recipes for *Pasta per perle del Magagnato* (Glass to make beads for Girolamo Magagnati), recipes datable to the years 1605–1635 during which Girolamo Magagnati was working in Murano. Materials used in the recipe are minium and common or crystal glass frit – nitre is not mentioned. Using a rough calculation, the Anonymous melts should give glass with 22–8% lead oxide, Neri's recipes glass with a 56% lead oxide while Magagnati's glass should have a calculated content of lead ranging from 19.7 to 66.2%.

There are also some important recipes recorded in the last part of Giovanni Darduin's manuscript of 1644 (Zecchin 1986). In this part, added later to the original text, there are some particularly innovative recipes dated from 1693, such as the ones for *Girasole*, the new white opalescent glass based on the precipitation of lead arsenate, a true novelty in glass technology. In these recipes nitre appears for the first time in Venetian notebooks. More importantly for our consideration, is another group of recipes, present in the same part of the Darduin manuscript and dating from 1697, to make a crystal glass resembling natural rock crystal (TABLE 2).

Considering the eleven recipes in detail we observe that all contain nitre, arsenic and lead compounds (minium or ceruse), nine contain also borax. Again using a rough calculation of the glass compositions the recipes should result in contents, on average, of lead oxide at 19%, potassium oxide at 21%, sodium oxide at 0.9%, boron oxide at 2% and arsenic oxide at 1%.

TABLE 2 RECIPES FOR VENETIAN LEAD CRYSTAL FROM THE LAST PART OF DARDUIN'S MANUSCRIPT WHERE RECIPES ARE LARGELY, FORTUNATELY, DATED. WE REPRODUCE HERE ONLY THE RECIPES THAT PERMIT AN APPROXIMATE CALCULATION OF THE RESULTING COMPOSITION OF GLASS, EXCLUDING RECIPES WHERE MATERIALS ARE INCLUDED WHOSE COMPOSITION IS NOT DEFINITELY KNOWN. WE HAVE GROUPED THE NINE RECIPES IN WHICH THERE IS A SIMULTANEOUS USE OF NITRE, BORAX, LEAD OXIDES AND ARSENIC AND THE TWO WHERE BORAX IS MISSING

Recipe number	**240**	**241**	**242**	**243**	**244**	**245**	**252**	**255**	**268**	**246**	**263**
Date	1 Aug 1697	23 Nov 1697	27 Jul 1697	5 Aug 1698		6 Aug 1699	15 Oct 1698	9 Dec 1698	20 Feb 1701	5 Aug 1700	18 Feb 1699
Raw materials											
Silica sand/quartz	42	36	10	10	14	27	7	56	46	54	92
Arsenic	0.50	0.33	0.33	0.33	0.50	0.17	0.17	0.50	0.25	0.63	0.67
Biacca – ceruse	18	17	4	–	–	–	1	–	16	–	–
Borax Deca Hydrated	4	4	1	1	1	1	2	0.7	0.5	–	–
Minium	–	–	–	4	5	10	–	24	–	19	32
Nitre/Saltpetre	36	27	7	7	10	20	6	48	36	42	74
Tartar Calcinated (potash)	–	–	–	–	–	–	0.33	0.50	0.33	0.38	0.67
Ammoniac salt	–	–	–	–	–	0.17	0.33	0.67	0.50	0.58	1.00
	100.5	84.3	22.3	22.3	30.5	58.3	16.8	130.3	99.6	115.6	200.3
Calculated composition (oxides weight%)											
SiO_2	54.4	54.6	56.6	55.2	56.7	57.6	57.5	54.2	59.2	57.9	57.7
B_2O_3	1.9	2.2	2.1	2.0	1.5	0.8	6.0	0.2	0.4	–	–
PbO	20.2	22.4	19.6	21.7	19.9	20.9	7.1	22.8	17.8	19.7	19.7
Na_2O	0.9	1.0	0.9	0.9	0.7	0.3	2.7	0.1	0.2	–	–
K_2O	21.8	19.2	18.6	18.1	18.9	20.0	25.0	22.1	22.0	21.6	22.0
As_2O_3	0.8	0.6	2.2	2.1	2.4	0.4	1.6	0.6	0.4	0.8	0.5
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

In conclusion the comparison with Venetian technology shows that lead glass had been known in Venice for a long time but was not normally used for blown articles. The absence of nitre in the batch, at least until 1693, made this glass more difficult to produce. Borax appears in Venetian recipes only at the end of the 17th century in Darduin's last part; tartar, by contrast, was known at least from the 15th century, being cited in recipes of Trattatello Toscano II and III and in the Montpellier and Anonymous manuscripts.

CALCULATION OF LUDWELL'S RECIPE

Looking at Ludwell's recipe we calculated the composition of the glass resulting from the formula after melting. The results are surprising and are reported in TABLE 3. The first calculation starts from Ludwell's recipe for the use of deca-hydrated borax and tartar (Ludwell formula L1). The glass so obtained would contain 86.4% silica, 4% B_2O_3 and 9.6% alkaline oxides (sodium and potassium), and would be too hard to melt in the temperature conditions used in contemporary glass furnaces. If we consider borax as anhydrous (Ludwell formula L2) the result is a glass with 82.3% silica, 7.1% B_2O_3 and 10.5% alkaline oxides, always a hard glass. Considering the tartar as calcinated (Ludwell formula L3) the result is a glass with 78.7% silica, 6.8% B_2O_3 and 13.6% alkaline oxides. These computations always give a borosilicate glass difficult to melt at the probable temperatures in the glass furnaces of that time (?1200°C). In assessing the credibility of the Ludwell formulae we must also consider the following part of Plot's story, that is that the 'glasses made of these (materials) being subject to that unpardonable fault called crizzling, was caused by the too great quantities of Salts in the mixture'. From our above calculations the glass resulting from Ludwell's formulae is definitely not too rich in fluxes and so it is practically impossible not only to melt it but, even if melted, to produce surface decay.

Taking these considerations into account, even though based on approximate calculations, we cannot understand how the version of Ravenscroft's development of flint glass from Plot/Ludwell's formula can be accepted. The starting formula, as we have demonstrated, cannot be the one indicated by Plot because it would have produced a non-meltable batch, at least in the proportions indicated for the different materials, so the story has a missing element. Plot's opinion that the solution to crizzling lay in the reduction of the fluxes is also not realistic with the elements given. Only the addition of lead oxide in recipes containing anhydrous borax and calcined tartar could have achieved a realistically meltable glass in the furnaces of that time. In our calculations (Ravenscroft formula R3), only with the addition of 8oz of minium could an easily meltable batch be obtained. This recipe leads to a composition containing 56.7,% silica, 4.9% B_2O_3, 9.8% alkaline oxides and 27.9% PbO. With the substitution of tartar and borax with equal quantities of potash (potassium carbonate) – following the hypothesis of Watts (1975) – the composition of the glass becomes (Ravenscroft formula R5): 58.1% silica, 13.3% K_2O and 28.6% PbO. The composition of this glass should be quite similar to the one assumed by Watts as the final recipe, i.e. silica 53.2%, K_2O 12.6% and PbO 34.2%.

CONCLUSIONS

From our, albeit approximate, calculation of the Plot/ Ludwell recipe, it was evident that this formula is not

TABLE 3 RAVENSCROFT'S RECIPES FOLLOWING PLOT/LUDWELL, D.C. WATTS'S AND OUR HYPOTHESES AND COMPOSITION CALCULATIONS

Flint Glass	**Ludwell**	**Ludwell**	**Ludwell**	**Ravens**	**Ravens**	**Ravens**	**Ravens**	**Watts**
Recipe number	L1	L2	L3	R1	R2	R3	R5	hypothesis
Silica/quartz	16	16	16	16	16	16	16	49
Decahydrated Borax	2	–	–	–	–	–	–	–
Anydrous Borax	–	2	2	2	2	2	–	–
Nitre	2	2	2	2	2	2	2	6.3
Tartar	2	2	–	–	–	–	–	–
Calcinated tartar	–	–	2	2	2	2	–	–
Potash	–	–	–	–	–	–	4	12.7
Minium – Litharge	–	–	–	2	4	8	8	32
	22	22	22	24	26	30	30	100
Calculated composition (oxides weight%)								
SiO_2	86.4	82.4	78.7	71.7	65.9	56.7	58.1	53.2
B_2O_3	4.0	7.1	6.8	6.2	5.7	4.9	–	–
CaO	–	–	0.8	0.8	0.7	0.6	–	–
PbO	–	–	–	8.8	16.2	27.9	28.6	34.2
Na_2O	1.8	3.1	3.0	2.8	2.6	2.2	–	–
K_2O	7.8	7.4	10.6	9.7	8.9	7.7	13.3	12.6
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

realistic; as we have said the resulting glass would be a hard borosilicate impossible to melt in normal conditions. This glass, following Plot's description, should be subject to surface alteration; an impossible hypothesis due to the lack of fluxes in the formula. Only by adding lead oxide, following the suggestions of Watts, is it possible to reach a realistically meltable lead glass composition.

We consider it truly surprising that, till now, no complete chemical analysis seems to have been made on the residual samples of the glasses produced by Ravenscroft; these glasses, although few in number, exist and could be analysed with modern non-destructive methods. Such an analysis could give more exact information and support arguments based on effective data and not on hypotheses.

In conclusion, due to the lack of further documentation, we cannot say what the initial recipe was, or whether this recipe was contributed by Da Costa as Plot says. It is possible to conclude that the formula was not the one suggested by Plot, at least in the quantitative figures indicated for the raw materials. We must emphasize that the only information available to us on Ravenscroft's formula is that referred to by Hooke and by Plot/Ludwell, who visited the Savoy and Henley glasshouses, where they had probably only seen what those in charge agreed to show. One hypothesis that we would suggest is that in the recipes reported by the two visitors there was at least one material missing, that is the barilla ash, leached or not, a flux that was normally used to produce the soda-lime crystal imitating Venetian crystal. The second missing material could have been minium. If this hypothesis is realistic it would be possible to make a different estimation of the initial recipe, bearing in mind that this new formulation must justify the problem of crizzling, i.e. the low chemical stability of that initial glass. This phenomenon is incontrovertibly due to the existing documentation of the commercial relations between Ravenscroft and his glass seller clients and to the appearance of some of the samples which have survived today.

From the examination of the Venetian recipe documents, the use of nitre unfortunately appears with certainty only about 20 years after Ravenscroft's patent. In the manuscripts currently known there is no indication of its previous use in Venice; whereas documents reveal that in England they began to be used in the 1630s. As far as lead-containing glass is concerned, documentation in any case shows that in Venice it was used at least from the 15th century, although not for blown articles.

Regarding the possible technology possessed by Da Costa – who was credited with the initial formula – there is, unfortunately, no documentation so far about the technical knowledge possessed by the glass workers at the Altare glass centre because no recipe manuscript has been found.

Recently Colin Brain has kindly sent me an abstract of the transcription of Robert Boyle's work diaries, now available on the web. The diary covers the period from 1654 to 1674 (Boyle 1654–74). The information from the notes of this famous scientist is very interesting, and can give us some light on English glass technology some years before the Ravenscroft patent. First of all lead glass, corresponding to the Venetian *vetro di piombo* is mentioned many times by Boyle, sometimes with the alchemical indication of *Vitrum Saturni*. Nitre is also cited, often associated with minium. Borax is cited in a note dated 1660 and its function in the glass is correctly interpreted (to render the glass more enduring and resistant). Barilla, the Spanish ash of the *Salsola Sativa*, is noted in many sentences as a flux for melting silica. Tartar is recorded frequently. This important information from Boyle's diary adds further doubts about the originality of Ravenscroft's recipe.

In conclusion, we consider that the entire history of the technical development of flint glass has been treated so far in a superficial way. It is not based on sound documentation and lacks analytical comparisons of the hypotheses put forward, and consequently the whole question should be re-examined more deeply.

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ENGLISH SEVENTEENTH-CENTURY CRYSTAL GLASS STUDY: PHASE 1

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In 1670, Venice led the world in the production of high-quality glassware through 500 years of state-sponsored industrial development. By the end of that decade this pre-eminent position was lost, mainly due to the commercial development of 'a perticuler sort of cristaline glasse', in England and Ireland. Venice carefully safeguarded its centuries of glassmaking lore, but this did not protect it from the rapid spread of new knowledge through freely communicated scientific research in printed books. The merchant George Ravenscroft is widely credited with having achieved this transformation in the fortunes of the British glass industry. This romantic view has obscured the need to understand how this remarkable paradigm shift was actually achieved. Francis (2000) discusses the history of glassmaking at this period.

This paper summarizes the first phase of a continuing study on English 17th-century crystal glass. In this we aim to address the roles in its development of:

- technology;
- the scientific and academic communities;
- access to capital and trained manpower;
- government and the city institutions;
- access to markets and the marketing roles of merchants;
- availability of raw materials and the use of coal and wood as fuel;
- the transport infrastructure;
- international dimension in materials, skills and colonial trade;
- diversity of production.

The study of glass in this period has, surprisingly, been rather neglected, perhaps because it falls between the 'archaeological' glass world that is comfortable up to 1640 and the 'historic' glass of the 18th and later centuries. Our research should help bridge this gap and allow this key development to be properly reflected in the national context of pre Industrial Revolution technological development and the world context of glass technology. There has been considerable conjecture about how crystal glass was developed, including well-researched papers (Watts 1975; Moretti this volume), but this has suffered from a lack of hard evidence from scientific analysis of excavated pieces and glasshouse sites. Thus, this study is founded on scientific analysis to establish the chemical constitution of 'crystal' glasses to support reasoning about how they were made and the materials used. In summary, this first phase of a study aims to understand how glass technology changed during the period 1665–1690 and the resultant inter-relationships between the development of the glass trade and these technological changes.

DOCUMENTARY BACKGROUND

Given the availability of period documents that discuss glassmaking, it might be argued that the technology could be understood without detailed chemical analysis. However, practical trials of some documented glass recipes have demonstrated that they are not viable (see Moretti this volume, previous paper). Others are incomplete or their date cannot be sufficiently established to serve as a foundation for reasoning about rapid technology developments. However, they are still very useful and important sources for this study.

Some documentary sources are well known, e.g. Neri and Merret (1662) and Robert Hooke's diary (Robinson and Adams 1935), but others are less known and worth briefly mentioning here. Glauber (1652), is perhaps the earliest relevant reference after Neri. This discusses metallic glasses (including lead) and the use of flint, tartar and nitre in glassmaking.

A recently available source on the Internet is Robert Boyle's Work Diaries (Boyle 1654–74). The following are a few relevant quotes with their approximate dates.

- Glasses of Tin, Lead and Antimony [*c*. 1654].
- A quarter of a common hundred weight of Tartar (amounting to 28 pound) being calcind at the Glasshouse to a pretty degree of Whitnesse yeelded 10 pound wanting three ounces of Calx. Black flints (thô others of that colour had bin in vain indeavord to be calcind by other meanes) being plac'd in the gutter through which the flame passes in the Potters Furnace, were turn'd into good Strong Lime [on or after 24 August and before 11 September 1663].
- A convenient proportion of Borax melted with the Ingredients of glasse, will much serve to toughen it, as I am informd by an Experiencd master of a Glasse house [thought to be late 1660s]
- Also that some salts make glasse much more or lesse brite than others, as that Borellia makes it more tough than the Salt of common ashes; and that the Salt of Tartar makes it yet more tough than that [probably 1668].

Another rich source of information is the notebook of Gustav Jung (Jung 1666-). Jung visited England from Sweden/Finland in 1667/8 during a state-sponsored tour

TABLE 1 SHOWING THE RESULTS OF SEM-EDS ANALYSES OF GLASS SAMPLES; Clr=COLOUR, Crz=CRIZZLED (Y–YES, N–NO)

Site	Reference	type	seal	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	MnO	Fe_2O_3	As_2O_3	Sb_2O_5	PbO	Total	Clr	Crz	Group
Northampton		taper	Bow & Lilly	16.8	0.6	0.6	74.3	0.4	0.4	1.1	2.9	1.5	0.6	0.3	–	–	–	99.6	pink	Y	1
London, Lloyd's Lime Street	GM96 ER87	cigar		17.3	1.0	0.5	72.3	0.3	0.2	1.5	1.9	2.6	0.3	0.2	–	–	–	98.1	pink	Y	1
Jamestown	NN40/7AT	bowl		16.1	0.7	0.6	72.9	0.3	0.4	0.9	3.4	2.2	0.3	0.2	–	–	–	97.9	pink	Y	1
Ironmonger's Hall, Aldersgate	GM14630	taper	bird's head	16.3	1.1	1.2	68.1	0.4	0.2	1.1	5.3	4.4	0.5	0.3	–	–	0.9	99.8	pink	N	2
London, Pindar/ Clifton Street	GM15629	taper		12.8	2.9	1.1	63.9	0.2	0.2	0.9	5.2	9.1	0.8	0.5	–	–	3.0	100.6	green	N	2
Westminster	A889	taper	bird's head	13.9	1.1	0.5	68.1	0.2	0.3	1.0	7.4	3.9	0.4	0.2	–	–	–	96.9	pink	Y	2
Guildford, Tunn Inn	Catalogue 37	Greene	Boar/Bear	14.2	1.1	1.3	67.9	0.4	0.2	0.9	8.9	3.8	0.9	0.4	0.5	–	–	100.4	pink	Y	2
Nonsuch	1-13	knop		15.1	2.4	1.0	60.8	0.3	0.1	1.2	5.2	9.1	0.3	0.4	–	–	–	96.1	–	N	2
Hull	61/74/69	Greene		8.3	2.8	1.0	66.4	0.4	0.1	0.4	10.8	8.7	0.7	0.5	–	–	0.3	100.6	pink	N	3
Port Royal	PR89 764-4	bowl		7.0	2.1	1.2	64.6	0.2	0.4	0.4	14.8	7.1	0.2	0.2	–	–	1.7	100.1	green	N	3
London	A27637	*roemer*		0.1	0.1	0.3	67.5	–	–	–	17.1	0.8	–	0.1	–	–	13.8	99.8	–	Y	4
London	V&A c589-1925	taper	S	0.3	0.1	–	63.2	–	–	–	15.5	0.7	–	–	0.4	–	14.7	95.0	–	Y	4
London	NRF88 468 780	taper		0.2	–	0.7	66.1	–	–	0.1	16.4	–	–	0.1	–	0.2	15.5	99.1	–	Y	4
Nonsuch	19-58		damaged	0.1	–	0.1	64.9	–	–	0.2	15.5	0.7	–	–	–		17.4	99.0	–	Y	4
Oxford	1915 99d	taper	unidentified	0.3	0.1	0.9	63.4	–	–	0.2	16.1	–	–	0.1	–	0.3	17.6	99.0	–	Y	4
Nonsuch	285	taper		0.1	–	0.3	60.2	–	–	–	16.9	0.7	–	–	–	–	17.8	96.0	–	Y	4
Wells	2/1095	taper	broken	0.2	–	0.8	61.6	–	–	0.1	16.3	–	–	–	–	–	17.8	96.8	–	Y	4
Billingsgate	BIG82 309 1004	taper	Plain	0.3	0.1	0.8	64.2	–	–	0.2	16.4	–	–	–	–	0.3	18.0	100.3	green	Y	4
Port Royal	PR89 599	taper		0.2	–	0.8	61.9	–	–	–	15.9	–	–	–	–	–	19.5	98.2	–	Y	4
Port Royal	PR87 556-7	knop		0.2	–	0.6	61.4	–	–	0.2	15.4	–	–	–	–	–	19.5	97.3	–	Y	4
Wells	2/1009	taper	missing	0.1	–	0.2	55.6	–	–	0.1	17.1	1.7	–	0.1	–	–	20.0	94.8	–	Y	4
Port Royal	PR90 9012-0	bowl		0.6	–	0.8	62.1	–	–	0.2	15.9	–	–		–	–	20.2	99.8	–	Y	4
Port Royal	PR90 2074-14	taper	S	0.1	–	0.4	56.4	–	–	0.2	12.6	–	–	0.2	1.4	–	26.0	97.3	–	N	5
Billingsgate	BIG82 570 915	taper	N stamp	0.1	0.1	0.6	58.7	–	–	–	12.5	–	–	–	–	–	26.2	98.2	–	N	5
Port Royal	PR87 632 0	bowl		0.2	–	0.6	58.5	–	–	0.3	12.4	–	–	–	–	–	26.3	98.2	–	N	5
Long Alley, Moorfields	GM16948	*roemer*		–	–	0.2	56.3	–	–	0.2	11.5	–	–	–	1.3	–	29.7	99.1	–	N	5
Southwark	GM21890	*roemer*		–	–	0.4	54.1	–	–	0.2	9.9	–	0.1	–	0.9	–	32.8	98.4	green	N	5
Moorfields	GM1649	quatref'l		0.1	–	0.2	55.0	–	–	–	9.0	–	–	–	1.0	–	34.6	100.0	–	N	5
London	A26067	*roemer*		–	–	0.4	55.9	–	–	0.2	8.8	–	–	0.2	–	–	35.1	100.5	–	N	5

of leading glassmaking sites. His notebook from those visits is fortunately preserved, but little analysis seems to have been done on its recipes. Naturally most of it is in Swedish and the pages were not used in sequence. However, we hope to make use of this source during the second phase of the study.

Conduct of the study

Three strategies were used to select glasses for analysis in this first phase (COLOUR PLATE 74). These gave three roughly equal, geographically diverse, groups:

i. in a sequence at roughly two year intervals;
ii. with a common date around 1678;
iii. displaying different surface degradation.

The main analytical approach was to use the SEM-EDS facility at the English Heritage Centre for Archaeology on very small samples taken from the excavated material (with the owners' permissions). Each sample was embedded in epoxy resin, where possible perpendicular to weathered surfaces. This allows observation of the degree of weathering and so helps avoid the analysis of weathered surfaces. The mounted samples were ground (silicon carbide abrasive papers) and polished (diamond slurry) to a 3μ finish (Cox and Pollard 1977).

The samples were examined in a LEO S440i scanning electron microscope (SEM) operated at 25kVolts with a typical probe current of 1.5nAmps using secondary and back-scatter electron detectors to ensure that the surface was flat, free from contaminants and not excessively weathered. Weathered surfaces could be seen as darker areas when using the back-scatter electron detector and rarely exceeded 0.2mm in thickness.

Each was analysed to determine its chemical composition using the energy dispersive spectrometer attachment (SEM-EDS). The Oxford Instruments germanium detector used allows simultaneous detection of all elements above the detection limits from carbon to uranium. Each spectrum was collected from an area approximately 50 by 100μ for 100 seconds livetime, calibrated for gain using a cobalt standard, and deconvoluted using the Oxford Instruments SEMQuant software (with phi-rho-z correction procedure). This makes use of element profiles derived from single element or simple compound standards (pure iron, jadeite, etc). The compositions were also calibrated against nine available glass reference materials. This provided accurate measures and allowed the calculation of analytical errors. Robert Brill of the Corning Museum has made four additional reference materials available. These are currently being analysed by several laboratories. Once completed, this data will be used to refine the calibrations.

Energy dispersive X-ray spectrometry provides no direct information about the valence state of any elements (e.g. metallic iron, FeO, Fe_2O_3 or Fe_3O_4), so an appropriate valence state was chosen (largely following the valence state in the Corning glass standards) and the oxide weight percent calculated stochiometrically. The (SEM-EDS) facility used cannot detect the presence of boron.

Past studies (e.g. Kunicki-Goldfinger *et al.* 1999), have shown that historic glass can be heterogeneous (e.g. potassium oxide concentration varying 13–20%). Thus, when acceptable to the owner, more than one micro sample was analysed per piece. These showed only minimal variation. Many fragments were also examined for composition variation under UV light. Some show small white fluorescent patches against the blue fluorescence of lead oxide as illustrated in COLOUR PLATE 75. The white patches are almost certainly due to borax, most likely introduced through the use of cullet (reused broken glass) in the melt.

Another technique used to complement the SEM-EDS was UV fluorescence analysis (Brain 2002). This currently provides only qualitative results, but indicated the presence of borax in some glasses and in others the presence of lead as a network former and/or a network modifier. The structural role of lead in glass is still not well understood, despite recent studies using different analytical techniques (Zahra and Zahra 1993; Wang and Zhang 1996; Schultz-Münzenberg *et al.* 1998; Fayon *et al.* 1999; Kohara and Umesaki 2001; Takaishi *et al.* 2001). Whilst these show that lead oxide exists as network-forming PbO^{4+} pyramid structural units at medium lead molar concentrations, they agree less on its structural role at the lower lead concentrations typical of this study. All seem to assume that lead's structural role is determined solely by its concentration. The results reported by Brain (2002) appear to show, on the contrary, that different forms of lead co-ordination exist at the same nominal concentration. This is what one would expect, since even the 17th-century glassmakers knew that lead oxide was more easily reduced than other glass constituents:

> 'Lead returning into it's body, breaks out the bottom of the pots. Lead can hardly be so well calcin'd but some particles will remain uncalcin'd, which the heat of the furnace reduceth to Lead again' (Neri/Merret 1662).

Mark Taylor amply demonstrated this (FIG. 1) during simulated manufacture of lead glass using tartar as the alkali (uncalcined tartar is a reducing agent).

Thus the reduction/oxidation (REDOX) balance in the melt and probably the melting temperature will influence the network role of lead oxide. Uncertainty of lead co-

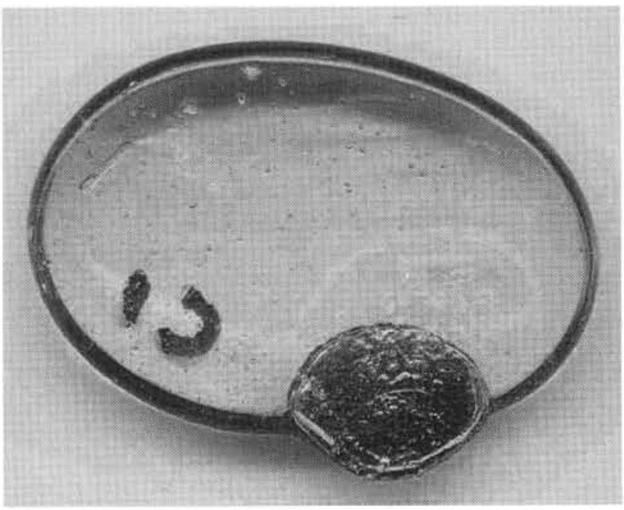

FIG. 1 Showing a manufactured lead glass sample with lead oxide reduced to metallic lead

ordination state affects the total calculated percentages for samples. This may be a reason for the low totals often reported for lead glasses. However it may be possible to make use of the ionic structure of lead to tell us more about how the glass was produced.

Results and discussion

Table 1 gives the results of the SEM-EDS analysis of the glasses selected for this first phase.

Using surface corrosion to differentiate the type of glass was the least successful selection strategy. As is well known, crizzling is mainly due to insufficient stabilising 'RO' constituents (usually lime or lead) in the batch. Our analyses supported this. Other surface corrosion seems to depend on the object's burial conditions. It may be significant that the low-lead glass with the least crizzling appears from UV fluorescence to have the highest borax content, although this is yet to be confirmed. Borax is said to reduce the tendency for surface cracking of unstable glass because it reduces thermal expansion. Hook (Robinson and Adams, 1935) reported that Ravenscroft was using borax in his glass on 29 July 1673, three years before he publicly acknowledged he had a problem with crizzling. Even earlier, Boyle mentions the use of borax in glass as quoted above.

The glasses analysed fall into five groups, differentiated by the alkali and lead content. All except the third group include at least one sealed glass, suggesting they were contemporary in England in the period 1674–1682 when glass seals were used to denote the manufacturer.

Group 1. Good quality soda glass comparable to that produced in Venice. No lead is present and manganese is used as a decolouriser. The probable source of alkali was highly refined Mediterranean marine plant ash (the lime content of the glass was around 2%). All glasses in this group were crizzled and two have a distinct pink tint. This tint was almost certainly not there when the piece was made and is the result of solarization (conversion of MnO to Mn_2O_3 under the action of UV light with the consequent reduction of other polyvalent components such as iron oxide).

Group 2. Comparable to *façon de Venise*, but two of the four have low levels of lead (1–3%). Whilst it is possible that this results from the use of cullet containing lead, several enduring European glass recipes have this level of lead, suggesting that this was there by design. Manganese was present in all and the most likely source for the alkali was kelp (Sanderson and Hunter 1981). Particularly interesting glasses are those with a seal resembling a Raven's head (identified as a bird's head in Table 1). The pink powdery deposits on the inside of both stems are similar and one at least was mentioned by a previous author (Thorpe 1929, 123) who concluded that it was not part of the normal Ravenscroft production. They differ chemically from most sealed Ravenscroft pieces and the seals on both are similar, but not identical to, the normal seals, suggesting they may be period forgeries.

Group 3 are mixed alkali (probably kelp and potash: Sanderson and Hunter 1981) glass, one particularly noteworthy for the use of cobalt as a decolouriser instead of manganese, presumably to prevent the pink tinting.

Group 4, the largest in this phase, is early lead crystal, with lead oxide contents in the range 14–20%. The low level of contaminating oxides shows a switch to using much purer batch materials. The sulphur levels also show low contamination from combustion products. Current evidence suggests that this is likely to have been through the use of wood fuel, rather than early adoption of covered glassmaking pots. Some samples showed detectable amounts of iron and calcium. Cesare Moretti kindly provided analyses of tartar that show it contains some calcium. Thus the calcium may be indicative of the use of calcined tartar. Similarly, English glassmaking sands of the period from Lynn, Maidstone and the Isle of Wight contained low levels of iron (Boswell 1918). Some of these also contained calcium, making it difficult to confidently distinguish sources of raw material with current measurement accuracy and little data to characterize the variability of source materials. However, the main components were probably flint and high quality nitre (saltpetre) imported by the East India Company. Because it is used in gunpowder the import of nitre had been a royal monopoly, but this changed when Sir John Banks negotiated its sale by auction in 1672. There is no obvious difference in this group between the recipes used for glasses with different seals, suggesting that the new technology spread quickly and uniformly across the industry. Analysis of material from glasshouse excavations will shed more light on the link between manufacturing processes and raw materials and the finished chemical compositions. The most promising material available is that excavated from John Odaccio's 1673 Dublin glasshouse.

Group 5 are full lead crystal glasses with lead contents in the range 26–35% and the first signs of the use of arsenic. The rapid increase in lead content is shown by two virtually identical bowl bases excavated in Port Royal that differ by 7.4% in lead content.

Further work

This paper discusses only the interim results of the first phase of this work. During the next phase of the study we hope to:

- Gain additional confidence on the make-up of the lead 'lab glasses' through peer analysis;
- Use additional analysis techniques to allow quantification of the borax present;
- Finalize the analysis of the existing samples;
- Obtain and analyse additional samples;
- Research the structural role of lead in these early glasses;
- Undertake detailed comparison with excavated crystal glass-making material from glasshouse sites, particularly Dublin;
- Improve the calibration and analysis for the UV fluorescence technique;
- Simulate the manufacture of some glasses;
- Further research period documentary sources, particularly Jung's notebook;

- Publish additional reports and papers;
- Identify key topics for further study.

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THE SCIENTIFIC STUDY OF LATE SEVENTEENTH-CENTURY GLASSWORKING AT SILKSTONE, ENGLAND

David Dungworth

Introduction

The 17th and 18th centuries saw dramatic changes in the glass industry in England with the change in fuel (from wood to coal) and the types of glass produced (e.g. clear lead glass). The archaeological excavation of glass production sites has revealed the changes in furnace design (Crossley 1990) but relatively little attention has been paid to the compositions of the glass produced at individual glasshouses. A small-scale excavation at the site of a late 17th-century glassworking site has provided the opportunity to carry out a detailed scientific investigation of the glass produced.

Historical records

Silkstone was the site of a glassworks started by two Pilmay brothers around the middle of the 17th century which carried on into the 18th century (Ashurst 1987; 1992a; 1992b; Vose 1994, 63). In the early 17th century the Pilmays worked the Haughton Green glassworks outside Manchester (Vose 1994). The burial of a George Pilmay (son of 'Mr John Pilmay of the Glasshouse') in 1653 is the last reference to glassworking at Haughton Green. The first record of the Pilmays in Silkstone is the marriage of John Pilmay to Abigail (Scott) in 1658. John Pilmay died in 1675 but his widow Abigail continued the business, apparently with some success. She died in 1698 and her will and inventory contain details of the business at that time. These specify that there were two glasshouses: a 'greenhouse' (i.e. for producing alkali glass for bottles, etc) and a 'whitehouse' (i.e. for producing clear lead glass for tablewares, etc). Glass production continued after the death of Abigail Pilmey but appears to have gone into decline. The will and inventory of John Scott (one of Abigail's children by her first marriage) in 1707 refers to one 'old glasshouse', which was still producing lead glass, but makes reference to another which by this time was being used as a kitchen (Ashurst 1992a, 24). A conveyance of 1720 (between John Scott of Silkstone and William Scott) records 'land including a glasshouse'. A deed of 1754 makes no mention of a glasshouse, but does refer to 'pot ovens', i.e. pottery production (Ashurst 1992b, 18).

Archaeological investigation

A standing building at Silkstone has been tentatively linked with the historical glassworks and in 2002 English Heritage carried out a small (1x 2m) excavation to assess the nature of the site. The excavation showed that the building postdated the glassworking but did reveal a deep stratigraphic sequence with five phases of activity (FIG. 1). The dating of these phases is based on the clay pipes recovered (Higgins 2003). Importantly, there were two major phases of glassworking, one dating to *c.* 1670 (phase 2) and one dating to *c.* 1680–1700 (phase 4) which were separated by a substantial demolition deposit. The evidence from the limited excavation carried out suggests that glassworking ceased around 1700 (i.e. somewhat earlier than implied by the historical records). Soil samples were taken from phase 2 and phase 4 contexts; these were sieved in order to maximize the recovery of glassworking waste. Phase 1 contexts also provide some evidence of glassworking.

Examination of glass and glassworking waste

Most of the glass recovered from Silkstone was too small to allow the reconstruction of vessel form. Nevertheless, beakers, dishes, flasks, phials and wine bottles have been identified (Willmott 2003). There are very few fragments of window glass from the site. A wide range of glassworking waste was recovered, including glass threads, glass pulls and runs, frothy glass, slag/clinker, crucibles and vitrified stones from a demolished furnace (Dungworth 2003).

Chemical analysis

An intensive programme of chemical analysis of all types of glassworking debris has been carried out. Over 400 samples have been analysed using an energy-dispersive X-ray fluorescence detector attached to a scanning electron microscope. This technique is well suited to the analysis of glass from glassworking sites as it allows the chemical composition to be checked against microstructure (e.g. weathered surfaces, glass adhering to crucible fragments). The results have been calibrated using a wide range of standard reference materials (e.g. Corning glass standards). This information provides a detailed view of glassworking at Silkstone but will also show what sorts of scientific analysis are likely to be fruitful on other sites (see Dungworth 2003 for further details and analytical data).

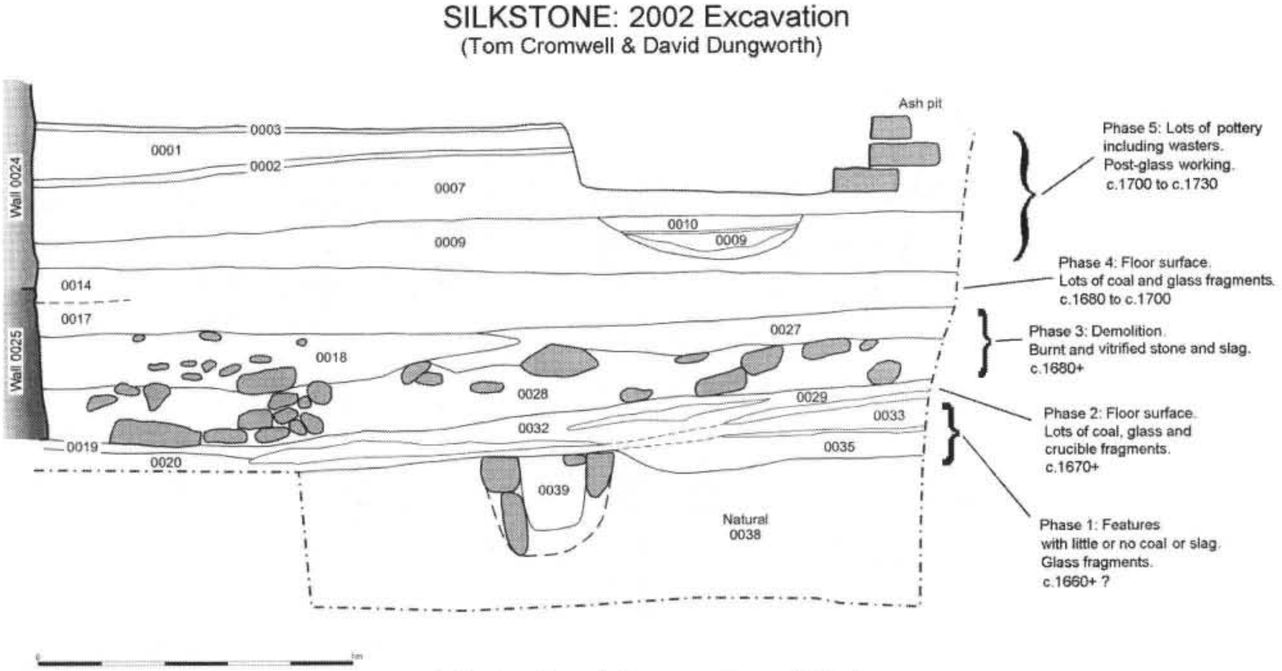

FIG. 1 Section through the excavations at Silkstone

Identifying types of glass

The chemical analysis of glass and glassworking waste has concentrated on the 143 fragments which could be clearly identified as glassworking waste (e.g. moils and threads). This has shown that three different types of glass were manufactured: a high-lime low-alkali (HLLA) glass, a mixed alkali glass and a lead crystal glass. Within each of these broad types of glass, several compositional groups could be detected. These compositional groups were often specific to particular phases of activity, e.g. the mixed alkali glasses from phase 1 and phase 2 have slightly different chemical compositions.

HLLA: 'green glass'

HLLA glass typically has a lime content of over 20% and a combined alkali (soda and potash) content of <10% (Mortimer 1991). The HLLA glass is always a fairly strong green colour (this is due to the presence of iron oxide) and it was probably referred to as 'green glass' in the 17th century (Godfrey 1975).

HLLA glass first appears in the early 17th century and has been identified at two other 17th-century glass production sites: Kimmeridge, Dorset (Crossley 1987), and Haughton Green, Manchester (Vose 1994). At Kimmeridge the HLLA glass tended to contain less magnesia, alumina and iron oxide than the Silkstone HLLA glasses, while at Haughton Green the HLLA glasses tended to contain more soda and less potash than the Silkstone HLLA glasses. While it will be necessary to carry out further research on glass from other contemporary production sites, it might be possible in the future to use chemical analysis as a means of provenancing 17th-century English green glass vessels.

The chemical composition of most HLLA glass shows many similarities with medieval forest glass (e.g. low soda, high magnesia and high phosphate). It is likely that HLLA glass was made using similar sorts of raw materials. It is generally assumed that medieval forest glass was produced using the ash from the wood fuel used to heat the furnaces in which glass was produced. The HLLA glasses were probably made using plant ashes, however, the switch to using coal as a fuel had deprived the glassmakers of their original source of alkalis (Crossley 1998; Godfrey 1975, 158). The variation in the chemical composition of HLLA glass between different production sites may reflect some of the problems that 17th-century glass producers experienced in securing alkalis. HLLA contains appreciably more iron oxide than forest glass; it is not clear whether the iron oxide was added separately or simply the consequence of using less pure ingredients.

Recognized HLLA green glass products from Silkstone include wine bottles (*cf.* Willmott 2002, fig. 114) and phials (*cf.* Willmott 2002, figs 116–7). The composition of the Silkstone HLLA green glass in phases 1 and 2 is indistinguishable and it is likely that the same raw materials were used with the same recipe or batch in both phases (TABLE 1). The phase 4 green glass is still clearly an HLLA type glass but the composition is significantly different to that of phases 1 and 2 (e.g. the low phosphate and potash contents). Phase 1 contexts also provided fragments from several unfinished or unworn green glass vessels that are likely to have been manufactured at Silkstone. These fragments were also HLLA glass but of compositions that did not match precisely any of the glassworking waste from Silkstone (TABLE 2).

Mixed alkali

Mixed alkali glasses contain roughly equal proportion of soda and potash and so fall between the two traditional late-medieval glass types: *cristallo* (which contained high

TABLE 1 AVERAGE COMPOSITION OF HLLA GLASS PRODUCTION WASTE

Phase	1	2	4
Samples	6	52	39
Na_2O	1.5±1.1	1.1±0.2	1.6±0.4
MgO	5.4±0.7	5.1±0.8	4.8±1.0
Al_2O_3	4.0±0.5	4.5±0.8	3.6±0.3
SiO_2	54.1±3.0	52.5±3.8	57.2±2.3
P_2O_5	3.2±1.0	3.1±0.7	2.0±0.3
SO_3	0.3±0.1	0.3±0.1	0.3±0.2
Cl	0.3±0.2	0.3±0.1	0.3±0.1
K_2O	8.0±1.6	8.5±0.9	3.9±1.1
CaO	20.5±2.2	21.4±1.8	23.8±1.9
TiO_2	0.2±0.0	0.3±0.1	0.2±0.1
MnO	0.8±0.5	0.9±0.5	0.5±0.2
Fe_2O_3	2.1±0.3	2.1±0.4	1.9±0.5
SrO	0.06±0.02	0.06±0.02	0.09±0.02

TABLE 2 AVERAGE COMPOSITION OF HLLA UNFINISHED/ UNWORN VESSELS FROM PHASE 1

Group	1	2
Samples	10	8
Na_2O	2.7±0.2	3.1±0.3
MgO	4.3±0.7	4.5±0.1
Al_2O_3	4.1±0.5	3.5±0.1
SiO_2	54.3±0.5	53.3±0.4
P_2O_5	4.0±1.0	3.9±0.4
SO_3	<0.1	0.1±0.1
Cl	0.7±0.0	0.7±0.0
K_2O	6.2±0.1	6.9±0.1
CaO	21.1±0.1	21.8±0.3
TiO_2	0.2±0.1	0.2±0.1
MnO	0.9±0.0	0.7±0.0
Fe_2O_3	1.7±0.1	1.6±0.1
SrO	0.08±0.01	0.07±0.01

levels of soda and low levels of potash) and 'forest glass' (which contained high levels of potash and low levels of soda). In addition, mixed alkali glasses can be easily distinguished from HLLA glasses as they contain lower levels of lime (*c*. 10%). The mixed alkali glasses usually contain less iron oxide than the HLLA glasses and so are less strongly coloured green. The paler colour of mixed alkali glass is much closer to the soda-based *cristallo* and *façon de Venise* glasses than traditional 'forest glass' or HLLA glass – mixed alkali glass may have been a 'poor man's' *cristallo*. Mixed alkali glasses may have been made using a variety of plant ashes (including marine ones). Mixed alkali glasses have not been detected in post-medieval assemblages from London (Mortimer 1991) but have been identified at Lincoln (Henderson 1998).

In phases 1 and 2 at Silkstone pale green glass vessels were manufactured using mixed alkali glasses (TABLE 3). Unfortunately, while many fragments of glassworking waste were composed of mixed alkali glass, very few of the mixed alkali glass fragments were large enough to allow the recognition of specific vessel forms (in only two cases could the vessel form be identified as phial).

The phase 1 mixed alkali glass contains relatively high levels of soda and chlorine and marine plant ashes were almost certainly used as the flux. This glass also contains minor amounts of strontium oxide, however, the levels are much higher than any of the other glass from Silkstone.

TABLE 3 AVERAGE COMPOSITION OF MIXED ALKALI GLASS PRODUCTION WASTE

Phase	1	2	2
Group		1	2
Samples	6	7	5
Na_2O	8.3±0.4	6.9±0.4	3.5±0.4
MgO	5.5±0.3	2.9±0.1	3.7±0.1
Al_2O_3	3.1±0.1	1.4±0.3	4.7±0.3
SiO_2	62.7±0.2	68.3±1.9	60.3±1.9
P_2O_5	1.3±0.1	0.3±0.3	1.7±0.3
SO_3	0.2±0.0	0.1±0.1	0.2±0.1
Cl	0.9±0.1	0.5±0.1	0.3±0.1
K_2O	5.9±0.1	6.6±0.2	6.8±0.2
CaO	9.3±0.2	10.5±1.6	14.4±1.6
TiO_2	0.2±0.0	<0.1	0.3±0.1
MnO	0.4±0.0	1.0±0.1	0.8±0.1
Fe_2O_3	1.1±0.0	1.4±0.2	3.0±1.0
SrO	0.27±0.01	0.05±0.01	0.10±0.02
PbO	1.4±0.1	<0.3	<0.3

The strontium to calcium ratio is much higher than seen in most limestone and so the strontium is unlikely to have been introduced with any lime that might have been added to the glass. It is possible that the strontium oxide was introduced with the marine plant ash. If marine plant ash is the source of the strontium oxide then it is unlikely that the ash was processed as described by Neri (Neri 2001). Neri stresses the importance of dissolving plant ashes in water and boiling these solutions to remove the 'terrestery' (e.g. alumina). Such processing would tend to remove insoluble materials such as strontium oxide. The phase 1 mixed alkali glass is also unusual because it contains low (*c*. 1.4%) levels of lead oxide. This may represent an early (i.e. pre-Ravenscroft) attempt to use lead as a flux in glass, however, the levels of lead oxide are too low to have had an appreciable effect on the properties of the glass.

In phase 2 there are two mixed alkali glasses with slightly different chemical compositions. Group 1 is broadly similar to the phase 1 mixed alkali glass, although no lead oxide was detected and the strontium oxide levels are much lower. The phase 2, group 1, mixed alkali glass may have been made using marine plant ashes which had been processed (following Neri) as they contain low levels of 'terrestery'. The composition of the phase 2, group 2, mixed alkali glass lies between the group 1 mixed alkali glass and the contemporary HLLA glass. It may have been manufactured by mixing these two glasses together.

CLEAR LEAD GLASS

The incidence of clear lead glass at Silkstone shows a remarkable correspondence with the stratigraphic sequence. Leaving aside the small amounts of lead oxide in the phase 1 mixed alkali glass, no lead glass was detected among the glass from phase 1. In phase 2 a single thread and three fragments of lead glass were recovered. Lead was not detected in any samples of glass adhering to the inner surfaces of any of the crucibles from phase 2. However, in phase 4 (i.e. *c*. 1680 to *c*. 1700) there is no evidence for the manufacture of mixed alkali glass but there is abundant evidence for the manufacture of clear lead glass (TABLE 4). There are almost no other data with which the Silkstone

TABLE 4 COMPOSITIONS OF LEAD GLASS PRODUCED AT SILKSTONE

Phase	**2**	**4**
Samples	4	6
Na_2O	<0.3	<0.3
MgO	<0.3	<0.3
Al_2O_3	0.6±0.1	0.7±0.2
SiO_2	54.1±0.8	51.9±1.8
P_2O_5	<0.2	<0.2
SO_3	<0.1	<0.1
Cl	<0.1	<0.3±0.1
K_2O	12.9±0.7	9.0±0.5
CaO	<0.1	0.2±0.3
TiO_2	<0.1	<0.1
MnO	<0.1	<0.1
Fe_2O_3	<0.1	0.1±0.2
SrO	<0.02	<0.02
As_2O_3	<0.3	0.4±0.2
PbO	32.0±0.7	36.4±2.6

glass' was initially a mixed alkali glass but *c.* 1680 this was replaced by the new clear lead glass.

The analysis of glassworking debris can provide a detailed insight into production technologies, however it is essential that a large number of glass samples are analysed and that these samples need to be carefully selected (both in terms of their 'form' and their stratigraphic positions).

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CENTRAL EUROPEAN CRYSTAL GLASS OF THE FIRST HALF OF THE EIGHTEENTH CENTURY

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Since 1998, a project of investigation into 18th-century central-European vessel glass has been underway. Physico-chemical analyses have been carried out, as well as stylistic analyses of over 1000 objects of different provenance. The scheme of the whole project has been built on three main steps and has already been discussed in a previous paper (Kunicki-Goldfinger *et al.* 2003b). These steps are historical studies, non-destructive examination of the vessels, and quantitative chemical analysis of the samples taken from selected objects. Some preliminary results of the energy dispersive X-ray spectrometry analysis (EDXRF) have already been discussed (Kunicki-Goldfinger *et al.* 1999; 2000b). Here some further results with regard to the electron probe microanalysis (EPMA) of the selected samples will be discussed, and we want to focus on the characteristics of crystal glass which were recognized among the glass manufactured in certain places in central Europe during the first half of the 18th century.

In the 17th century, in some centres of northern Europe, new technologies of colourless glass were experimented with as a consequence of the scientific developments of that time, as well as the spread of technological innovations resulting from the migration of glassworkers. In some glasshouses, new types of furnace construction, new kinds of fuel (coal), new raw materials and batches etc appeared. Many historical documents direct our attention to certain territories, and information revealed in recent years might lead us to the statement that most of the late 17th and early 18th-century luxury colourless glass in almost all of Europe, including English lead crystal, could have had their technological roots somewhere in the French and Dutch borderlands. However, few chemical analyses of these glasses have been undertaken to support such a statement up to now.

The significant changes in glass technology can be observed in the early 1660s in the Netherlands, the France/Netherlands border and in Britain, and then in the 1670s, among other places, in central Europe (Francis 2000; *Buquoy Glass* 2001; Brain 2002; Brain and Dungwarth this volume). Louis le Vasseur d'Ossimont (1629–1689), a native of France, was probably the first and most important glassworker known to us who transferred the new technology of crystal glass to central Europe. He appeared in Bohemia in Buquoy service in 1673 and established a glasshouse in Nové Hrady (Gratzen) (Drahotová 1981; 2001). The lists of raw materials used by him there (which included, among others, quartz pebbles, saltpetre, arsenic, borax, chalk, wine stone) are characteristic of the crystal glass batch. This set of raw materials appeared in Nové Hrady at the same time as Johann Kunckel published a crystal glass recipe in *Ars vitraria experimentalis*. At present, it is very difficult to state where and when this new batch first appeared in central Europe. But what is obvious, in the light of documentary evidence as well as the results of the chemical analyses of glasses discussed below, is that these raw materials were characteristic of crystal glass in the last quarter of the 17th century and the first half of the 18th century as well. This glass formulation was practised in a very limited number of glasshouses. An important improvement of the batch, the addition of lead compounds, was probably of slightly later origin. Intentionally introduced lead in central European glass, common in 18th-century glasses, can be observed in items dating around 1700 (Kunicki-Goldfinger *et al.* 2003a). This date might well become earlier in the future when more 17th-century crystal glass wares are examined.

Almost until the end of the 17th century this new glass formula competed with the Venetian *cristallo* that had been dominant up to that time. This period saw the decline of soda-ash colourless glass as well as the end of the dominance of *façon de Venise* in the market of the luxury tableware. At the turn of the 17th century in Europe, at least three main glass formulae for luxury colourless vessels were being developed separately: crystal glass, which developed probably somewhere on the France/Netherlands border, chalk glass which was credited to Michael Müller (1639–1709) in Bohemia, and lead-crystal glass which is ascribed traditionally to George Ravenscroft (1618–1681) in England (see Moretti this volume). The first two mentioned formulae quickly spread over the continent. Chalk glass (later also called Bohemian glass) became the really 'popular' one while the manufacture of crystal glass was limited to a number of glasshouses that mainly ran under royal, ducal or aristocratic patronage. Michael Vickers writes

> No longer were kings and princes the arbiters of taste, but this role was increasingly played by the middle classes of Europe and America. The eighteenth century witnessed these important changes (Vickers 1998, 20).

Although this refers to the changing role of rock crystal and glass, it also seems true in regard to the differentiation of crystal glass as the most valuable metal at this time, and chalk glass as a cheaper one, though good enough to fulfill the new baroque taste which expressed itself in frequently dense rich decoration. This decoration could occasionally be used even on metal of imperfect quality. Nevertheless, this simplified history of baroque glass technology in northern Europe nowadays seems not entirely accurate. Firstly, chalk was already in use in western Europe at the time of Michael Müller, and secondly lead compounds were used for colourless metal on the continent probably independently of the influence of English technology. Tracing the successive steps in the introduction of the new raw materials has, until now, been very puzzling.

The terminological context of this crystal glass is no less complicated. It is not the intention of the authors to discuss this problem here, but at least two of its aspects need to be highlighted. The first one concerns the differentiation between the original technological terms and those introduced to the professional literature by art historians during the last two centuries. The term Bohemian crystal constitutes one such example since crystal glass was manufactured in Bohemia only in a few glasshouses in the last quarter of the 17th century and then probably not before the middle of the 18th century (*Buquoy Glass* 2001). The second one concerns the different semantic connotations of the term crystal glass, which were sometimes used interchangeably even in historic times. The term crystal derives from Greek *krystallo* denoting glass that resembles rock crystal – one of the most precious materials (Stern 1997). The quality of the metal therefore constituted an important feature when the term crystal glass was used. On the other hand, this high-quality glass was used to imitate very expensive, rare and frequently richly decorated wares made of rock crystal (Vickers 1996). Put simply, glass ware resembled the more expensive rock crystal ware. The type, shape and decoration of the ware were as valuable features as the quality of its metal. David Jacoby in his article about the raw materials used in Venice and Terraferma writes regarding the term *cristallino*:

> We may safely assume that once this material [glass] had been improved, a specific type of vessel was designed to be exclusively made of it so as to highlight its particular features. As a result, the term *cristallino*, first applied to the material, was later used to designate the mold and the vessel related to it. There was thus a direct link between the type of material used and the specific shape given to the finished luxury product. This relationship was similar, say, to that existing between the particular features of the glass from which vessels were made and the choice of specific cutting designs and techniques used for their decoration (Jacoby 1993, 87).

Regarding Venetian *cristallo,* W. Patrick McCray draws our attention to statements by Renaissance-period (15th to 17th-century) writers 'regarding what was desired in terms of glass quality (the *material* and not the form)' (McCray 1999, 93). The phenomenon of understanding the term crystal glass as a certain type of vessel and/or a certain type of its decoration seems to return in the 18th century or even at the turn of 17th century. It can not be excluded that this phenomenon was influenced by changes in 'good taste' at that time, as strongly underlined by Michael Vickers (1998). Numerous 18th-century glasshouses were called crystal glasshouses, and the term crystal glass was widely applied to certain types of vessels frequently very richly decorated but manufactured with the use of the cheaper chalk glass. The ability of glass to take fashionable decoration constituted a more important feature than the quality of the metal. In the discussion below, the term crystal glass will only concern the special kind of metal.

According to known sources, in the 1670s in Central Europe crystal glass was manufactured only in a few glasshouses in Bohemia (Buquoy glass) and Brandenburg. At the beginning of the 18th century, crystal glass seemed to survive in central Europe only in some German and Polish glasshouses – in the territories where luxury glass production was still maintained mainly by the royal and aristocratic courts. The Polish-Saxon Union (1697–1763) was of some importance in this process too (Kunicki-Goldfinger *et al.* 2000a).

In central Europe in the first half of the 18th century, three main types of colourless vessel glass – crystal, white (chalk) and ordinary (FIG. 1) – were manufactured. They corresponded to the former Venetian glass types: *cristallo, vitrum blanchum* and *vetro communale* (Moretti and Toninato 1987).

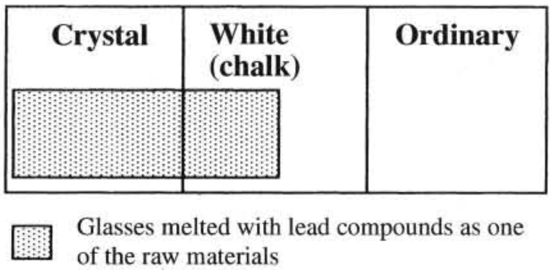

FIG. 1 Three main technological groups of colourless glass melted in the first half of the 18th century

Vetro communale, as the most ordinary glass, might be compared with forest glass. Ordinary glass was its successor. It was melted as a rule with the use of four basic raw materials – sand, lime, potash and pyrolusite – which with the exception of pyrolusite were gained from local easily accessible sources. Such glass can be recognized on the basis of features of its composition, the first of which would be the absence of arsenic, assuming obviously that the element was not introduced with cullet, while the high content of glass contaminants is no less important.

White (also called chalk) glass might be considered as the successor of *vitrum blanchum*. Multi-component batches were used for its production and its raw materials were better selected and purified. Chalk was used in place of limestone, potash was partly replaced by saltpetre, and the quality of the sand constituted a very important feature. Pyrolusite remained the main decolourizing agent. Beside saltpetre, new materials were applied – arsenic and wine stone. The saltpetre/potash ratio as well as batches as a whole differ depending on the glasshouse and glassmaking tradition.

Crystal glass production required the best quality raw materials though obviously in this regard particular glasshouses differed from each other. The crystal glass batch was also distinguished by certain other qualities. The saltpetre/potash ratio was much higher than in the case of the white glass batch, and potash could even be completely replaced by saltpetre. The saltpetre/chalk ratio was also higher than for white glass. On the basis of chemical analysis we are not able to distinguish the fraction of potassium introduced with saltpetre from that introduced with potash and wine stone which also constituted a source

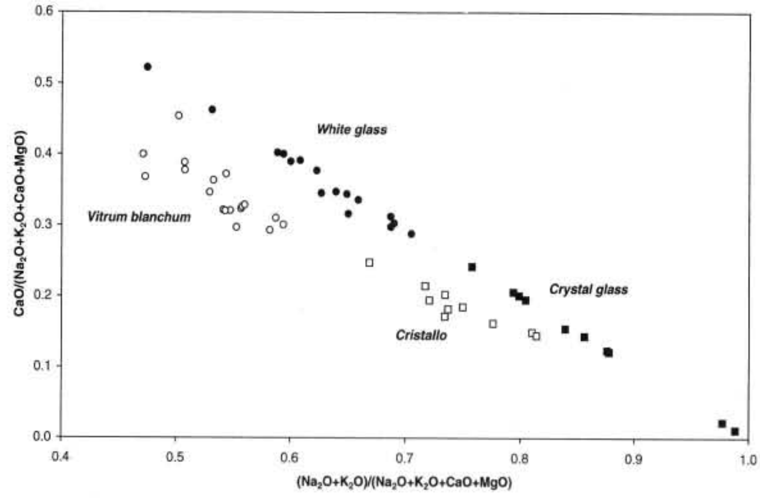

FIG. 2 Venetian soda-ash glass (*vitrum blanchum, cristallo*) (after Veritá 1985) and 18th-century central-European potassium glass (white, crystal) (own results) shown in a scatter-plot for the variables calculated from the alkaline and alkaline earth oxide concentrations

of the element. Looking at the concentration of alkaline and alkaline earth oxides in the glass, the differentiation of white and crystal glass is possible in most cases though not all. FIGURE 2 illustrates well the technological relationship between *vitrum blanchum* and white glass as well as between *cristallo* and crystal glass. The scatter-plot does not undergo significant changes when looking at *vitrum blanchum* manufactured in places other than Venice, even in northern Europe. Only in the sum of alkaline oxides (Na_2O+K_2O) does the contribution of sodium and potassium oxides change with respect to the type of applied ash. It can thus be easily seen that white glass constitutes a continuation of northern *vitrum blanchum* frequently manufactured with mixed alkaline ashes or even noticeable potash ash. The same is true for crystal glass where *salicornia* is replaced mainly by saltpetre and the sodium contribution in the sum of alkaline oxides appears almost insignificant though the overall ratio of alkaline and alkaline earth oxides remains the same. Due to the possible overlapping of regions characteristic for crystal and white glass when the alkaline oxide/alkaline earth oxide ratio is considered, the As_2O_3/CaO ratio constitutes the better and more convenient technological indicator (FIG. 3). Firstly, the proportion of arsenic is related (in many cases) to the proportion of saltpetre because of technological requirements. Secondly, it is easier to estimate the arsenic than the potassium content in glassware by the use of non-destructive methods (like EDXRF). The next important feature that distinguishes crystal glass is the presence of boron in the glass. We are not fully convinced that borax was used exclusively for crystal glass production. It is difficult to detect boron by the analytical methods commonly applied to baroque glass analysis and their detection limits for boron are not sufficient. However up to now both the scanty written sources and the results of chemical analyses confirm the presence of boron only in crystal glass.

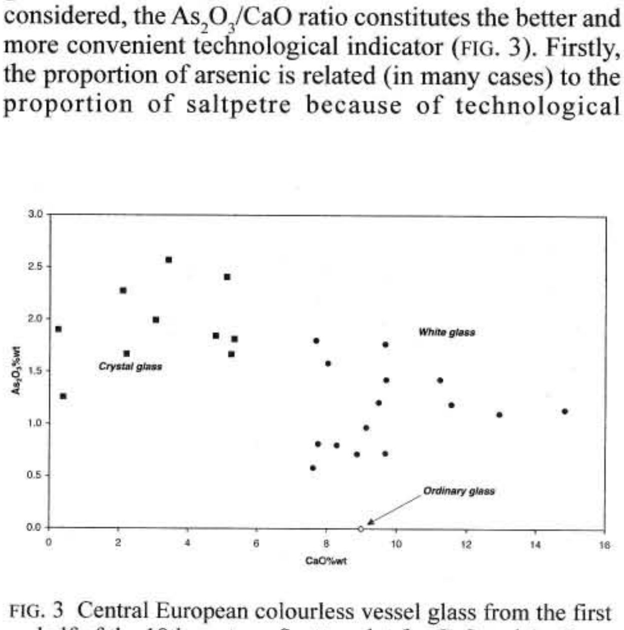

FIG. 3 Central European colourless vessel glass from the first half of the 18th century. Scatter-plot for CaO and As_2O_3

Having distinguished the main glass formulations, it is important to underline that among crystal and white glasses were found glasses which also contained lead (FIGS 1, 4: Kunicki-Goldfinger *et al.* 2003a). For white glass only some of the items examined contained lead with the highest concentration reaching *c.* 2wt%. It was impossible to distinguish white glasses with intentionally and accidentally (e.g. cullet) introduced lead. Most crystal glasses contained lead and it is possible to distinguish unleaded from leaded items. This is surely influenced by a better technological regime and the greater care taken when crystal glass was manufactured. For the leaded crystal glass, the PbO concentration exceeded ~0.4wt%. and reached in certain cases almost 13wt%. The overlapping of these PbO concentration ranges (~0.4 – ~2%) means that analyses of lead concentrations do not always serve to distinguish the features for white and crystal formulation, although when the PbO content is really high (much higher than 2%) it may be assumed that the examined glass is made of crystal metal (further results might change these ranges). We have found only one unleaded glass sample among all the crystal glass samples analysed by the use of EPMA, but a few more were found by the use of EDXRF. Supported by these results, we want to verify some of our previous conclusions (Kunicki-Goldfinger *et al.* 1999; 2000b; 2003b) and to state that most crystal glasses melted in the first half of the 18th century in central Europe contain lead though some do not. Among leaded crystal glass, the highest PbO concentration was found in the case of glass medallions on the Dresden (or Naliboki) goblets (<13%) and goblets made in Altmünden and Dresden (< 11%). For the Naliboki and

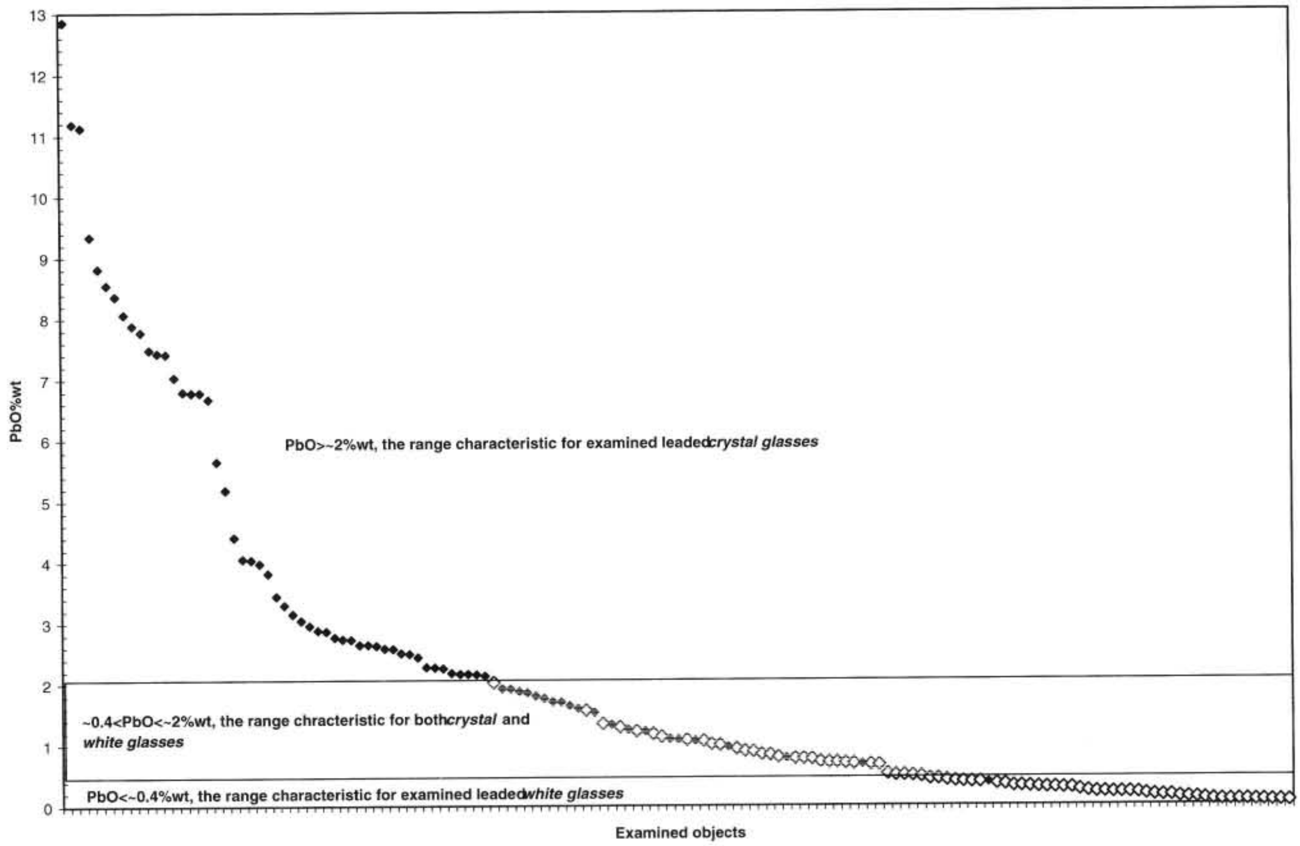

FIG. 4 The PbO in central European crystal and white glass in the first half of the 18th century (for PbO range ~0.1–13wt%, EDXRF)

Zechlin glasses examined, PbO content did not exceed 6%, and for Potsdam glass 3%. It should be emphasized once again, that where leaded crystal was manufactured for the whole first half of the 18th century, the examined unleaded crystal glasses would originate only from the beginning of the century.

The following glasshouses were found to produce crystal glass (regardless of lead compounds used) in the first half of the 18th century: Potsdam (from 1737 – Zechlin), Altmünden, Dresden, Naliboki (from 1722) and Bielany (from ~1710). Only certain written sources listing imported raw materials allow us to include a factory at Bielany in the list, since no glass manufactured in Bielany has been recognized up to now. In TABLE 1 some results of chemical analysis of crystal glass are included. These will be thoroughly discussed together with other results in a forthcoming article which also covers a bibliography survey.

TABLE 1 MAIN CONSTITUENTS OF CRYSTAL GLASS FROM THE FIRST HALF OF THE 18TH CENTURY IN CENTRAL EUROPE (WT%, EPMA, SIMPLIFIED RESULTS)

Provenance	**Unknown***	**Altmünden**	**Dresden**	**Germany**	**Zechlin**	**Zechlin**	**Zechlin**	**Naliboki**	**Naliboki**	**Naliboki**
Dating	Uncertain*	*c.* 1710	*c.* 1740	1700-50	*c.* 1740	*c.* 1740	*c.* 1738-47	*c.* 1740	*c.* 1740	*c.* 1740
Object	Cover	Goblet	Goblet	Plaque	Goblet	Goblet	Goblet	Goblet	Flute	Goblet
Museum	Warsaw[1]	Wrocław[1]	Warsaw[1]	Wrocław[1]	Wilanów[2]	Wrocław[1]	Wilanów[2]	Warsaw[1]	Wilanów[2]	Wrocław[1]
Inv. No.	187642/b	II.811	23.222	II.340	Wil 74a	1473	Wil 49	211599	Wil 3540	II.249
SiO_2	73.84	72.88	66.38	69.50	76.77	75.22	76.78	70.04	68.85	69.31
Al_2O_3	0.12	0.15	<	0.11	<	0.20	<	0.92	0.73	0.73
Na_2O	2.23	0.18	0.53	<	0.43	0.44	0.50	<	<	<
K_2O	17.64	16.43	15.42	20.17	14.66	16.11	15.10	19.69	20.50	20.79
CaO	0.24	0.39	5.10	3.42	2.10	3.05	2.21	4.78	5.32	5.24
As_2O_3	1.90	1.26	2.41	2.57	2.27	1.99	1.67	1.84	1.81	1.67
PbO	<	9.48	8.91	5.73	2.70	2.63	2.27	2.09	2.01	1.85
MnO	<	0.05	0.03	0.07	0.06	0.05	0.05	0.12	0.12	0.14
Fe_2O_3	0.1	0.07	0.08	0.04	<	0.04	0.03	0.19	0.13	0.12
B_2O_3	3.9	<	0.6	<	0.8	<	0.4	<	<	<
Cl	0.2	<	0.4	<	<	<	<	<	<	<

* The provenance of the cover depends on that of its goblet which is made of white glass
[1] National Museum, [2] Museum Palace

Experimental details

Analyses by wavelength dispersive spectrometry in the EPMA system were carried out using *Cameca SX-100* with three simultaneously working spectrometers (PET, LIF, TAP crystals and PC2 for boron) at the Electron Microprobe Laboratory (Faculty of Geology, Warsaw University). The measurement conditions were as follows. For main constituents: 15kV, 6nA, 20μm beam diameter, counting time – 20s for each element; for minor and trace constituents (with fixed concentration of main constituents): 20kV, 100nA, 80μm beam diameter, counting time – 20-60s; for boron (with fixed concentration of main and minor constituents): 5kV, 100nA, 20μm beam diameter, counting time – 20s. Standards were oxides and minerals. Corning C, D and NIST 610, 612 were used as secondary standards. There was good agreement between the EDXRF and EPMA results according to most of the examined elements. For example, correlation coefficient (R) for PbO concentration analysed by both systems amounted to 0.9952 (n = 12). Although some small discrepancies have also been found. They are discussed in the above-mentioned forthcoming article.

Acknowledgements

The authors express their gratitude to the Boards of Museums who made the vessels available for examination: National Museums (Kraków, Poznan, Warszawa, Wrocław), Royal Castle (Warszawa), Museum-Palace in Wilanów, District Museum in Tarnów, and Historical Museum of Warsaw.

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THE SEVENTEENTH AND EIGHTEENTH CENTURIES: VESSELS AND THEIR USE

JOHN GREENE'S GLASS DESIGNS 1667–167?

Colin and Sue Brain

To set the scene, we want to take you back one third of a millennium to 17 September 1669. The place is Cary House in London's fashionable Strand. We find a 33-year-old glass seller writing a letter, his fourth, to the Venetian glassmaker Alleisio Morelli. His name is John Greene, still a partner with fellow glass seller Michael Measey, but hoping to set up on his own in the Poultry in the heart of the city as soon as it has been rebuilt after the late disastrous fire. It is likely that Greene had served his seven-year apprenticeship as a glass seller with Measey and was following in the trade of his grandfather. As he wrote to Morelli, he might even have reflected that 50 years earlier his grandfather had been jailed for importing glass from Venice. Reflecting on his grandfather's imprisonment, he may have wondered if a similar fate would await him if the King's customs ever found out that he was, as usual, defrauding them by asking Morelli for two bills (facterijs):

> Sr further wee desire you to send us Two facterijs and in one of them ... to enter shortt the true number in everij chest of drinking Glasses ten dozen for the Custome is also verij high apone them ... (Hartshorne 1897, 443).

Still he had the consolation that he was already a powerful member of the new Glass Sellers' Company of London. He had been named as one of its founding assistants in their Royal Charter and nearly five years earlier he and Measey had attended its initial court held in the George Tavern in Ivy Lane. These connections might serve to keep him out of jail if ever the customs found out about the 'Two facterijs'. But Greene's rise in the Glass Sellers' Company was only just beginning – in 1671 and 1672 he was Renter Warden of the Company, then Upper Warden the next year, rising to become Master in 1679.

Back in 1669, John Greene was writing to order more glass from Morelli. His last order had only been received a few weeks ago, but they were selling well. Folk were still replacing glass they had lost in the fire, but the main demand was for new fashions to keep up with the court and its followers. Business had never been so good and 'persons of quality' such as the Duke of Bedford were buying as many as five dozen of these Venice beer glasses at a time. Even though it was inconvenient to send to Venice for these glasses, with poor Mr Burrough's glasshouse still being rebuilt after the fire, there were just not enough glassmakers in London to supply the quantity of glasses he and his fellow sellers needed. This was always supposing they could routinely improve the quality of their products to match those from Venice. Still the poorer sort of people were glad to get any glass in the new fashions so there was bound to be some sort of market even for the lesser sort of glass made in London. It was vital though to protect the market from the 'country' glasses bought in by the peddlers who gave the Glass Sellers' Company so much trouble. Only a few months ago he had paid a full 20 shillings to help pay for the prosecution of William Wyatt who had proved particularly difficult. Still they had all dined well at the Woolsack after that council meeting.

Sloane 857

Fortunately copies of the letters that John Greene wrote have been preserved in Sloane Manuscripts 857, now in the British Library. Sir Hans Sloane almost certainly obtained them from his estate when John Greene died in 1703. This may well have been facilitated by the fact that Sir Hans was then secretary of the Royal Society (1693–1712). The MSS include Greene's copies of nine letters and drawings he sent to Alleisio Morelli in Venice and some of his later glass drawings. Most of the letters have been transcribed and published (Hartshorne 1897). Unfortunately Hartshorne omitted the first letter and misdated letter eight, resulting in numbers eight and nine being printed in reverse order. A few of Greene's drawings have been published, but never to my knowledge in concert with the letters to which they relate. One of the drawings to which I refer here has been published (Percival n.d.. pl. vii).

Orders from Venice

John Greene first ordered from Venice in October 1667. There is not space to do justice to even one of his orders, so this paper concentrates on part of letter 4, dated

September 1669. This was the largest of the orders, amounting to about 600 dozen glasses. This may represent about 10,000 glasses, since Morelli probably supplied at 16 to the dozen. Some glass sellers later complained that the company was only being furnished at 16 to the dozen, whilst other glassmakers were selling at 18 to the dozen. Glasses were sold retail at 12 to the dozen, so 16 to the dozen represented a profit margin of one third, whilst 18 to the dozen was a profit of one half. I will concentrate on drinking glass in this paper, since these represented the majority of the vessels ordered. From the letters we know that at least Mr Richard Sadlers and Mr Allen were also then buying drinking glass from Morelli, who seems to have specialized in manufacturing for export. Typically Greene received his glass about four months from the date of ordering.

GREENE'S REQUIREMENTS

In the early part of the 17th century, vessel glass fashions changed seldom and the design function was just an extension of the glassmakers' skill. However, in the later part of the century this changed dramatically, as shown by a letter written to Greene by his nephew Edward. It was sent in about 1691 from on board his Majesty's ship *The Loyal Servant* in the Caribbean (Thorpe 1938, 170). Edward was probably just starting in the glass trade, since it is likely that he went on to be Clerk of the Glass Sellers' 1702–1721 (Howard n.d., 30). He wrote that a hogshead of glasses Greene had asked him to sell were very old fashioned and he could not even sell them at 40% of their former value. A few years later, in 1695, the rapid devaluation of 'old fashioned' stock is emphasized in a petition to parliament. This claimed that typically a quarter of the batches of glass in the warehouse had to be sold at a loss of '£40 per cent', because they had gone out of fashion before they could all be sold (Buckley 1914, 39). Anticipating and leading rapidly changing fashions is not something a glassmaker can do easily, but a merchant can. In these letters we see the design role being adopted by the London merchants who were best placed to follow fashion and who had most to loose if they failed. Thus John Greene was very dogmatic about exactly what he wanted. The following is typical of his instructions to Morelli:

> Sr Wee praij you most Carefully to observe these directions under written
> 1st That all the drinking Glasses be well [inserted] made of verij bright cleer & whit sound Mettal and as exactlij as possible may be to the formes for fashion size and Number and that noe other fashions or Sortts be be sent us but this one patterns onlij.
> 2d That the Chests be strong Large whole Chests well hooped and naijld and Markt and Numberd as in the Margent at one end of everij chest and also apone the Covers or Lids, to prevent the seamen from setting the Lid or upper part of the Chest undermost and to be sure theij be all verij well and Carefullij packt up and with thorou drij weeds, for if the weeds be not well drijed or doe take anij wett after theij be packt theij staijne and spoijle the glasses.
> 3dlj Remember to send 2 facterijs the 1st Right ye 2d wrong.

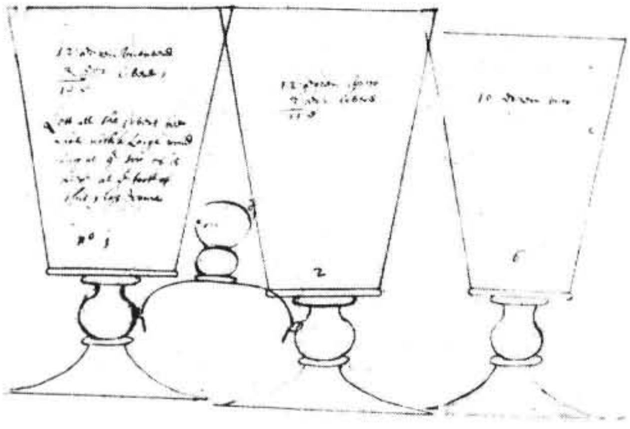

FIG. 1 Composite image of three beer glasses from the same order. By permission of the British Library Sloane Manuscript 857

Note here his insistence that the glasses delivered were to be exactly as he had drawn with no variations. Thus Morelli and his workmen were being used as a production facility, with no scope for using their traditional craftsman's flair for design. What is even more surprising is the very small variation between some of his designs. FIGURE 1 shows three beer glass designs from this one order, that at first glance appear almost identical. Clearly Greene considered that they were sufficiently different to warrant separate designs.

Another feature of these orders is the range of drinks they catered for. In the first half of the 17th century there were generally only two types of drinking glasses sold in quantity – wine and beer glasses. Greene starts to expand on this and we regularly see beer, French wine (claret) and Spanish wine (sack) glasses in his orders, with the occasional non-stemmed glass for German wine (roemer) and brandy (beaker). Approximately 55% of all the stemmed glasses ordered by Greene from Morelli were for beer, 30% for claret and 15% for sack. Although FIG. 2 shows essentially the same design in the three sizes, this seems to have been the exception rather than the rule. Little, if any, attempt was made to use glass in sets or to have matching glasses at table. In fact it seems unlikely that each drinker would even get their own glass, with one glass being shared between a number of people. As FIG. 1 shows, a few glasses were ordered with covers.

Whilst the instructions with this order emphasize the need for the glass to be 'bright, clear and sound', later orders start to emphasize the need for strength, weight and clarity. This marks a major shift from valuing Venetian glass for its fragility and delicacy to valuing glass for its serviceability and solidarity.

COMPARISON WITH ARCHAEOLOGICAL FINDS

There are surprisingly few excavated pieces from English sites that exactly match any of Greene's drawings. Whilst many are similar, most excavated pieces do not have the collars above and below the stem knop that are so characteristic of his drawings. Most of these pieces are also made of a tinted 'mixed alkali' glass more typical of English manufacture than the clear soda glass one would

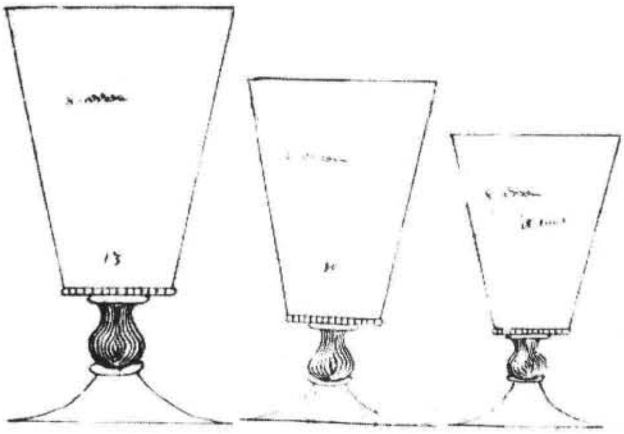

FIG. 2 Composite image of similar designs ordered for beer, claret and sack. By permission of the British Library Sloane Manuscript 857

expect from Venice. It seems improbable that any of these stemmed glasses has survived intact. A number of private and museum collections have seized on the fact that Greene illustrates one (and only one) design for a very simple glass that has a conical bowl and a spherical knop as a stem, with no collars above it or below. On the basis of this one design, all examples of glasses like this are then claimed to be associated with John Greene. If any of these many claims are true, it is remarkable that one or more of the 100 produced by Morelli of this design has survived, whereas the 35,000 produced of the more typical styles have left no surviving example.

FIGURE 3 shows a comparison between a fragment excavated in London (Museum of London acquisition number A27839) and a beer glass design from the order under consideration here. They are reproduced at the same scale. It is interesting that the site of Greene's later premises in the Poultry has been excavated and a number of glass fragments found (Willmott 2000). However none of these appear to precisely match the drawings.

There is no indication from the archaeological record that these kinds of glass styles significantly predate Greene's letters. There have been suggestions that the styles derive from the silver or golden mounts made for simple glass beakers. Considering the wide range of glass designs that accompanied even the first order, it seems unlikely that this was the sole source of Greene's inspiration, although it may have been a significant influence.

CONCLUSION

This paper has very briefly reviewed John Greene's role as one of the founders of the Glass Sellers' Company of London and some of his orders to Alleisio Morelli in Venice, preserved in British Library Sloane MS 857. Some of Greene's designs enclosed in one of the letters have been discussed, with emphasis on the small variations there are between some of them. The range of drinks catered for was also discussed.

Perhaps the major significance of this material is in the light it sheds on the shift of the glass design function from manufacturer to merchant. This created, or responded to, a fashion-led demand for choice diversity and change, coupled with the traditional yearning for quality, solidity and longevity. As a merchant designer, John Greene knew exactly what he wanted to satisfy his customers and how to get it.

FIG. 3 Comparison between a drawing and a stem fragment of probable Venetian origin. By permission of the British Library Sloane Manuscript 857

In John Greene's later orders he made the point that England was fast developing the glass technology to rival Venice. These technology developments have been extensively discussed in the literature, including the glass seller's role in fostering them. However, the importance of shifting design from the chair to the shop seems to have been overlooked in this concentration on the chemistry of glassmaking. The new type of English glass metal was not well suited to the kinds of designs ordered by Greene and needed a simpler style to excel. Thus, for it to be a success, the new lead glass needed to be marketed in new styles. It is arguable that the close association between the merchant and the glassmakers, and the merchant's role in design was the major factor that made English glass predominant over foreign rivals who possessed similar technology. Design was critical to selling in a world of rapidly changing fashions and in influencing the market in a profitable direction.

Soon (1674) English glassmakers also found it was the glass seller who (Hartshorne 1897, 451):

> ... knowes better what is fitter to be made for the Trade both as to ffashion and size, then any other there ... .

ACKNOWLEDGEMENT

The reproductions of the glass designs are taken from a microfilm copy of Sloane 857 and are illustrated here by permission of The British Library.

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THE KIT-CAT CLUB DECANTER

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When an engraved flask emerged from the dusty loft of a house in the South-west of England in 2003 (Sotheby's 2003, 76–7, lot 101) and was subsequently sold to a private collector at auction in London, it created more than a small amount of interest. How long it had been in that attic remains a mystery though the vendor had suggested that it had once belonged to an unnamed opera singer who had vacated the property some 20 years earlier. Its subsequent owners were oblivious of its true significance. However, as a piece of English social history this flask has an importance far beyond its intended use and decorative appeal and is central to our understanding of the *mores* of the period.

Dating from the first quarter of the 18th century, the flask is of soda metal, 280mm tall and in shape is of a flattened ovoid or tear-drop form possessing a string rim below the lip of the neck. An applied foot-ring completes the ensemble (FIG. 1).

Its dusty appearance owes nothing to the loft from whence it came but sadly the glass is affected by crizzling. This weathered look may appeal to the archaeological members of this Congress but, as we know, this condition was not achieved through burial in the ground but by the interaction of the atmosphere with the soda alkali (see for example Fearn *et al.* this volume).

On either side of the flask appear formal scenes of seated gentlemen wearing elaborate wigs, dining or toasting, their tables bedecked with wine glasses and decanters, the decanters of similar form to our flask itself but with what appear to be stoppers and with plates and cutlery. Whilst in the 18th century engraving was a popular form of decoration on glass and, of course, glass was commonly used at dining tables, engraved scenes of dining on glass vessels are relatively rare, especially on English manufactured examples. One famous later example is the English lead-glass punchbowl at the Metropolitan Museum of Art (Sotheby's 1964, lot 154). Dating to *c.* 1760, one side of the bowl depicts a wheel-engraved view of men seated around a table holding drinking glasses, not unlike the scene on our flask. It also bears the coat-of-arms of the Wentworth family and a view of a large house on the reverse thought to be that of either Wentworth Woodhouse, Yorkshire, or Milton, Northamptonshire.

What makes our earlier continental soda-glass flask unique are the inscriptions. On the obverse appears 'The Kitcat' (FIG. 2) and on the reverse 'The Toasts' (FIG. 3). On the neck above the cartouche on the obverse side it is inscribed 'This Unites us' and within the scene of dining is inscribed the name *Jacob Tonson P.*

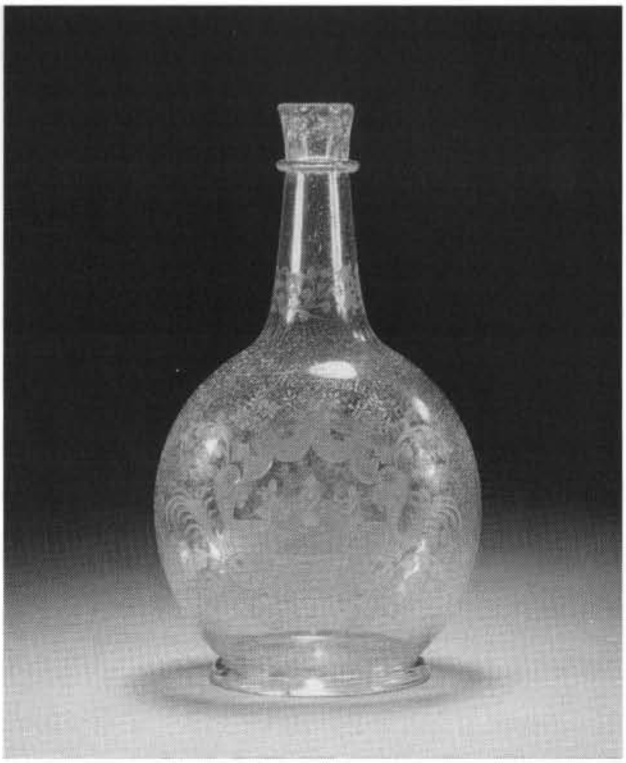

FIG. 1 The Kit-Cat Club decanter (courtesy of Sotheby's)

The iconography and inscriptions are a direct reference to the Kit-Cat club, founded in London towards the end of the 17th century largely by Lord Somers, the Lord Chancellor, and the publisher Jacob Tonson, its secretary. Variously spelt Kitcat, Kit-Cat and Kit Cat, the club's members were influential Whig politicians, leading men of letters, architects, poets and the like. They began meeting in Christopher Catling's tavern near Temple Bar in the City of London. It is generally believed that the club took its name from his mutton pies which we are told were known as Kit-cats. These pies may be seen on the table on the front of the flask. Members included leading politicians and landowners, younger men like Sir Robert Walpole and William Pulteney, the writers Joseph Addison, Sir John Vanbrugh, William Congreve and Sir Richard Steele, as well as the Duke of Marlborough and the Earl of Burlington.

Their ostensible object would seem to have been the encouragement of literature and the fine arts, but the end they diligently sought to accomplish was the promotion of loyalty and allegiance to the Protestant succession in the House of Hanover. The club's political significance was

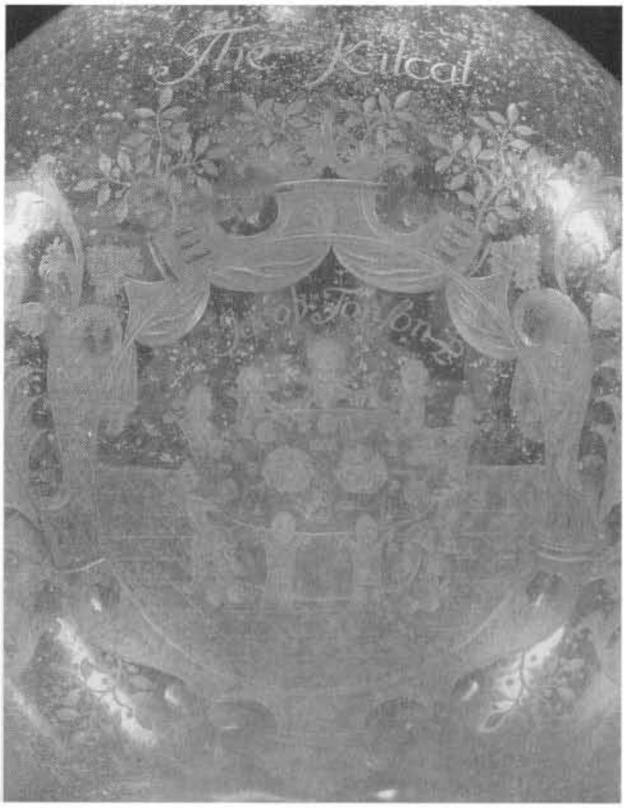

FIG. 2 The Kit-Cat Club decanter: detail of obverse 'The Kitcat'

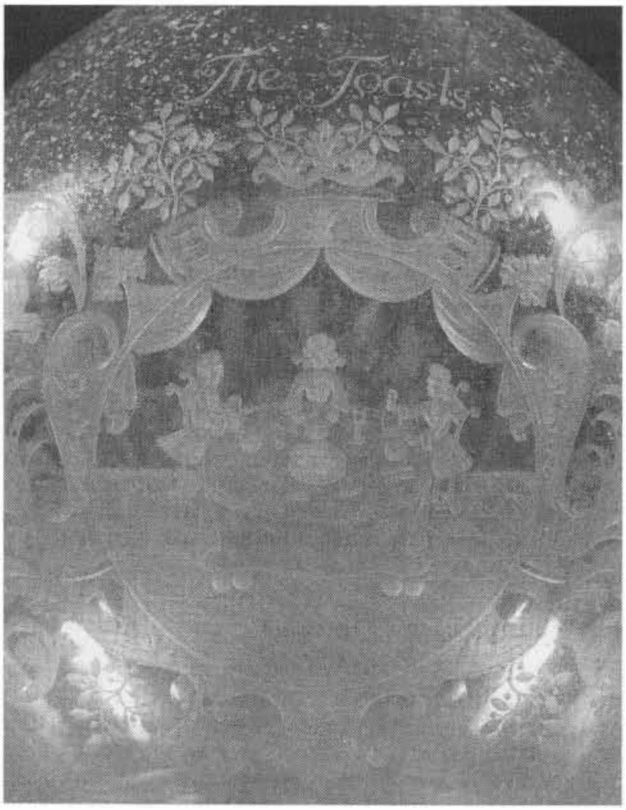

FIG. 3 The Kit-Cat Club decanter: detail of reverse 'The toasts'

such that Robert Walpole records that though its members were generally mentioned as a 'set of wits', they were in reality the patriots who saved Britain. The club consisted of at least 39 members, all men of the first rank and quality of learning, most of whom were at times employed in the greatest offices of state, or in the army, and none were admitted but those of high distinction in one way or another.

To collectors of 18th-century English drinking glasses, the Kit-Cat club is best known by a type of glass. Varieties of the type are found in the collectors' literature (Bickerton, 1986, 81, fig. 117). Generally referred to as 'balustroid', such a glass is considered to have a tall trumpet-shaped bowl set on a short inverted baluster with a conical foot (Treglown and Mortimer 1981, 48). The club is better known to historians through the magnificent set of portraits of its members – which were indeed all gifts to Jacob Tonson – now hanging in the National Portrait Gallery, London, and at Beningbrough Hall, Yorkshire. They were painted over a space of more than 20 years by the well known portrait artist, Sir Godfrey Kneller, himself a member of the club. More than 40 of the original 48 portraits survive. Two balustroid wine glasses appear indistinctly in Kneller's club portrait of the Earl of Lincoln and the Duke of Newcastle, *c.* 1721. It is these images which have led historians to call what they believe to be similar glasses 'Kit-cats'. However, it has been suggested that the glasses in Kneller's portrait are unlikely to be precise copies of specific glasses used by the club (Treglown and Mortimer 1981, 46).

The portraits of the members were originally intended to be hung in the room which Tonson had added to his residence at Barn Elms, Surrey, for the meetings of the club. Due to the low height of the ceilings of this room the portraits had to be of a half size – 36 inches long by 28 inches wide. This merited 'Kit Cat' to become a technical term in painting.

It was the club's practice to toast famous and beautiful women. When a woman was toasted her name, and perhaps a verse, would be engraved on a glass. Tonson himself published *Verses Written for the Toasting-glasses of the Kit-Cat Club in the year 1703.* This year seems to be an important one in the life of the club about which I will say more shortly. The custom of toasting ladies after dinner was peculiar to the Kit-Cat club, and it emerged from a smaller club called 'The Knights of the Toast'. This is alluded to in no. 24 of the London society paper *The Tatler*.

> Though this institution had so trivial a beginning it is now elevated into a formal order, and that happy virgin, who is received and drunk to at their meetings, has no more to do in this life but to judge and accept of the first good offer. The manner of her inauguration is much like that of a choice of a Doge at Venice; it is performed by balloting; and when she is so chosen, she reigns indisputably for that ensuing year; but must be elected anew to prolong her empire a moment beyond it. When she is regularly chosen, her name is written with a diamond on one of the drinking glasses. The hieroglyphic of the diamond is to show her that value is imaginary; and that of the glass, to acquaint her that her condition is frail, and depend on the hand which holds her.

The club had its toasting glasses inscribed in diamond point – an interesting contrast to the wheel engraving of the flask – with a verse or toast to some reigning beauty, amongst whom were the four lovely daughters of the Duke of Marlborough – Lady Godolphin, Lady Sutherland, Lady Bridgwater and Lady Monthermer; Swift's friends, Mrs Long and Mrs Barton – the latter the beautiful and witty niece of Sir Isaac Newton; the Duchess of Bolton, Mrs Brudenell, and Lady Carlisle; Mrs D. Kirk and Lady Wharton.

One such toast is that to the Duchess of Richmond:

> Of two fair Richmonds different ages boast,
> Theirs was the first, and ours the brightest toast.
> Th' adorer's offering proves who's most divine,
> They sacrificed in water, we in wine

Unlike on the European continent, glass engraving in England is quite rare. Wheel engraving was highly popular in Germany especially where the craft came under the patronage of the royal courts and local aristocracy. This was not the tradition in England. The use of a diamond point is thus more commonplace in England where the technique was largely undertaken by amateur engravers. The copper wheel was more likely to have been used by itinerant German artisans who had been trained in its use.

Returning to the flask, the club's secretary, Jacob Tonson, may have been the commissioner. However, since Kneller's portraits were gifts from the members of the club to Tonson, the flask may have been one further gift. Not only does his name appear within the design – with the addition of the curious 'P' suffix (possibly an allusion to his profession as a publisher) – but it might have been made for use at his home in Surrey where the club occasionally met. A London bookseller and publisher from 1676, he is best known for his close association with the poet John Dryden and published most of his works. He also bought the valuable rights to Milton's *Paradise Lost.* In 1712 he became joint publisher with Samuel Buckley of *The Spectator* which is still to be seen on our newsstands today. Tonson's portrait was painted by Kneller in 1717.

In 1703 Tonson went to Holland for the purpose of procuring paper and getting engravings made for the edition of Caesar's *Commentaries* which he published in 1712. It is during this visit that I originally believed that Tonson acquired the flask. From a study of the style of the decoration used by itinerant Bohemian engravers – such as Georg Kreybich – the flask was thought at first to be Dutch or Bohemian. There are several aspects of this flask which now suggest a Saxon origin. Firstly, the flask is undoubtedly of continental manufacture and is similar to types made both in Germany and Holland at the turn of the 18th century. Figural scenes, mostly engraved in diamond point, are relatively commonplace in the Dutch glass engraver's repertoire, the tiled flooring reminiscent not only of contemporary oil paintings of Dutch interiors but also found later in the ever popular 'pregnancy' or 'Kraamwrouw' glasses produced by copper-wheel engraving in Holland in the middle of the 18th century. However, the early date of the engraving on this glass, the fact that it is done with a copper wheel, the strong similarity to glass produced in Dresden at this time and the style of Saxon engraving, would suggest otherwise.

The depiction of decanters in the table settings on the flask portray them with stoppers made as a wide band of glass below a ball finial with a hollow tapering peg below. Such stoppers are commonplace on Saxon flasks or decanters and were used later in the century. Two ruby-tinted flasks are known, dated 1713–1719, of the same form as the Kit-Cat club decanter, each with a similar stopper, the sides bearing leaf and scroll cartouches, a flowing engraving style and applied foot rings (Haase 1988, 88–9, figs 101, 102). The Dresden glasshouse of Augustus the Strong, the Elector of Saxony, was known for its production of glass which were either royal gifts or commissions for people living far from the Saxon borders. As a centre of the arts it would not have been difficult for a member of the Kit-Cat club to have acquired such a commemorative piece from a glasshouse in Dresden, where engraving workshops were quite used to supplying foreign clients.

It is very likely that through his need for printing plates Tonson would be familiar with engravers in London. Therefore, it is interesting to see that a continental flask with English inscriptions was commissioned from Dresden rather than using a local engraver working in lead crystal. This might underline the lack of a glass-engraving tradition in London at this time, especially for wheel engraving. The Bohemian engraver Georg Kreybich is reported to have arrived in London from Hamburg in 1688 after travelling throughout Germany and Austria (Schmidt 1922, 391–2). He brought with him a shipment of glassware. He complained in his diary about the competition from six glassworks in the town which 'at that time made more beautiful glass than that which we had brought with us'. Kreybich was ultimately successful and attributed this success to the novelty of engraved and enamelled glass:

> Our glass was engraved and painted and none like it had yet appeared there – we were the first. This again was an unexpected boon.

Kreybich returned to Bohemia via Harlem, Delft, Leyden, Amsterdam, Zwolle, Hannover, Wolfenbuttel, Leipzig and, interestingly, Dresden, engraving glass to order on his cart-mounted equipment.

In the summer the club met at the 'Upper Flask', Hampstead Heath, which was described as a gay resort with its races, ruffles and private marriages (Barrett 1889, 43). The allusion to Hampstead Heath as a gay resort is used in a very different manner from that of today where indeed in popular parlance it has become such!

Tonson appears to have been the key-stone of the Kit-Cat club, as may be collected from the following extracts from letters addressed to him from several members. The Duke of Somerset tells him in a letter dated 22 June 1703 'Our Club is dissolved till you revive it again, which we are impatient of.' In the same month and year, Vanbrugh, who was always exceedingly well disposed towards Tonson, and corresponded with him for over 20 years, writing to him in Amsterdam, says:

> in short, the Kit Cat wants you much more than you ever can do them. Those who remain in town are in great desire of waiting on you at Barn Elms, not that they have finished their pictures, neither; though, to excuse them as well as myself, Sir Godfrey has been most in fault. The fool has got a country house near Hampton Court, and is so busy in fitting it up (to receive nobody), that there's no getting him to work.

Perhaps the inscription on the flask 'This Unites us' was an addition by Tonson to revive the flagging spirit of the club referred to by the Duke of Somerset.

From about the year 1720, the elder Tonson seems to have transferred his business to his nephew, and lived principally on his estate in Herefordshire, until 1736, when he died. From his will, made 2 December 1735 and proved 9 April 1736 it appears that he had property in Herefordshire and Gloucestershire. I have yet to find the will which one hopes might list this flask and other table vessels used in the service of the club. If this flask was a part of the larger gift of portraits to Tonson, it is tantalising to think that there may be other individual flasks extant which bear the names of the other members and that might have been used at Barn Elms.

The spirit engendered in this flask, its sentiments and its wide international appeal remind one of today's AIHV Congress where the appreciation of wine, women and glass Unites us all.

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L'INFLUENCE ANGLAISE SUR LA MORPHOLOGIE DU VERRE LIÉGEOIS DANS LA DEUXIÈME MOITIÉ DU XVIIème SIÈCLE

JANETTE LEFRANCQ

Dans la deuxième moitié du XVIIème siècle, afin d'étendre son marché à un territoire plus vaste que la principauté de Liège, la famille liégeoise des Bonhomme parvient à s'approprier la plupart des verreries à la façon de Venise établies dans les Pays-Bas méridionaux et à y dominer bientôt la fabrication du verre de luxe. Propriétaires de plusieurs verreries à Liège même, et bien qu'étrangers aux Pays-Bas espagnols, les Bonhomme acquièrent bientôt la verrerie de Bruxelles, mais aussi celles de Maastricht-Wijk, de 's Hertogenbosch (Bois-le-Duc), et de Verdun, leur ouvrant non seulement le marché des Pays-Bas espagnols mais encore celui des Provinces-Unies et d'une partie de la France.

L'énorme travail de dépouillement exécuté à la fin du XIXème siècle par Pinchart, Schuermans et Van de Casteele dans les archives de Bruxelles et de Liège a révélé plusieurs mentions relatives à la fabrication dans les usines des Bonhomme de 'verres à la façon d'Angleterre'. Ainsi voit-on apparaître dans certains contrats d'engagement de maîtres altaristes les formulations de 'verres à l'anglaise' (Schuermans 1883, 162) ou de 'verres à l'anglaise à la bière à deux règles' (Schuermans 1884, 320). En 1680, les Bonhomme engagent à Liège et dans leurs autres sites des ouvriers pour faire des 'verres à l'Angleterre' (Schuermans 1887, 329; 1890, 120); cette formule est précisée dans le renouvellement du contrat d'Ottavio Massaro qui stipule:

> 60 verres à l'Angleterre, pour chaque mud soit qu'ils aient des ances ou des amprons, pourvu qu'ils n'aient point de gorlettes, auquel cas ils seront comptés 55 pour chaque mud (Van de Casteele 1887, 466–7; Schuermans 1887, 224).

Les patrons liégeois embauchent aussi des maîtres verriers ayant préalablement séjourné à Londres. Parmi ceux-ci, le Vénitien Paolo Mazzolao, parti de Murano en 1640, qui travaille quelques années à Londres où il est spécialisé dans le façonnage des verres ornés, est embauché en 1655 par les Bonhomme, travaille dans leur usine de Wijk et baptise un enfant à Maastricht; il part en 1662 pour Rouen et est ensuite appelé par Colbert à Paris où il est encore en 1691 (Schuermans 1890, 100, 131, 157–8; 1892, 117–22; Thorpe 1935, 126). Un autre Vénitien, Vincenzo Pompéïo, après avoir travaillé vers 1670 chez Ravenscroft à Londres, où il aurait appris la fabrication du verre au plomb, s'établit d'abord à Anvers en 1677, avant de rejoindre les Bonhomme à Maastricht pour regagner Londres en 1686 (Schuermans 1885, 39; 1887, 340; 1888, 208; 1890, 126, 161; 1891, 74; Thorpe 1935, 156; Chambon 1955, 117; Charleston 1968, 157).

En 1956, en raison de l'existence sur le continent de certains verres qui pouvaient être confondus avec les premières productions de Ravenscroft, Robert Charleston a suggéré que ce Pompéïo pouvait être l'initiateur, dans les Pays-Bas, d'une nouvelle recette de verre contenant une faible quantité de plomb (Charleston 1956, 4–7; 1968, 157).

Si un premier regard sur le verre anglais antérieur à Ravenscroft ne fournit aucun parallèle probant pour déterminer à quel produit des Bonhomme peut correspondre la mention de 'verre à l'Angleterre' et quel a pu être l'apport de ces verriers migrateurs, la production de Ravenscroft des années 1675 et le verre au plomb anglais du dernier quart du XVIIème siècle montrent par contre plusieurs caractères révélateurs.

Les particularités communes au verre anglais et à certains verres liégeois sont:

• Le *crizzling*, qui affecte les productions de Ravenscroft antérieures à 1675, donc façonnées dans un verre cristallin dépourvu de plomb.

• Le décor de côtes pincées en X, appelé *Nipt diamond waies* par Ravenscroft lui-même en 1677, décor qui peut être couvrant ou partiel.

• Les bulbes mis en forme polylobée, non plus par soufflage au moule comme dans la façon de Venise, mais à l'outil.

• Parfois la substitution de nœuds massifs allégés d'une bulle d'air à la place des bulbes creux.

• Des 'oreilles' ou anses en joignant les deux bulbes et façonnées dans de gros filaments lourdement travaillés à la pince.

• Des couvercles dont l'aplanissement est décoré du *nipt diamond waies* et dont la prise est constituée d'un gros anneau tors soudé dans une collerette ondée.

Tous ces caractères se retrouvent sur le continent dans une série de bocaux et de calices d'apparat qui peuvent atteindre de 0.4 à 0.5m de hauteur totale. La majorité de ces pièces étant gravée, certains thèmes illustrés permettent de les situer assez précisément dans l'espace et dans le temps. Je ne m'arrêterai qu'à ces dernières.

Le bocal de la collection Wolf est décoré de l'aigle impériale, timbrée des armes d'Espagne et d'Autriche encerclées du Collier de la Toison d'Or, et entourée d'un arbre contenant les écus des électeurs avec leurs insignes. Cet exemplaire présente les principaux caractères typologiques retenus: le motif de *nipt diamond waies* appliqué à la base de la coupe et à l'aplanissement du

FIG. 1 Calice, gravé à la roue; Liège, Musée du Verre, Inv. B 2283.3

couvercle, l'anneau soudé dans une collerette ondée, les deux bulbes quadrilobés à l'outil et le *crizzling* qui en affecte toute la surface. La conjonction des armoiries permet de le situer dans une fourchette chronologique assez précise, soit entre 1694 et 1705 (Klesse and Mayr 1987, no. 186). Il est à préciser que parmi ces armoiries se trouvent celles de Joseph-Clément de Bavière, électeur de Cologne qui devint prince-évêque de Liège précisément en 1694; il était le frère de Maximilien-Emmanuel de Bavière, gouverneur général de Pays-Bas, qui eut une conduite héroïque lors du bombardement de Bruxelles par les troupes de Louis XIV en 1695.

De nombreux exemplaires sont décorés des armes, et parfois de l'effigie, de Guillaume III d'Orange-Nassau, stadhouder des Provinces-Unies de 1672 à 1702 et roi d'Angleterre à partir de 1689. L'ordre de la Jarretière et la devise *Honny soit qui mal y pense*, figurant sur la plupart d'entre eux, font référence à son règne sur l'Angleterre et leur assignent donc une date postérieure à 1689 (Ritsema van Eck 1995, no. 189–90; Theuerkauff-Liederwald 1994, no. 323; 2 exemplaires au Victoria & Albert Museum, Inv. 8778–8779). Eu égard aux autres dates connues, les hésitations de Charleston et de Warren quant à la probabilité de verres de propagande diffusés en Angleterre avant l'accession au trône de Guillaume ne se justifient plus (Charleston 1956, 7; Warren 1973, 105–6, fig. 7). Les exemplaires faisant uniquement référence à la Hollande pourraient, eux, remonter à 1672.

Un couvercle isolé qui, bien que ne présentant pas le décor de côtes pincées en relief, correspond au même modèle, est signé et daté 'Crama f. 1688 21/5' (Ritsema van Eck 1995, no. 109).

FIG. 2 Bocal gravé à la roue; Bruxelles, Musées Royaux d'Art et d'Histoire, Inv. 200; photo IRPA-KIK. 1

Un calice, monté sur deux bulbes lobés mais dépourvu du décor de côtes pincées en relief, est gravé des armes du roi d'Espagne et de la ville d'Anvers ainsi que d'une figure équestre jadis interprétée comme une illustration de la Joyeuse Entrée de Christine de Suède à Anvers en 1654 (FIG. 1). Cette datation très précoce et peu fondée est remise en question par une ancienne analyse chimique effectuée à l'Institut Royal du Patrimoine Artistique, qui révélait un pourcentage minime de plomb (Philippe 1970, 695–6, figs 53, 56–7; 1982 no. 121).

Un second calice également dépourvu de côtes, porte d'une part les armoiries d'une famille de la région de Tournai en Hainaut et d'autre part celles d'une famille zélandaise (Sheppard and Smith 1990, no. 10).

Il existe également des modèles à coupe cylindrique dont la base est ornée du *nipt diamond waies*. Ils sont pour la plupart gravés des armes de Guillaume III d'Orange-Nassau et par conséquent postérieurs à 1672 ou 1689 (Anon. 1960, 143, no. 26; Vreeken 1998, no. 165; Sheppard and Smith 1990, no. 14).

Enfin, différant légèrement par la conception de la jambe, un bocal conservé au château de Frederiksborg commémore la restauration de la forteresse de Kronborg d'après une médaille de 1691. Un exemplaire de forme identique est conservé au château de Rosenborg (Villumsen Krog 1995, 42, fig. 7, 141–2, fig. 3, 270, no. 9).

Depuis la communication de Charleston, une trentaine de pièces correspondant à la même techno-morphologie et portant pour la plupart de forts beaux décors gravés, mais non signifiants pour leur attribution, ont été répertoriées.

Le bocal des Musées Royaux d'Art et d'Histoire se distingue par ses deux bulbes unis (FIG. 2). Ce verre, acheté complètement brisé en 1844, a fait l'objet d'une restauration

FIG. 3 Calice à ailes, gravé à la roue; Liège, Musée du Verre, Inv. B 2147; photo IRPA-KIK 2

par Chantal Fontaine à l'Institut Royal du Patrimoine Artistique en 2001. A cette occasion trois prélèvements analysés ont donné: 0.5, 0.6 et 0.7 % de plomb (Lefrancq *et al.* 2004).

Un calice du Musée de Liège, également traité par Ch. Fontaine, présente la particularité d'avoir une coupe bilobée, également décorée de côtes en X, et les deux bulbes quadrilobés joints par de lourdes anses en e ornées de palettes gaufrées (FIG. 3). Il est à souligner qu'il a été gravé par le même artiste que l'exemplaire des MRAH.

A l'exception des bocaux de Frederiksborg et de Rosenborg, dont on sait cependant qu'il ont été vendus par un marchand 'hollandais' avant d'être gravés au Danemark, il est bien évident maintenant que ces modèles ont été particulièrement diffusés dans les Provinces-Unies, les Pays-Bas méridionaux et la région rhénane, c'est-à-dire exactement l'aire commerciale des Bonhomme. Toutes les dates convergent par ailleurs vers le dernier quart et peut-être même plus précisément vers les 20 dernières années du XVIIème siècle: la fin de l'apogée des Bonhomme. A cette époque où le verre à la façon de Venise tombait en désuétude, ceux-ci ont sans doute cherché à renouveler l'éventail de leur production en introduisant la 'façon d'Angleterre'.

Un renouveau qui s'inscrit dans la technologie: leurs fours sont désormais chauffés au charbon; et peut-être tentent-ils aussi d'utiliser dans leur mélange le silex si abondant aux environs de Maastricht. Mais s'agit-il là d'emprunts aveugles à l'Angleterre par le biais d'un Pompéïo ou de recherches liées à l'air du temps? Le *crizzling*, témoignage tactile des problèmes liés à la mise au point d'un métal satisfaisant, affectera bientôt aussi les produits saxons et brandebourgeois (FIG. 4).

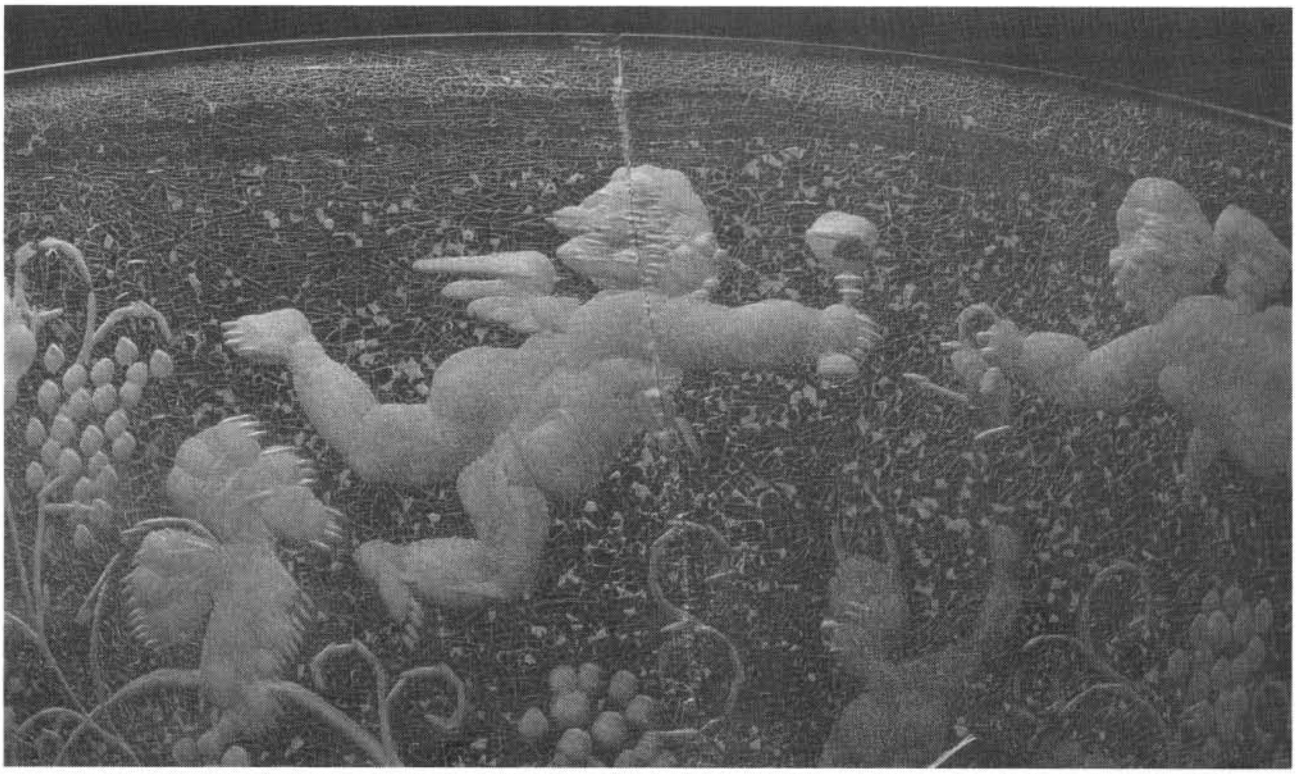

FIG. 4 Détail du bocal montrant le *crizzling;* Bruxelles, Musées Royaux d'Art et d'Histoire, Inv. 200; photo IRPA-KIK.5

Chronologiquement, les bocaux étudiés correspondent bien à la commande du contrat signé en 1680 avec Massaro; mais, si tous leurs détails de façonnage semblent bien empruntés à des modèles anglais, leur forme même est une adaptation au goût présent d'un modèle traditionnel dans la production des Bonhomme: le calice à deux bulbes.

Modèle répertorié dans un livre de comptes de la manufacture bruxelloise des Bonhomme couvrant les années 1667 à 1673 (Engen 1989, 160), la '*coupe à deux boutons à graver*', est aujourd'hui parfaitement reconnue dans une forme extrêmement gracile de calice en verre fin dont d'assez nombreux exemplaires sont conservés. Trois d'entre eux, l'un portant une inscription commémorative de la fête de Noël 1669 à Bruxelles (Chambon 1955, pl. xxii, no. 70; Engen 1989, 155), deux autres un portrait du roi d'Espagne Charles II enfant (né en 1661, règne de 1665 à 1700) dont l'un porte le chronogramme de 1666 (Pinot de Villechenon 1999, 90; Engen 1989, 160–1), attestent bien de leur fabrication à Bruxelles dans cet espace chronologique. Ces coupes à deux boutons, particulièrement destinées à la gravure, ont dû poser, par leur fragilité, un problème de résistance des matériaux aux premiers graveurs à la roue, arrivés aux Pays-Bas dans les années 1655–60. C'est probablement dans une optique de consolidation que la génération suivante a expérimenté de nouvelles recettes qui ont, paradoxalement, fragilisé davantage le produit. Parallèlement, les proportions du calice évoluent: les parois s'épaississent, la jambe raccourcie par la suppression des tiges intermédiaires gagne en robustesse, tandis que la coupe largement développée offre un espace plus ample à la gravure (FIG. 5).

Ce changement de qualité du mélange semble particulièrement lié à la gravure puisque certains modèles non gravés, soumis à la même évolution morphologique, continuent à être soufflés dans le verre fin; l'influence anglaise s'y marque seulement dans l'amollissement des formes et du décor plastique. Un bocal du Musée de Liège, entièrement couvert de côtes pincées à la manière de Ravenscroft (FIG. 6), a cependant révélé une teneur infime de plomb dans une analyse effectuée à l'IRPA (Chambon 1955, pl. xxvii, no. 84).

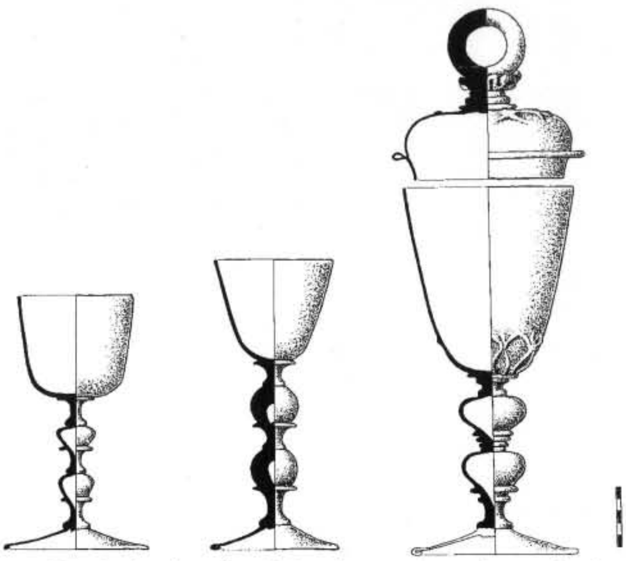

FIG. 5 Evolution du calice 'à deux boutons': gauche, production de Bruxelles, *c.* 1665–75; centre, production du Hainaut (?), dernier quart du XVIIème s.; droit, production de Maastricht (?), fin du XVIIème s.; dessin J. Lefrancq.

FIG. 6 Calice à décor plastique; Liège, Musée du Verre

Cette série de calices et de bocaux fabriqués dans le dernier quart du XVIIème siècle correspond-elle réellement au contrat passé entre les Bonhomme et Massaro en 1680? Rien ne permet de l'affirmer si on en reprend tous les termes, d'autant plus que certains vocables sont aujourd'hui tombés dans l'oubli:

• 'verres à l'Angleterre': l'influence anglaise y est indéniable.

• 'qu'ils aient des ances ou des amprons': certains exemplaires portent bien des anses mais ils sont rares; si 'amprons' exprime sous une forme germanique (ansporn) les éperons façonnés à la pince qui ornent ces dernières, ils existent aussi.

• 'pourvu qu'ils n'aient point de gorlettes auquel cas il seraient comptés 55 le mud': qu'en est-il de ces 'gorlettes' sensées accroître la valeur des verres? En dialecte liégeois, 'gorlète' désigne entre autres les fanons ou nervures de l'encolure des bovidés; peut-être définit-il de façon imagée les côtes en relief de la base des coupes? On s'étonnera par contre que le contrat ne fasse aucune allusion aux deux bulbes, au couvercle ou à l'anneau qui constituent pour nous l'essentiel du modèle.

A la fin du XVIIème siècle, après les dissensions intervenues au sein même de la famille et une concurrence de plus en plus agressive se manifestant à Bruxelles et à Liège, les Bonhomme tendent à se replier sur leur usine de Maastricht où séjournent, nous l'avons vu, plusieurs transfuges londoniens. Il y a tout lieu de croire que c'est à Maastricht qu'ont été produits ces bocaux particulièrement prisés dans les Provinces-Unies. Une nature morte peinte par Hendrick de Fromantiou, artiste né à Maastricht en 1633–1634 et mort à Berlin en 1694 ou 1700, présente d'ailleurs un verre apparenté (Bonnefantenmuseum Maastricht; comm. P. Te Poel).

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EVOLUTION AND POPULARISATION OF THE CATALAN *FAÇON DE VENISE* IN THE EIGHTEENTH CENTURY

IGNASI DOMENECH

In Catalonia, during the 18th century, there was a growing trend towards the production of locally produced glassware with markedly different forms from those produced on the rest of the Iberian peninsula and the rest of the continent. This trend popularized the forms of Catalan glass produced during the previous two centuries.

In the 16th century and the first half of the 17th century, Catalan glassworks produced glassware influenced by the Venetians. They were regular in proportion, made from crystalline material and featured extremely refined decorative elements. In spite of these influences, in practice the local substrate and the technical abilities of local craftsmen usually gave rise to glassware with a distinctive personality, as occurred elsewhere in Europe (Doménech 1999, 489–504).

The process of change in the taste for crystalline materials and Renaissance-style forms which emulated the Venetian models began to be seen in glassware produced in the second half of the 17th century, when Catalan glassworks began to disregard the demand for transparent, thin-sided vessels and sophistication in the development of the balusters. This trend was consolidated over the following decades, as new forms were being developed and established, which still had elements in common with previous forms.

The reasons for this change in aesthetics can be found in the far-reaching changes that took place in Catalan society from this period onward.

International tension between the supporters of the Hapsburgs and the Bourbons over the succession to the Spanish throne ended with the establishment of the Bourbon dynasty in 1701, when Philip V, Louis XIV's grandson, came to the throne. This led to the importation of new political and artistic criteria that were French in origin. On a political level, the setting up of a centralized state had among its strategies the creation of a royal court, which took the high nobility away from the lands where they wielded power and brought them to the Madrid court (Kamen 1974, 421). This meant that part of the Catalan nobility emigrated to the capital and the manufacturers of sumptuous objects in Catalonia lost many of their regular customers (Mercadé 1976, 42). Although it is true that during the previous two centuries Catalan glassmakers exported some of their wares to the rest of the country or different places in Europe, most of their glassware was sold to the Catalan nobility (García-Baquero 1974, 268–93).

Furthermore, the setting up of the Royal Glassworks of La Granja and the different and deep-seated crises it experienced led to the promulgation of protectionist laws in the middle of the century, which prevented the sale of glassware produced in other regions near the court and in a wide area of Castile. The impossibility of continuing to export glassware to Castile led Catalan craftsmen to devote themselves to producing glassware for the home market.

From 1714, when the War of Succession ended in Catalonia, the country experienced an important economic upturn, partly due to the major benefits of exporting wine, brandy and textiles to the American colonies. The new Bourbon dynasty allowed this trade to continue, but did not abolish the law that had existed since the 16th century preventing Catalan ports from trading with America. The trade brought a major increase in wealth among small craftsmen, important farmers and traders.

It was at this time that a new natural market for the production of Catalan glassworks became established: those people who had not been able to afford the glass objects purchased by the nobility now became new clients and demanded types of objects which were more baroque and had less to do with international taste, having clear local origins.

The three key objects of this phenomenon are the *porró*, the *càntir* and the *almorratxa*, which, although not the only forms of Catalan glass of the period, are the perfect embodiment of the new spirit of Catalan glassmaking, lasting well into the 19th century.

The glass *càntir* (COLOUR PLATES 76, 77) takes its shape from a type of Catalan pottery that had been in production since the end of the Middle Ages. Ceramic *càntirs* were used to keep water cool and facilitate its transport. The ones made from glass obviously did not have this cooling function and became decorative objects; or, following a tradition which seems to have begun in the 18th century and remained alive in some towns in Catalonia until the mid 20th century, were given as christening presents. This is why the *càntir* can be masculine or feminine, according to whether the form of the lip of the spout used to fill the vessel with water is circular or almond-shaped. Although the ceramic *càntirs* were objects that had been very common since the 14th century, the first example made of glass that has been preserved dates from the 16th century and is conserved in the Santa Maria Monastery in Pedralbes, Barcelona. It was not, however, until the end of the 17th century and throughout the 18th century that it became a characteristic form of local production.

The *porró* (COLOUR PLATE 78) is, without doubt, one of the most characteristic shapes in 18th-century Catalan glass. It seems that we are dealing with the evolution of the cruet, and in some cases the line that distinguished them is often blurred. It is an object with an elongated neck that is grasped. The vessel is tilted so that a stream of wine goes directly into the drinker's mouth. Its origin appears to be linked to the tradition of drinking out of glass horns, an object used for this purpose until the end of the 15th century. The *porró* is thus a bottle attached to a horn, or else a horn attached to a bottle. The oldest surviving examples of the *porró* are from the end of the 17th century, although its presence in literature points to its origins further back in time at the end of the 14th century (Amades 2003, 22). In this case, there is obviously no equivalent ceramic version, as the glass made it possible to see the impurities floating in the wine. Just like the *càntir*, the *porró* became more complex with the transformation of the lip into the characteristic form of the three-cornered hat, a typical piece of Spanish attire at the time, as well as the addition of different pinched glass decorations.

The *almorratxa* (COLOUR PLATE 79) is a shape that was documented as long ago as the 14th century, although the oldest surviving examples dates from the 17th century, such as those in the Amattler Collection in Barcelona (Gudiol 1936, pl. 69) and the Mateu Collection from Peralada Castle, Girona (*ibid.*, pl. 68). The Kunstgewerbemuseum in Berlin also has another interesting example from this period (Dreier 1989, 74, no. 52). It was a perfume bottle used to sprinkle rose water in the home. In the 18th century its outline and decorative elements became more complex. The etymological original of its name derives from the Arab word *marassa*, which with the addition of the article becomes *al-marasa*, a word that denotes the same type of object as the *almorratxa*, a container and rose water sprinkler. There are two types of *almorratxa*: the hand-held type, without a base, and the free-standing version. Both have a spout that is used to fill the vessel with rose water and different spouts used to sprinkle it. In the 18th century, this vessel was put to new ceremonial uses, when it was used in religious processions to sprinkle holy water, or in popular festivals as a key element in the dance of the *almorratxa* (Amades 1982, 583). Nowadays, the dance of the *almorratxa* is the central event of many annual festivals held in different Catalan towns and villages, in ceremonies that recall archaic ritual and ceremonies aimed at bringing rain. On these occasions, the *almorratxa* is 'dressed up', and decorated with silk bows or satin ribbons and flowers.

Catalan glassmakers tried to keep many of the changing techniques of *façon de Venise* alive by producing these three forms, as well as many other types of wares, such as vinegar bottles, salt cellars, bottles, jars and many more shapes (COLOUR PLATES 80, 81).

We can therefore see that most previous formative or decorative techniques remained active, in spite of the Renaissance-style forms influenced by Muranese glass. Among these techniques we can find frosted glass, as we can see in the *càntir* from the collection of the Cau Ferrat Museum in Sitges (Carreras and Doménech 2003, 107) (COLOUR PLATE 76). Without a doubt, one of the most widely used decorative techniques throughout the 18th century was the application of *latticino* threads. We must remember that Catalan makers of *façon de Venise* did not apply these threads with the skill of the Muranese glassmakers who created impressive filigree effects. The application of white threads in Catalan glassmaking in the 18th century was done in the same way it had been in previous centuries – by applying them towards the end of the manufacturing process in a spiral or by combing them into different shapes, although with less regularity in the designs. This technique was used to decorate the surfaces of bottles, *càntirs*, *almorratxas* and vinegar bottles among other objects.

Another surviving technique with important links with *façon de Venise* was the application of blue-glass decorations, in contrast with the surfaces of clear glass and occasionally contrasting with the white of the *latticino*.

Much more widespread was the technique of applying glass that was pinched or moulded into different zoomorphic, floral or abstract shapes. These applications added to the irregularity of the forms, which were often far removed from the Muranese aesthetic canons. Nevertheless, variations in types and the intended uses of the glass were much greater, and glass was introduced into different areas of social life, such as the religious, the folkloric and the domestic.

This change of orientation in the production of glassware in Catalonia was understood by the first historians of Catalan glass as a crisis – as the end of a period of splendour and the beginning of the decline of hand-crafted glass, which lasted until the initiation of the application of industrial production methods to Catalan kilns from the middle of the 19th century. This idea was expressed for the first time by J. Gudiol and P.M. de Artiñano, and taken up once again by Alice Wilson Frotingham some years later (Frotingham 1963, 49). Both talk about a recession (Gudiol and Artiñano 1935, 59; Frotingham 1963, 50), when today we know, thanks to the study of municipal archives from various Catalan towns, that the number of active furnaces during the 18th century was greater than in the 16th century, the highpoint of Catalan glassmaking in terms of Venetian splendour. On the other hand, Catalan glassmaking spread geographically in the 1700s, and various furnaces have been documented to the south and the east of the region, areas in which production had been almost non-existent during the two previous centuries, while production was maintained at most of the original glassmaking centres.

Recession and crisis are thus not the two words that best define the panorama of Catalan glassmaking in the 18th century. Instead, we are dealing with a transformation and a popular adaptation of the new naïve baroque style – far from the sophistication of the previous influence of mannerism – and the invention of new uses, at a time when glass became available to the lower classes in Catalonia. Although it is certain that during the 18th century there was less interest in decolourising, leading to glass with syrupy or smoky tones, steady demand for thin-sided objects was maintained. This, however, was not always possible because, among other reasons, some types of objects were larger than previous ones, and their new functions required them to be more resistant.

Nowadays it is difficult to be precise about the chronology of Catalan glassmaking in the 18th century. The poverty of Catalan painting at that time, dedicated above all to religious art, does not offer us examples of still lives featuring glass. Meanwhile, the lack of precision in the inventories, as well as in the literature of the time does not help us to limit the chronological framework.

In conclusion we can say that 18th-century Catalan glassmakers kept alive the spirit of the Muranese influence which had given meaning to the glassware of previous centuries, while they also created a universe of decorative shapes and details catering to a new and broader clientele. This occurred when the aristocratic aesthetic of English and Bohemian glass had reached its zenith – an aesthetic characterized by transparency, lack of colour in the glass compounds and cutting and engraving techniques, and less concerned with hot-working techniques which produced more sinuous, irregular forms. At the same time the craftsmen in Venice endeavoured to retain the elements that had brought prestige to their glassworks over the previous two centuries, covering their objects with complex adornments and using colour. Catalonia underwent a similar process from a formal point of view, and retained its taste for the production of more complicated pieces at the mouth of the furnace, creating forms that catered to purely local tastes. Imaginative designs and the consolidation of local styles make these objects truly original on the European glass scene.

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THE DATING AND TYPOLOGY OF BRITISH AND IRISH CUT GLASS DECORATION, 1700–1840

ANDREW RUDEBECK

Cut glass is a major phenomenon in glass history and Britain and Ireland played a large part in its development. However, it is a relatively neglected area now and nowhere is the literature on cut glass both comprehensive and accurate. With the help of some simple research I hope to show how cut glass can be better dated.

In 2002 I picked my way through the illustrations in Christie's silver sales catalogues. A small percentage of silver lots is in fact cut glass framed in silver. I found 290 pieces, categorized them by their type of cutting and borrowed the dates from the silver hallmarks. I have added another 60 dated pieces from the literature and my own cuttings. In TABLE 1 you see the quantity and distribution of the data with the types of cutting and the frequency of their appearance in each decade from 1700 to 1840.

My method was to attribute a piece of glass with one type only, usually the main one or the one in the centre of the decoration, even though most cut-glass pieces have more than one type of cutting. As a consequence I overlooked the detail of rims, necks of bottles and bases. The list of types of cutting was distilled from the decoration on cut glass in my collection. Allowing more than one type per glass would fill gaps in the data sheet. There were a few lots that did not fit the types I was using and another group where the type of cutting could not be identified from the catalogue illustration. A frustrating group was Warwick cruets (Holland 1985, 139) where photos regularly showed the silver cruets obscuring the glass cruets.

An obvious criticism is that glass and frame can be swapped. My answer is that there is safety in numbers. Swapping has occurred, but the ones that might spoil the story stand out as outliers on TABLE 1 and are shown in italics.

The range of cut glass I encountered was very different from the stem-ware that illustrates many books of this period. Cruet sets were the most numerous but there were also epergnes or centre pieces, inkwells, spirit sets, butter dishes, decanters and claret jugs. So silversmiths only enhanced a limited number of shapes.

This research is based on pictures, but it has to be admitted that pictorial research has its limitations when it comes to the question: when did British cut glass start? Jill Turnbull (2002) has published some London invoices dated 1682 to a Scottish buyer of 'scollupt' dishes. Scalloped rims are shaped by cutting. This is the earliest reference that I know of. It is not long after John Robert's patent of 1678 for the polishing and diamonding (bevelling) of mirrors and 1682 is the date of Hawley Bishopp taking over the Savoy glasshouse. But I do not know what these dishes looked like.

To answer that question we need pictures. Due to limitations of space in this volume, I have replaced the illustrations of my lecture with simple drawings of the types (FIG. 1) and added references to illustrations in the literature.

1 *Flat flutes* (Charleston 1984, pl. 48B) are much the same as the bevel on the edge of a mirror. Indeed the polish on some early cut glass is equal to the polish on a mirror. This type is known from 1705 and it continued up to 1840. The statistics show two peaks, so some care in dating is required when confronted by a glass with this decoration and no accompanying silver frame. The 19th-century revival of the type is paralleled by revivalism in 19th-century silver patterns.

2 *Hollow diamonds* (Charleston 1984, pl. 50E) are cut on the rim of a small wheel and are slightly dished. This is in contrast to flat diamonds (no. 31 below) which are cut on the flat of a big wheel. They are usually dated as *c.* 1760. This date coincides with the peak of the distribution on the sheet. It may surprise wine glass experts that the date range of this type appears to be from the 1720s to the 1790s, especially as it concerns cruet bottles.

3 *Split hollow diamonds* (Charleston 1984, pl. 48E).

4 *Large raised diamonds* (Harding 1930, 95). The Victoria and Albert has a large jug with these big raised diamonds. It was acquired from the Harding collection, but because W. Harding's book is unreliable in a large part, they cautiously, but in my opinion wrongly, describe it as 1920s.

5 *Large cross cut diamond* (Harding 1930, 67 top).

6 *Diamonds, with eyes* (Charleston 1984, pl. 49C). In view of the terminology below eyes could also be described as split lentoid.

7 *Pillar diamond* (Buckley 1925, pl. xlii, 2nd from left). The pillar cut is a volute inside the diamond outline. Pillar cut outside the diamond also exists, but this is a type that I did not find in the silver catalogues. The types about which I would still like a dating method are listed below.

8 *Curved flutes* (Charleston 1984, pl. 44A). Flat flutes not only stay the course up to 1840, they also develop first by going round curves.

9 *Wavy flutes* (Mortimer 2000, pl. 33).

10 *Notched flute* (Harding 1930, 11, no. 122).

11 *Hoop and stave flute* (Hughes 1956, pl. 220). Like the construction of a wooden barrel, with horizontal lines across the flutes.

TABLE 1 THE DISTRIBUTION OF CUTTING TYPES PER DECADE 1700–1840; SOURCES: CHRISTIE'S SILVER CATALOGUES AND OTHER SOURCES COMBINED

	1700	1710	1720	1730	1740	1750	1760	1770	1780	1790	1800	1810	1820	1830	Total
1 Flat flute	3	2	10	4	4	4	3	1	-	-	1	1	2	5	40
2 Hollow diamond	-	-	1	1	2	2	7	3	2	1	-	-	-	-	19
3 Split hollow diamond	-	-	-	1	-	1	-	-	-	-	-	-	-	-	2
4 Large raised diamond	-	-	-	1	2	2	-	1	-	-	-	-	-	-	6
5 Cross-cut diamond	-	-	-	-	-	4	-	-	-	-	-	-	-	-	4
6 Diamond with eye	-	-	-	-	3	1	1	3	1	1	-	-	-	-	10
7 Pillar diamond	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
8 Curved flute	-	-	-	-	1	2	1	1	2	4	-	-	-	-	11
9 Wavy flutes	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2
10 Notched flute	-	-	*1*	-	-	-	-	3	3	-	1	1	-	-	9
11 Hoop &stave	-	-	-	-	-	-	-	-	3	1	-	-	-	-	4
12 Ladder	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
13 Petal flutes	-	-	-	-	-	-	-	-	2	3	1	-	-	-	6
14 Gadroon flute	-	-	-	-	-	-	-	-	1	2	3	-	-	-	6
15 Flute and band	-	-	-	-	-	*1*	-	1	2	11	21	9	4	-	49
16 Hollow flutes	-	-	-	-	-	-	-	-	2	-	-	-	-	-	2
17 Hatching	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
18 Bricks	-	-	-	-	-	-	-	-	-	1	-	-	-	-	
19 Small raised diamond	-	-	-	-	-	-	-	-	-	3	20	30	9	-	62
20 Step cut	-	-	-	-	-	-	-	-	-	1	7	10	1	-	19
21 Uncut diamond	-	-	-	-	-	-	-	-	-	-	1	-	2	-	3
22 Strawberry diamond	-	-	-	-	-	-	-	-	-	-	-	3	2	2	7
23 Double/treble mitre	-	-	-	-	-	-	-	-	-	-	-	1	-	1	2
24 Small cross cut diamond	-	-	-	-	-	-	-	-	-	-	-	3	3	1	7
25 Large pillar	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
26 Small pillar	-	-	-	-	-	-	-	-	-	-	-	1	10	4	15
27 Lentoid & fingernail	-	-	-	-	-	-	-	-	-	-	-	-	2	8	10
28 Printies	-	-	-	-	-	-	-	-	-	-	*1*	-	1	1	3
29 leaf pattern	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3
30 Large flute	-	-	-	-	-	-	-	-	-	-	-	-	1	5	6
Oddballs	1	-	1	2	-	2	1	2	1	1	2	4	-	2	19
No design visible	-	-	-	-	5	2	8	1	3	2	1	-	-	-	22
Total	4	2	13	9	17	21	21	18	24	31	59	63	37	34	353

12 *Ladder* (Christie's 1998, 7, no. 38). Often seen on the necks of early cruet bottles.

13 *Petal flutes* (Mallett 1992, 49 bottom).

14 *Cut gadroon* (Charleston 1984, pl. 52B). My illustration at the lecture was a jug with a metal handle and this type of decoration. It had been sold by a descendant of the Vawdrey family who had worked at the Perrin and Geddes glasshouse in Warrington.

15 *Flute and band* (Buckley 1925, pl. xlii, 3rd from left). Usually the band is of raised diamonds, but hollow flutes also occur. This type of cutting is well suited for glass to be put in silver cruet frames. The flat flute takes less damage from a silver frame than a raised diamond, so the raised band is above the silver frame. I naturally found several of this type in silver catalogues.

16 *Hollow flutes* (Warren 1981, col. pl. D). This type is most usually seen round the base of decanters but it was also used to decorate pieces all over.

17 *Hatched and cross-hatched* (Westropp 1978, 226). I have placed this type earlier than the single item in the silver catalogues justifies. This is because it was the main feature of decoration used by the Penrose Waterford glasshouse founded in 1783. Glass from this factory does not appear in the silver catalogues.

18 *Bricks* (Savage 1965, 49, top right). Towards the end of the 18th century a modified type of Split hollow diamond (No. 3) appears. It is often called bricks. About the same time there was a fashion for glass that was not cut all over.

19 *Small raised diamonds* (Truman1984, 26). This is the most frequently seen type and it is the type with greatest potential to sparkle.

20 *Step or prism cut* (Charleston 1984, pl. 53A). A single line of this type is sometimes called a mitre-cut.

21 *Uncut diamonds* (No illustration known). This type is akin to strawberry diamonds, the next type, but without the hatching.

22 *Strawberry diamonds* (Newby 2003, 20, no. 23). The hatched version of the uncut diamond appears much more often. It may just remind you of the little pips on the skin of a strawberry.

23 *Double or treble mitre cut* (McFarlan 1992, pl. 4). Though not a complete style in itself, double or treble mitre cuts enhance many patterns.

24 *Small cross cut diamonds* (Hadjamach 1991, pl. 52). This type is also called Hobnail.

25 *Large cut pillars* (Westropp 1978, pl. xix, lower right). The Irish drawings associated with Samuel Miller of

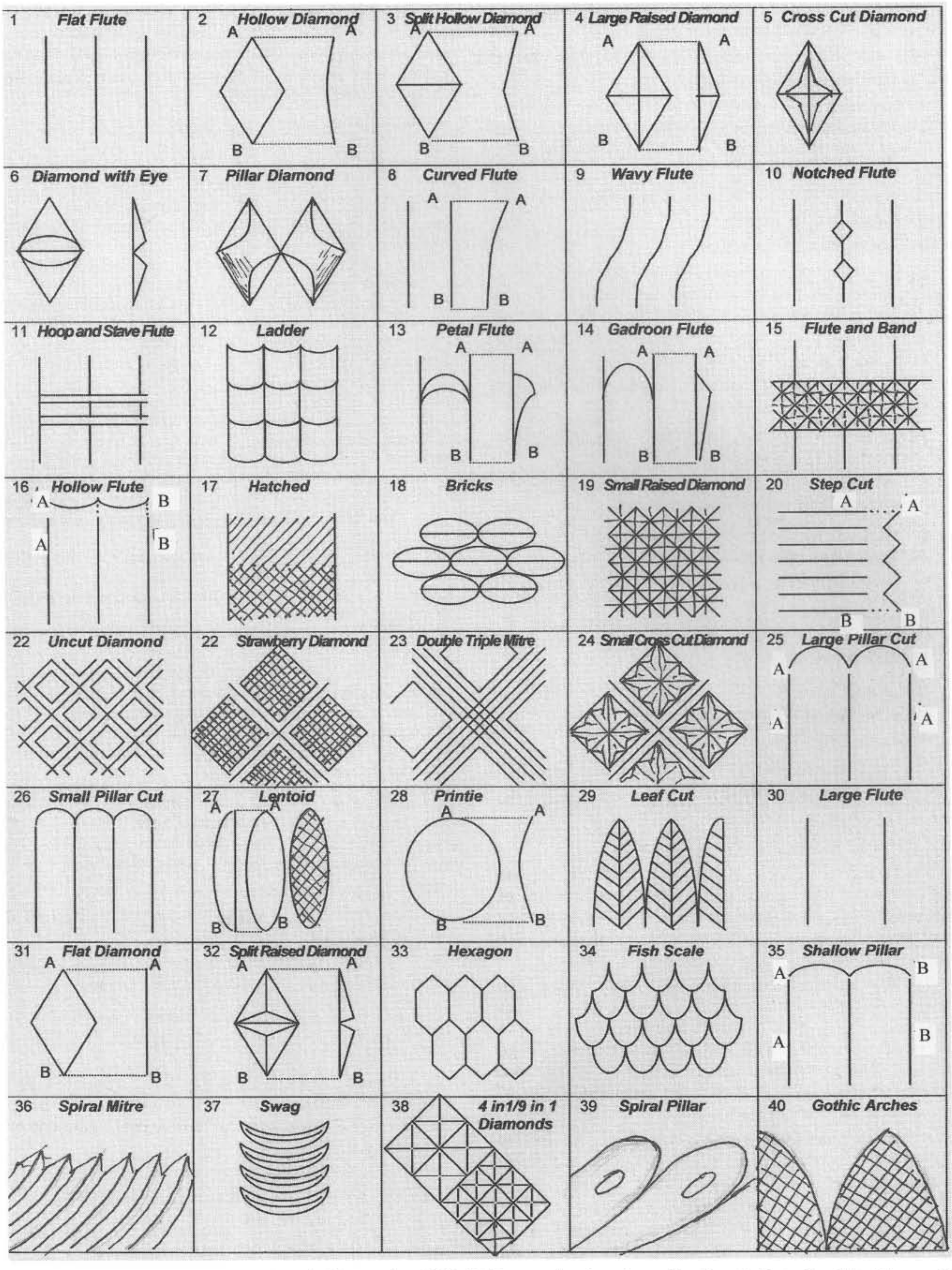

FIG. 1 The types of cutting on British and Irish cut glass 1700–1840; some drawings have side views indicated by dotted lines and initials AA and BB

Waterford and Fitzgibbon of Cork both include large pillar cut designs, but not the narrower pillar.

26 *Small pillar cut* (Newby 2003, 21, no. 26). Can be vertical pillars or horizontal bands.

27 *Lentoid* (Charleston 1984, pl. 52D left). The first piece of cut glass I bought had this decoration. This type can be decorated with either hatching or a modified form of pillar cut.

28 *Printies* (Westropp 1978, pl. xix, lower left). A traditional name for circles cut on glass.

29 *Leaf* (Mallett 1996, 54, top).

30 *Large flute* (Charleston 1984, pl. 52D, right). Some writers assert that this simple style superseded the earlier styles like pillar-cut. FIGURE 1 shows that in 1830–40 this type was making only a modest impression in a period of rich choice of new and revived types.

Other types. The other types of cutting that I did not find in the silver catalogues are:

31 *Flat diamonds*. These are seen on early chandeliers and a few pieces of table glass.

32 *Split raised diamond*. This is similar to the large cross cut diamond above but with only one cut.

33 *Hollow hexagon* (Hughes 1956, 294, top right).

34 *Fish scale* (Elville 1960, 94, no. 46).

35 *Shallow pillar cut* (Westropp 1978, pl. ii, bottom right).

36 *Spiral mitre* (Harding 1930, 7, no. 120).

37 *Swags* (Fitzwilliam 1978, 107, no. 227).

38 *4 in 1 or 9 in 1 diamonds* (Warren 1981, col. pl. B).

39 *Spiral pillar* (Westropp 1978, 232, top right).

40 *Gothic arches* (Warren 1981, 110, pl. 69).

So there are ten more types than the 30 that I found in the silver catalogues, making 40 in all.

In summary, not only does cut glass have at least 40 types, it also has no makers' marks, and a sometimes unreliable literature to confuse the viewer. I hope that this preliminary framework of dates for 30 types will make the subject easier to understand.

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ENGLISH AND IRISH CONTRIBUTIONS TO THE LA GRANJA ROYAL GLASS FACTORY

PALOMA PASTOR REY DE VIÑAS

INTRODUCTION

Like all Spanish royal manufacturing units, the Royal Glass Factory at La Granja was created in the middle of the 18th century under the protection of the Bourbon monarchy, primarily to accomplish two objectives. The first was protectionist in nature and focused on spurring national industry to compete with the foreign glass commerce that held sway throughout the peninsula. The second was technological, and designed to endow Spain with experts in all these industries, since the period comprising the end of the 17th and the beginning of the 18th century had been a time of serious technological recession, difficult to overcome without outside help. Thanks to negotiations by the Spanish State Secretariat and efficient espionage led by Spanish ambassadors in diverse European countries, many glassmaking experts acquainted with the most innovative recipes and techniques of the era were persuaded to come to Spain from Italy (Urbino), France (Paris and Nevers), Germany (Hamburg), Bohemia, Denmark, Norway and, of course, England and Ireland.

My topic deals precisely with these English and Irish technical and economic contributions to the La Granja Royal Glass Factory. They were mainly the work of three different men – the Irishmen Bernard Ward, who as a director introduced in the royal factories the reformist ideas contained in his best work *Economic Project* (Ward 1762; 1982), and John Dowling, inventor of a revolutionary new hydraulic machine for polishing flat glass, and the Englishman Joshua Kettilby, a maker of glass, who tried to perfect his compositions in order to produce the highly coveted English flint glass.

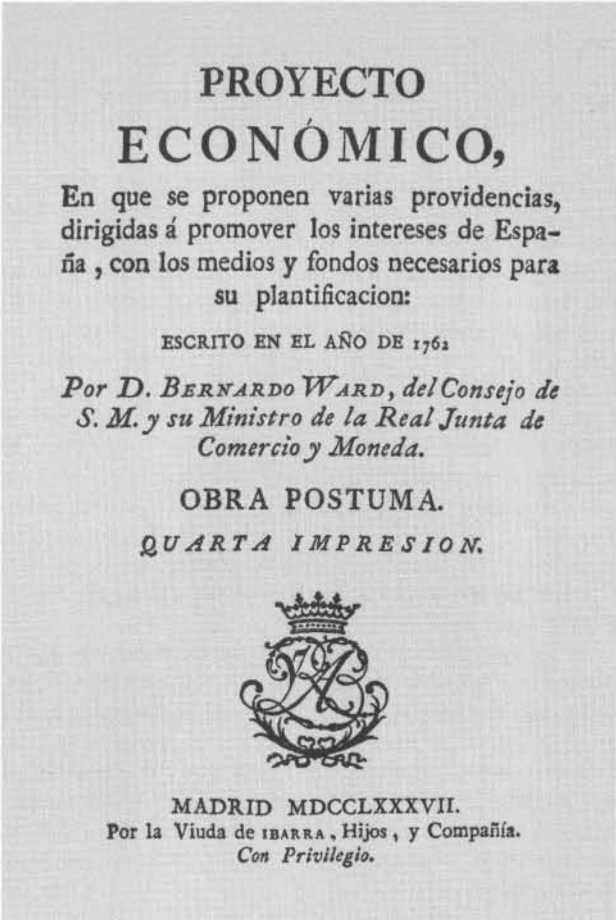
PROYECTO
ECONÓMICO,
En que se proponen varias providencias, dirigidas á promover los intereses de España, con los medios y fondos necesarios para su plantificacion:
ESCRITO EN EL AÑO DE 1762
Por D. BERNARDO WARD, del Consejo de S. M. y su Ministro de la Real Junta de Comercio y Moneda.
OBRA POSTUMA.
QUARTA IMPRESION.
MADRID MDCCLXXXVII.
Por la Viuda de IBARRA, Hijos, y Compañía.
Con Privilegio.

FIG. 1 Title page of Bernard Ward's *Economic Project*

BERNARD WARD

Bernard Ward, an Irishman, was undoubtedly one of the directors of the Royal Glass Factory most in tune with 18th-century enlightened reformist ideas. Ward received a commission from Ferdinand VI to visit several European countries to learn about and compare developments in agriculture, commerce and art. Upon returning to Spain in 1754, he was appointed a minister of the Board of Commerce and Currency and director of the Royal Glass Factory's main outlet in Madrid. As director, Ward's mission was very clear. He wanted to introduce a new production system in the factory, very much in line with the liberal ideas that he recorded shortly afterward in his most famous work *Economic Project*, printed in 1779 (FIG. 1).

Bernard Ward was a great realist who followed the purest tradition of English mercantilism in line with the ideas put forth by essayist José de Campillo. Ward tried to make the Royal Factory's production as profitable as possible during his tenure and to reduce the enormous volume of expenses as much as possible in order to increase income. Together with Agustín Sáenz de Zenzano, director of the Royal Glass Factory in La Granja de San Ildefonso, Ward planned to achieve these objectives in the following way:

First, to reduce expenses, he decided to gradually lower workers' salaries and eliminate any post that became vacant. Furthermore, he ordered the closure of the red lead factory in Villa del Prado due to its low profitability. He also decided to motivate employees by awarding bonuses or prizes for good work.

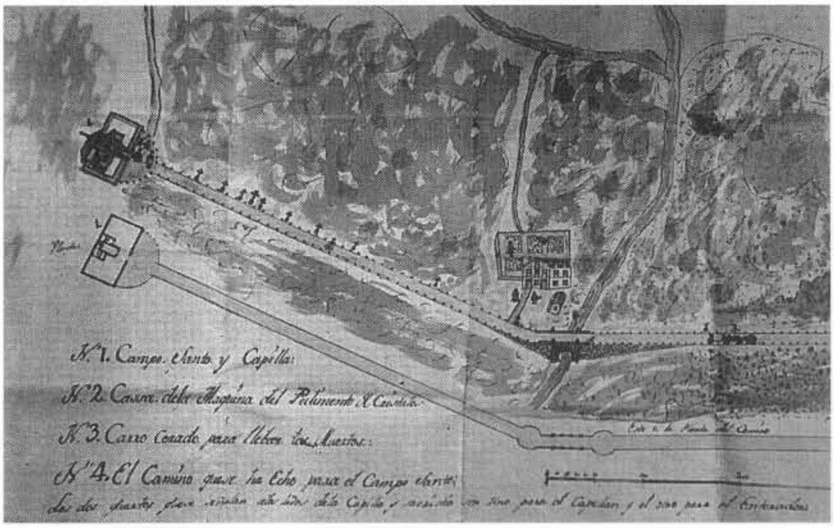

FIG. 2 A drawing by Alfonso Regalado Rodriguez, dated 1785, showing the exact location of Dowling's polishing machine; Royal Palace Archive

Next, to make production profitable, Ward sought to increase income by searching for new markets, both nationally (by offering credit facilities and discounts to wholesale customers) and internationally (by focusing on the American colonies). He also tried to adapt the offer to existing demand by lowering product list prices. As a market strategy, he ordered several price lists printed in order to distribute them among the *corregidores,* or mayors, of Spain's various regions so they could inform the public about the latest discounts and benefits. To reactivate consumption of these goods, in 1762 Ward obtained the exclusive right to sell in Madrid, San Ildefonso and within a radius of 20 leagues. The Court was also obliged to commission all glass, such as tablewares, windows, mirrors etc, for the royal residences and stables from the Royal Glass Factory.

All these measures promoted by Bernard Ward and backed by Zenzano soon produced encouraging results, since they resulted in a large increase in production and a parallel increase in sales volume. Nevertheless, the measures were not sufficient to achieve the objective of making production profitable. Actually, although the factory enjoyed an unprecedented economic boom, the effect did not continue, because income never covered the high running costs.

JOHN DOWLING

John Dowling, also an Irishman, was recommended by the director, Bernard Ward, and appointed by the Minister of the Treasury, the Marquis of Esquilache. Dowling, who was married to Margaret Fitzhenry, arrived in San Ildefonso in 1761, commissioned to build a new hydraulic machine for polishing flat glass for mirrors. The machine employed a double movement, both straight and circular, and could simultaneously activate up to 100 polishing devices on two levels. In the words of Bernard Ward, Dowling's brilliant work with the fulling mills and other devices of the royal cloth factories in Guadalajara and Brihuega augured his sure success in this new endeavour (Appendix, no. 1). A decision was made to build the new machine on the bank of the Cambrones stream on the slope of the Royal Site's cemetery after Dowling examined the location and verified that the stream carried enough water. The foreman, Antonio Niño, was in charge of building the house, the dam and the machine itself (Appendix, no. 2). A drawing by Alfonso Regalado Rodríguez, dated 1785, shows the exact location of the machine, next to the bridge crossing the stream (FIG. 2; Appendix, no. 3). Today, only the small building that housed this machine remains at La Granja (FIG. 3).

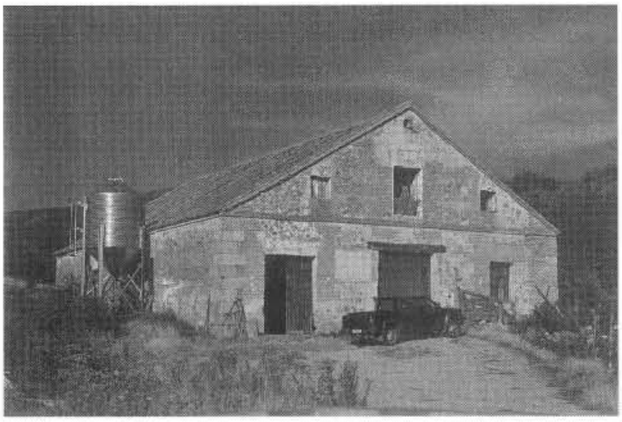

FIG. 3 The building in which Dowling's hydraulic machine was sited

Dowling's new machine saved time and salaries, since the work of each mechanical polisher was equivalent to the labour of two men, and it turned out to be so advantageous that in 1763 John Dowling was appointed hydraulic engineer for the kingdom's factories (Appendix, no. 4). This position obliged him to travel continuously in order to tune up the machinery and fulling mills in the royal factories. According to the documentation consulted, during this time he worked for the cloth factories in Guadalajara and Brihuega, the file and steel factory in the Royal Site of San Ildefonso, the Royal Site in El Pardo (which had a flour mill in 1764), the royal sword factories in Toledo, the new barracks in the Royal Site of El Escorial near Madrid (1763; Appendix, no. 5), the Alcaraz brass factory in Albacete (1778; Appendix, no. 6), the San Fernando paper factory, and the royal silk, silver and gold cloth

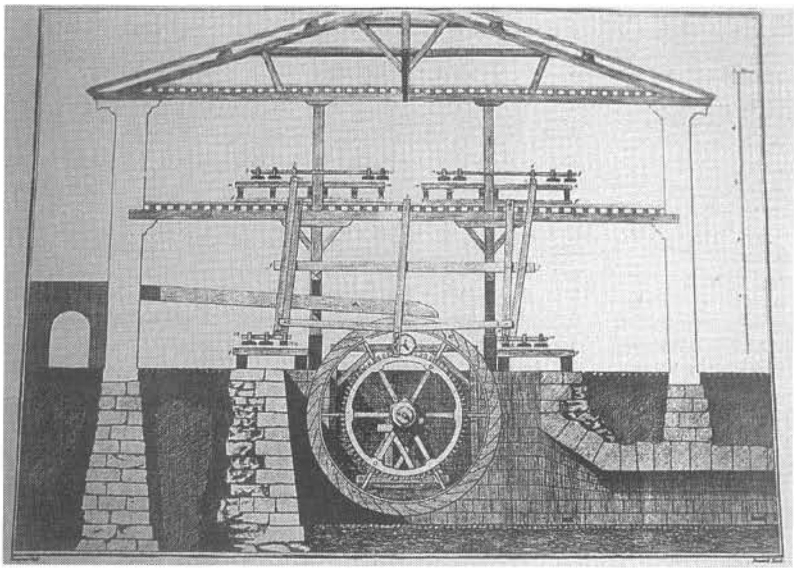

FIG. 4 John Dowling's hydraulic machine for polishing flat glass; from Diderot and D'Alembert's *Encyclopédie, ou dictionnaire raisonné des Sciences, des arts et des métiers*, vol. 4, xxxxiii–vi

factory in Talavera de la Reina. Although he continued to take care of the polishing machine at San Ildefonso, Dowling was free to leave the royal site occasionally to attend to all his other commitments. Very soon, he also became a confidant to the Minister of the Treasury, Miguel de Muzquiz, to such an extent that they corresponded and Dowling received orders directly from the Ministry, thus passing over royal factory management. A Royal Order of 14 November 1772 authorised him to fire at will any worker under his charge. Dowling also took part in the Royal Glass Factory's weekly meetings, in which diverse technical and administrative subjects related to manufacture were discussed and agreed upon. As was to be expected, all these concessions and liberties aroused the resentment of several Royal Glass Factory managers as they found themselves out of favour or displaced in their functions.

It is not unusual to find disparaging letters written by both sides in the archive. One example is a comparative statement of expenses made by the accountant Diego Navarro in 1764, which covered expenses produced by the polishing machine and by manual polishing. This study showed higher losses amounting to 15,844 reals for the machine, without counting materials (Appendix, no. 7). Dowling lost no time in returning the attack and he commented that

> the polishing machine ... is running perfectly ... I do not trust (these) accounts. And I shall prove to Your Excellency that glass breakage this winter was greater when polished by hand ... (Appendix, no. 8).

Other detractors were the hand polishers themselves. Since they felt their jobs were in danger, they intentionally broke mirrors made by the machine whenever possible to cause doubts about its working performance. However, in spite of the machine's numerous opponents, the end result was truly efficient. Proof of this is that the French encyclopaedists used it as a reference and showed its elevations and floors in great detail (FIG. 4).

Nevertheless, this type of machine was used only to polish or scrape small-size mirrors because larger mirrors were always worked by hand due to the risk of breakage. Another disadvantage of the machine was its inactivity during the long summer droughts, although an attempt was made to avoid this by building other machines powered by mules. The machines also consumed a much higher percentage of sand and other materials in comparison with those used by hand polishers or scrapers, and their efficiency was more dependent on a perfect adjustment of wheels and connecting elements.

To make Dowling more comfortable, Miguel de Muzquiz decided to move him from La Granja de San Ildefonso to Madrid so that he could reach the factories in Guadalajara, Toledo and Ávila more easily. Dowling left his nephew Demetrius Crow in charge of the San Ildefonso machines.

Joshua Kettilby

The third figure is the Englishman Joshua Kettilby. He was recommended by Spain's ambassador in Paris, the Count of Fernan Núñez, and arrived in San Ildefonso in July 1788, commissioned to imitate the flint glass much admired in Spain. The ambassador paid Kettilby 1000 *reals* in Paris to cover the expenses of his trip to San Ildefonso accompanied by his wife Martha and two boxes of raw material for trials. The Count of Fernan Núñez wrote the following to the Count of Floridablanca:

> I have been introduced to an Englishman named Joshua Kettilby, a maker of all types and colours of flint glass that they don't know how to produce even in France, of the quality so admired in England and with a diamond-like polish. He has shown me samples of everything and we have agreed that he should come, because he is one of those who can be useful to us in Spain. Since he was satisfied to have his trip paid and to receive a small amount of assistance to cover the first days in Madrid, I sent him on his way on the 11th of this month ... (Appendix, no. 9).

As soon as he arrived in La Granja de San Ildefonso, Kettilby secretly began trials and eight months later produced his first results. When the factory director Pedro de Lerena examined these samples, he commented that:

> the pieces appear to be good, although when you look at the flint glass sideways, you can see three layers or main zones of different colours in the glass that could make one

> fear that it does not have, a uniform density, which may cause different types of refraction; this is also observed in England's flint glass, which is why it is not used optically, only for regular instruments such as theatre glasses and occasionally for glasses for observing terrestrial objects, but never for astronomical lenses (Appendix, no. 10).

Pedro de Lerena also explained that the glass had turned out a bit lighter in weight than English glass, a problem that could be solved after new trials.

Kettilby's samples had to be perfected with these new trials, and to perform them it was finally decided to build a new furnace in the new flat glass factory isolated from the rest of the halls. Kettilby himself chose many workers for his factory from the *labrados* or blown glass factory, a move the factory foreman never forgave (Appendix, no. 11). Three years later, still in the midst of trials, Kettilby went mad. It is not known whether his illness was caused by the great stress he must have been under in his drive to produce the coveted flint glass, or whether his illness was simply part of a plan to be able to leave the country freely. In any case, Kettilby was expelled with his wife in 1793. Before, however, with the aid of John Dowling, the factory director attempted to wheedle the flint glass formulas from Kettilby's wife, but the secret was never disclosed (Appendix, no.12). The Kettilbys were given 14,000 *reals* to make the trip back to London (the equivalent to an entire year's salary).

If any doubt existed, a letter written by the Marquis del Campo on 15 August 1794 stated that Kettilby had been admitted into the Bedlam psychiatric hospital upon his arrival in London (Appendix, no. 13).

Thomas Hill

Finally, I would like to briefly mention one other Englishman who worked for the Royal Glass Factory. His name was Thomas Hill (married to María Llanos Denia) and he was a decorator. In 1817, Hill set up a workshop in the Royal Factory's main outlet in Madrid for painting on clear glass. He was supposed to teach two students the cold painting technique and simultaneously reveal the secret way he mixed the pigments. Although the documentation preserved in the Madrid Royal Palace Archives about Thomas Hill is very limited, we do know the two main reasons why this workshop lasted only a few years. The first and most important reason was that Thomas Hill never disclosed the secret of mixing the pigments, and the second was the meagre profit the workshop produced (Appendix, no. 14). Hill arranged for early retirement in 1819 (Appendix, no. 15).

Appendix – Documentary Sources

1 Royal Palace Archives (hereinafter R.P.A.) Glass Factory Section. File 1. Ward to the Marquis of Esquilache. San Ildefonso, 23 September 1761.

2 R.P.A., Glass Factory Section. File 1. Zenzano to the Marquis of Esquilache. San Ildefonso, 17 November 1762.

3 R.P.A., Plans, Nos 1067, 1068 and 1069.

4 R.P.A., Glass Factory Section. Box 31. The Marquis of Esquilache to John Dowling. San Ildefonso, 15 September 1763.

5 R.P.A., Glass Factory Section. File 2 bis. John Dowling, 13 August 1766.

6 R.P.A. Box 32. Madrid, 22 December 1778. Becerra to Muzquiz.

7 R.P.A. File 1 bis. Diego Navarro. San Ildefonso, 16 August 1764.

8 R.P.A. File 1. John Dowling to the Marquis of Esquilache. San Ildefonso, 23 March 1765.

9 R.P.A., Glass Factory Section. Box 63. July 1788.

10 R.P.A., Glass Factory Section. Box 744. Pedro de Lerena to Josef Pérez Quintana. Madrid, 26 March 1789.

11 R.P.A., Glass Factory Section. Box 744. Joshua Kettilby. 1789.

12 R.P.A., Glass Factory Section. Box 43. San Ildefonso. 2 September 1793.

13 R.P.A., Glass Factory Section. Box 45. Marquis del Campo to Diego de Gardoqui. London, 15 August 1794.

14 R.P.A., Glass Factory Section. Box 131. Index of Royal Orders.

15 R.P.A., Personnel, 512. 5 January 1819.

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THE STEPHENS BROTHERS AND THE ROYAL GLASSWORKS AT MARINHA GRANDE

JENIFER ROBERTS

Between 1769 and 1826, the royal glassworks at Marinha Grande in Portugal (70 miles north of Lisbon) were owned by two English brothers, William and John James Stephens (Roberts 2003). Born in poverty in England, the patronage of the Portuguese monarchy enabled them to become two of the richest industrialists in Europe.

Their factory at Marinha Grande covered an area of 44 acres and for almost 40 years fulfilled the demand for glass in Portugal and its colonies. The factory made window glass and crystalline glass of all types (including wine glasses and tumblers, decanters, salvers and vases, oil and vinegar dispensers, salt-cellars and inkwells, candlesticks and scent bottles), and provided employment for most of the village, the number of workers increasing from 220 in 1770 to 500 in 1826 (Roberts 2003, 56–9; Duarte 1937, 12–14).

William, the older brother (FIG. 1), was born in Cornwall in 1731 and apprenticed to a trading house in Lisbon at the age of 15. During the next few years, he became a successful merchant in the city, but his partner was killed and his home and business destroyed in the great Lisbon earthquake of 1755. The following year he built a lime factory to provide mortar for rebuilding the city and, when the reconstruction began in 1764, he proved to be a competent and efficient supplier.

At this time, Portugal relied on imports, unable to feed or clothe its people from its own resources. King José I (1714–1777) had little taste for public affairs and the country was run by his first minister, the Marquis of Pombal (1699–1782), who set up a number of new industries, granting loans to men of business who could compete with imported products. Several of the men chosen to run these industries were foreigners; there was so little commercial activity in Portugal, and the country was so heavily in thrall to the church, that it was difficult to find competent Portuguese with business experience.

In 1767, William was asked to reopen the royal glassworks in Marinha Grande, which had closed because of the bankruptcy of John Beare, its Irish director, and which Pombal planned to include in his programme of new industries. William refused the invitation several times, but in 1769 he was asked again, this time by order of the king. He was granted a private audience with José and, in his own words:

> The king was greatly pleased by my acceptance and promised his immediate royal protection, for the establishment and progress of the glassworks were very much in his royal interest (Marques 1999, 69).

The king honoured his promise. On 7 July 1769, he signed a decree ordering that William 'be given all the help and favour as is necessary', and listing 15 conditions under which the business would operate, a beneficial package which included an interest-free loan of about £700,000 in today's values, free use of firewood from the royal pine forest, and exemption from all sales taxes (Barros 1969, 37–48).

FIG. 1 William Stephens, engraving by A. Smith from a drawing by Bouck, 1799

The first instalment of the loan was paid on 20 July (Barros 1969, 205) and William left Lisbon the following day, arriving in Marinha Grande on 23 July (de Freitas 3 November 1895). Situated on the fringes of the royal pine forest of Leiria and close to the sea in an area of sandy soil, the village was an excellent location for a glasshouse. William employed the craftsmen who had remained in Marinha Grande and the factory re-entered production in October 1769 (Barros 1969, 50).

During the next three years, elegant stone buildings replaced the old wooden structures (Barros 1969, 251). Inside the gates and beyond the porter's lodge lay a large courtyard which William planted with trees to provide shade. The main workshops occupied two sides of the courtyard and, behind them, were several ancillary structures for carpentry, sawing and pot making, as well as engraving, cutting and painting the glass. There was a large warehouse and several covered areas where firewood was stored. On the third side of the courtyard, William built a small but well proportioned mansion house (FIG. 2). The rooms were partially tiled in *azulejo* tiles and the windows at the rear overlooked a garden with a lake, beyond which lay orchards and vegetable plots. (Roberts 2003, 57–8).

FIG. 2 The mansion house in Marinha Grande, built by William Stephens, *c.* 1772; reproduced by permission of Câmara Municipal da Marinha Grande

Output from the factory increased as the new workshops entered production, but sales were affected by competition from Bohemian glass and stocks began to pile up in the warehouse. Determined to put the glass importers out of business, William drafted a long and well argued petition to the king and travelled to Lisbon in June 1772 to present it personally to the government (Barros 1969, 167–76). His petition was considered by Pombal, who agreed to double the duties payable on imported glass (Barros 1969, 255–6). Marinha Grande was the only glassworks of any significance in the country, so William was given a monopoly of glass supply in Portugal and its colonies, a monopoly which (together with his exemption from taxes) would enable him to build up an enormous fortune (FIG. 3).

William and Pombal became friends in the summer of 1772, despite an age difference of more than 30 years. They shared advanced ideas about education and social welfare, and when Pombal travelled north in September 1772 to reform the University of Coimbra, he visited Marinha Grande and spent the night in William's mansion house (Vasconcellos e Sá, 436, 1720).

Pombal was the effective dictator of his country and, for the next five years, he ensured that William's operation at Marinha Grande ran as smoothly and as profitably as possible. He intervened in many of William's local difficulties – excessive bureaucracy in local government, intransigence of forest officials, and religious hostility (William, a Protestant, was often referred to as a heretic) – and promptly approved all William's ideas for improving conditions in the factory (Barros 1969, 250, 253; Marques 1999, 54–5, 69; Almeida 1980, 311).

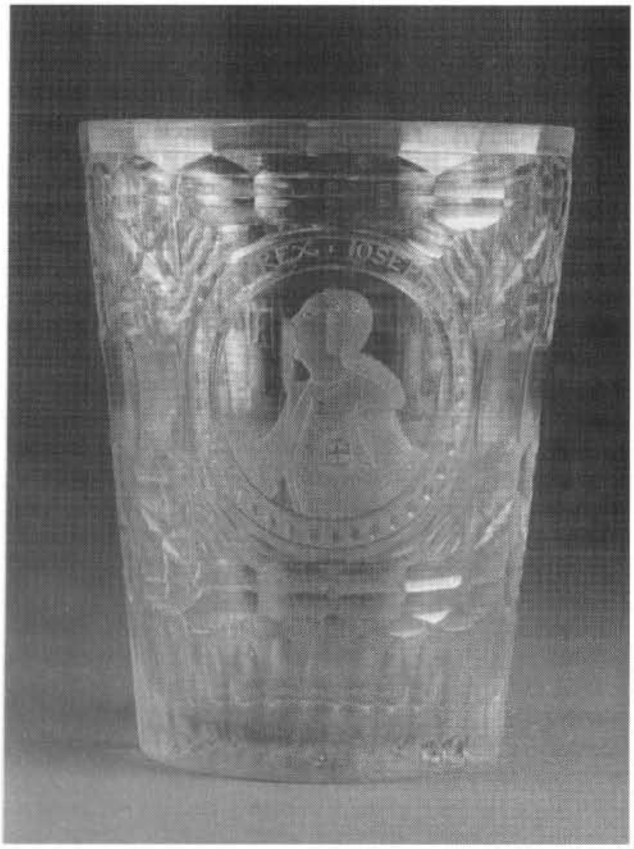

FIG. 3 Glass cut and engraved with a portrait of King José I, attributed to Marinha Grande, *c.* 1772. Reproduced by permission of Museu Nacional de Arte Antiga, Lisbon. Photographed by José Pessoa, Divisão de Documentação Fotográfica, Instituto Português de Museus

Despite his religion, William was much loved in the village. He saw himself as patron and protector of his workforce, and introduced a system of welfare 30 years ahead of similar developments in Britain. He paid good wages, opened an elementary school, provided a first aid post and a relief fund for illness, and set up a generous pension scheme. He closed the taverns and, to fill the spare time of his workers, he employed teachers of music and dance, and built a theatre where his workmen acted in plays translated from Shakespeare and Voltaire (Barros 1969, 24; Duarte 1937, 22–4)

His motives were not entirely altruistic, for he was aware that productivity increased with a happy and healthy workforce. With a monopoly of production, he could sell as much glass as his factory could produce – and at high prices too, for Pombal had approved a new price list at the same time as imposing higher import duties (Correira 1999, 41; transcription of price list in Barros 1969, 173–6).

During these years, most of William's success resulted from the patronage, not of the king, but of his first minister the Marquis of Pombal. But Pombal fell from power when José died in 1777 and the throne passed to his eldest daughter. The new queen, Maria I (1736–1816), harboured a deep distrust of Pombal and banished him to a small town 20 miles from Marinha Grande. She dismissed his collaborators from office and reduced payments to the new industries.

In this difficult situation, William had the courage to act with honour as well as self-interest. He maintained his friendship with Pombal (Stephens 1777–78, MS letters to Marquis of Pombal), but he also set out to charm the queen. Maria was extremely religious and it was difficult for William – as a Protestant as well as a friend of Pombal – to make a good impression. But he persevered, and such was his charm and charisma that he soon became her favourite industrialist. In December 1780 she endorsed the privileges agreed by her father and confirmed the high level of duties on imported glass. She even widened William's exemption from taxes, to include import tax on raw materials and export tax on finished glass. (Barros 1969, 261–3).

Maria visited the glassworks on two occasions. The first was in 1786, the year when William made the final repayment on his loan from the government. He told the poet, Robert Southey:

> I went through this affair with great *éclat*. It was an honour they have never done any of their own subjects. I was therefore without a precedent to go by. I requested nothing from the palace but their cooks and kitchen utensils (Southey 1960, 19–20).

The second visit was in June 1788 when Maria stayed in Marinha Grande for three days and was entertained with a play performed in the factory theatre (Withering 1822, I, 314–15; Marinha Grande, MS accounts book). But her mental health was unstable and, after the death of her eldest son a few months later, she began to lose her mind. Her second son, Prince João (1767–1826), became regent in 1799 and soon confirmed that William had earned the benefit of continued royal protection (Barros 1969, 285).

William's glass was not of the highest quality – with a monopoly of supply, there was little incentive to improve standards. The Count of Hofmannsegg, who visited Marinha Grande in 1798, commented on the high quality of the raw materials used and concluded that the factory failed to prepare them correctly. As a result, he explained, 'the glass has neither the durability nor the brilliance of imported glass and it breaks easily' (Hofmannsegg 1805, 256–7).

William was a good businessman and aware of the value of repeat sales. He is said to have told his manager to stop making tavern glasses that were thick and strong because they were too difficult to break (Barros 1969, 25).

He was also a man of intellectual curiosity and he experimented with the production of tempered glass. He gave samples of what he called his 'tough glass' to Dr William Withering, a member of the Lunar Society of Birmingham, who visited Marinha Grande in 1793. Withering brought them back to England and gave them to James Watt, a fellow member of the Lunar Society (a group of men from the Midlands who met monthly, near the time of the full moon, to discuss developments in science and technology – see Uglow 2002). Watt tested the samples and sent his findings to the president of the Royal Society, Sir Joseph Banks. 'Mr Stephens's glass', he wrote, 'bears the alternatives of heat and cold much better than any other I have had occasion to try' (Watt to Banks, 5 November 1797).

Unfortunately, Banks had an accident with the samples. 'I fear it was my inexperience in manipulation which broke Mr Stephens's glass', he wrote to Withering in December 1797 (Banks to Withering, 23 December 1797). A few months later, he asked for more samples, as 'I mean to put them into the hands of my chemical friends as soon as I get them' (Banks to Withering, 18 May 1798). Sadly, there is no further mention of glass from Marinha Grande in the Banks correspondence, probably because William's health was deteriorating and he was spending more of his time in Lisbon, leaving the factory in the hands of his manager, José de Sousa e Oliveira.

William died in 1803, leaving the factory – and his fortune – to his much younger brother, John James, a man who lacked William's charisma and intelligence. At the same time, the political climate was changing. England was at war with France and, although Portugal remained neutral, the French ambassador was inciting anti-British feelings amongst the Portuguese.

The factory was in good financial shape when William died (Barros 1969, 290–314), and John James should have acted quickly to protect its profitability. But he was too miserable at the loss of his beloved brother to think about procedure or to safeguard his royal patronage. At the same time, a number of government advisers were joining the French faction in Lisbon and the factory lost some of its privileges (Barros 1969, 315; Marques 1999, 86–7).

This was a time of increasing danger for Portugal. Napoleon tried to force Prince João to close his ports to British shipping and, when the prince refused, an invasion force crossed the border. The royal family fled to Brazil in November 1807, their ships leaving the harbour just one day before the French army occupied Lisbon. The glass factory was sequestrated by occupying forces on 7 December and, on 13 January, John James became a prisoner of war, spending four months incarcerated in the British Hospital in Lisbon which had been requisitioned to house English prisoners (Unattributed 1896, 11).

John James repossessed his factory after the country was liberated by British troops in September 1808 (Unattributed 1896, 11). Two years later, another French army crossed the border into central Portugal. By this time, the Duke of Wellington had built his famous lines of defence north of Lisbon – the lines of Torres Vedras – and now he ordered that all people and provisions between the lines and the border be cleared from the land. Workers in Marinha Grande closed the factory, destroyed their food supplies, and travelled to safety in the city. And during the next few months, enemy soldiers roamed the countryside in search of food, burning property and killing those who had remained in their homes.

The glassworkers stayed in Lisbon for seven months until starvation forced the French to retreat into Spain. In the spring of 1811, they returned to the factory and found it, in the words of the manager, 'in a state which would have saddened and discouraged the bravest of men'. The main workshop had been burned to the ground, 74 villagers killed by the French, and the area was suffering from starvation and disease (Balsamão 1815, 257–8; Aranha 1871, 154–6; Marques 1999, 87).

John James used his fortune to rebuild the glassworks to the exact design of William's buildings of the early 1770s. The factory re-entered production in October 1812 (Stephens to Sousa, October 1812) but it lost much of its royal protection. The government had become anti-British and the prince regent remained in Brazil. All matters relating to royal favour were referred for his personal attention and long sea voyages were involved in any exchange of correspondence.

Prince João inherited the throne on his mother's death in 1816, but he only returned to Portugal after the constitutional revolution of 1820. Meanwhile, duties on imported glass had been reduced. The glass factory had lost its monopoly and, after the declaration of peace in 1815, imports began to arrive in increasing quantities and at decreasing prices (costs of raw materials and transport had fallen with the ending of hostilities).

John James failed to understand the change in the market. He refused to lower his prices and he refused to cut back on production. As a result, his stocks increased and, as profits began to slide into loss, he made up the shortfall from his own deep pocket. By 1820 he was subsidising the entire running costs of the factory, estimated at almost half a million pounds a year in today's values (Marques 1999, 87–8, 90–1; Barros 1969, 321).

He died in November 1826, leaving the glassworks to the Portuguese nation. He wrote in his will:

> I firmly hope that prosperity, stability and permanency may afford this useful and beautiful fabric to the benefit of Marinha Grande in particular, and the advantage of this kingdom in general, and for ever (J.J. Stephens, will proved London, December 1826).

Meanwhile, Portugal was in political turmoil. King João had died a few months before John James, and his two sons, Pedro and Miguel, were manoeuvring for control of the country, a situation that would soon lead to civil war. State coffers were empty and, for several months, the government refused to accept such a loss-making enterprise. It was not until May 1827, when a consortium of businessmen offered to lease the glassworks on a rent-free basis, that the state finally accepted the bequest (Almeida 1860, 11–13; de Freitas, 1 December 1895).

William and John James had owned the factory for almost 60 years; the state would own it for more than one and a half centuries. It remained in production until 1992, when the older buildings were transferred to the town council of Marinha Grande (William's mansion house is now a glass museum) and the 20th-century workshop sold to a Danish industrialist who still operates the factory today. And William's legacy lives on, for Marinha Grande is the centre of glass production in Portugal, as well as moulds for the injection-moulding of plastics. It is also one of the wealthiest areas in the country.

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THE NINETEENTH AND TWENTIETH CENTURIES

'ON HEARING IT WAS IRISH [THEY] SAID IT COULD NOT BE GOOD': A WEEK IN THE LIFE OF A WATERFORD GLASS TRAVELLING SALESMAN, 25 AUGUST–1 SEPTEMBER 1832

Anna Moran

This paper takes as its focus the days between 25 August and 1 September 1832. It was during this week that two representatives from the Waterford glasshouse arrived in Southampton, England, with a cargo of glass, which they hoped to sell by auction. Taking a design historical approach, this paper seeks to investigate the methods by which the manager of the glasshouse and the travelling salesman set about organising and advertising their upcoming auction. Also explored are the reasons why, approximately seven days after their arrival, the representatives were forced to pack up their stock in failure, having sold little or no glass. A range of primary sources has been used to piece together the experiences of those involved in this unsuccessful venture. These include the surviving business correspondence (known as the Gatchell Letters) and the account ledgers associated with the Waterford glasshouse. Since 1956 these valuable and hitherto under used business records, purchased by Dudley Westropp in the early years of the 20th century, have been housed by the National Museum of Ireland. By using these primary sources in conjunction with Hampshire newspapers, it has been possible to gain an insight into the reality of selling Irish glass in early 19th century Britain. In doing so, a valuable snapshot of the business practices used at the Waterford glasshouse is provided. It also gives an opportunity to reflect on not only the perception of Irish glass in England at this time but also the broader spectrum of the glass trade within and between England and Ireland during the early 19th century.

With a view to providing a context for this sales trip, this article will address both the market in Ireland for luxury cut glass and the nature of contact which existed between the Waterford glasshouse and various individuals involved in the English glass trade. After recounting the details of the sales trip, this article will present some observations on the perception of Irish glass in England and will conclude by considering the nature and origin of this perception.

Background

The name of Waterford is synonymous with heavy, richly cut glass. Significant quantities of cut glass have been attributed to the Waterford glasshouse when only a fraction of it could possibly have been manufactured there. In 1920, Dudley Westropp commented on this when he wrote that 'so much modern glass and also continental glass is, at the present day, passed off as old Irish, or as 'Waterford'' (1978, 204).

Analysis of the statistics for duty paid in each country in 1833 demonstrates that, in comparison to the glass industry in England, the Irish glass industry was in fact relatively small (Wakefield 1982, 20). These statistics are supported by evidence within the Waterford glasshouse accounts, ledgers and business correspondence. These sources reveal the difficulties faced by the glasshouse managers during the economic depressions experienced in Ireland following the end of the Napoleonic wars in 1815.

Flint glass production in Ireland had always incurred high production costs. At great cost to the Waterford glasshouse, coal was imported from Wales and materials such as sand, clay, saltpetre and lead were purchased from suppliers in various parts of England. An account entry, dated 27 July 1827, records a reference to a steam engine being used at the Waterford glasshouse (Account ledger, registration no. 1956.138). While comparatively late to start using steam-powered cutting, this investment nevertheless ensured that the Waterford glasshouse would be able to produce glass in the same richly cut style as that of their counterparts in England and Scotland.

In 1832 the glasshouse at Waterford was under the management of the partnership Gatchell, Walpole and Co. However, the day to day running of the glassworks was the responsibility of Jonathan Wright, glassworks manager between 1830 and 1835, and the Gatchell Letters testify to the tireless attempts by Jonathan Wright and the partnership to increase sales (Moran 2003). The account ledgers show that glass was sold both through their retail ware room in Waterford and through a linen shop owned by a family member in Skinner Row, Dublin. Their travelling salesman, George Saunders, who travelled the country loaded with casks of glass, also played a vital role in securing wholesale custom from country retailers. However, with insufficient demand for the cut glass produced, they found it difficult to cover their labour costs, let alone recoup the cost of the steam engine.

Those at the Waterford glasshouse were not alone in their plight. Other Irish manufacturers of glass and other goods likewise found it difficult to compete with the competitively priced imported goods which, thanks to the advances made in steam shipping, speedily flooded into Irish ports. Irish consumers of luxury goods had a long-nurtured tendency to favour imported products over native-made goods, and since the early part of the 18th century Irish manufacturers had struggled to persuade their consumers to support Irish manufactures, through the purchase of Irish-made products (Foster 1997).

The demand for imported glass in Ireland during the early 1830s was made apparent by the testimony of Mr Frederick Pellatt of the Clyde Flint Glass Works, which appears in the *Appendix to the Thirteenth Report of Commissioners of Excise Inquiry* of 1835 (P. Francis and J. Turnbull pers. comm.). In reference to the market for their high-quality glass, Mr Pellatt stated 'our glass is superior to the Irish glass, and we do a good deal in the Dublin market'. When asked if there was an increased demand for 'a good article' in Dublin, he responded

> yes; but we find it difficult to keep pace with the taste in quality of the article; Dublin is our best market (*Appendix to the Thirteenth Report*, App. 39, 142–3).

It is important to be aware of the potential for exaggeration in the evidence presented in the legislative context of a Commissioners' inquiry. However, the impression gained from Mr Pellatt's evidence appears all the more credible when seen against the context provided by the Waterford glass business records. While Mr Pellat found his good-quality glass was in high demand in Dublin, cut glass began to mount up at a worrying pace in the store rooms at the Waterford glasshouse. A note of desperation is detected in the letter written by Jonathan Wright to his brother on 27 June 1830. While enquiring if there was any money owing to them in Dublin, he despaired

> send it here, we have almost nothing towards paying the men next 6th day so let it be before that time (Gatchell Letters, document 33).

Slightly later that year, in a letter dated 15 October 1830, he explained that: 'our sale for cut articles is bad & the stock accumulating' (Gatchell Letters, document 36). In response to the same amassing stock of cut glass, Jonathan Wright later wrote in a thankful but disillusioned tone 'our plain goods, we sell as fast as they are made' (Gatchell Letters, document 48, 27 July 1831 in Phelps Warren 1981, 40).

Clearly a market did exist in Ireland for their plain uncut wares. However, it was the English and Scottish glassmakers who met the demand for the more costly cut glass, which was supplied to the Dublin middle-class consumers. In the face of such strong competition, it was vital that the partners developed and maintained contacts which enabled them to keep abreast of the practices of other glasshouses, not just in Ireland but also in Scotland and England.

Trade links with Britain

At the Waterford glasshouse there was a need to source not just raw materials, but also specialist expertise and components such as chandelier drops in England. As a result of this, links were formed between those running the Waterford glasshouse and various individuals involved in the English glass trade. Such contacts proved useful on occasion, as shown when Jonathan Wright wrote in a letter to his father in Dublin, dated 20 February 1831, that he was awaiting answers 'from Stourbridge which may give some information of what the trade there are doing' (Gatchell Letters, document 45). In reference to an enquiry which was possibly of a similar nature, Jonathan Wright wrote in a later letter that 'the man sent some patterns with their prices' implying that their enquiries were answered (Gatchell Letters, document 51, 27 March 1832). It was against this highly competitive background that this selling trip to Southampton must be seen.

Alongside the methods of sale mentioned above, selling excursions or rather 'adventures' as they are called in the Gatchell Letters, were made to locations ranging from New Brunswick to Liverpool. Once there, a temporary sales outlet was leased where the glass would be laid out for viewing before an auction was held. In a letter dated 23 December 1830, Jonathan Wright wrote optimistically of the possibility of 'opening an intercourse with some of the towns in the south of England' (Gatchell Letters, document 41). He went on to say that

> there is another project started which I think worthy of a trial that is for GS [George Saunders] to be sent out with £200 of goods to Portsmouth which is a very stirring place and where all kinds of goods sell dear.

No further details are recorded in the surviving letters regarding this proposed trip to Portsmouth. However, a letter written by Jonathan Wright on 3 October 1832, records the adventure made in August 1832 to Southampton (Gatchell Letters, document 63 in Westropp 1978, 94). As will be revealed, such selling trips were attended by a certain amount of risk and not just the dangers encountered in rough seas.

The adventure to Southampton

On 21 August 1832, Jonathan Wright, along with George Saunders and Tom Harney, their packer, set off from Waterford on the steamer to Bristol. Following a two-day overland journey they reached Southampton. They were without their glass as it was being shipped direct. Upon arrival in Southampton, having organised their accommodation, they surveyed the competition posed by glass retailers in the town:

> After dining we went out on observation down High Street the shops of which frequently surpass in beauty and taste those in the best parts of Dublin – there is but one glass shop kept by a man named Baker (Gatchell Letters, document 63).

In a positive yet experienced tone, Jonathan Wright went on to describe how he had observed that

> Judging from the splendour of the buildings and tide of gentry … we saw that our stock would be easily made off – but the old saying tis not all that glistens was called to mind (Gatchell Letters, document 63).

In order to announce their upcoming auction planned for Thursday 30 August 1832, they placed an advertisement in the *Hampshire Advertiser and Salisbury Guardian*, scheduled to appear on Saturday 25 August 1832. Their goods arrived on Sunday, and on Tuesday evening they took possession of the rooms they had hired at Benwells Auction Rooms on High Street, Southampton. By Wednesday they had unpacked their goods and all was ready for viewing. They waited in anticipation but nobody came. Although Jonathan Wright attributed this to, in his words, the 'deluge of rain', this was not promising considering the auction was planned for Thursday (Gatchell Letters, document 63). The heavy rain was recorded in the local newspapers for that week, as was the visit of the famous Italian violinist Signor Paganini who was due to play on the same day as the scheduled auction.

The next day was finer and in the words of Jonathan Wright 'we attempted an auction but without effect, this we attributed to the gentry being drawn off by Paganini the Italian'. He went on to explain that 'numbers called in to admire but bought not on hearing it was Irish said it could not be good' (Gatchell Letters, document 63). That evening, as they drew their unsuccessful day to a close, they received an angry visit from Baker, the local glass retailer. Jonathan Wright explained 'Baker called and threatened to bring us before the magistrate for selling without a license but did not put it into practice' (Gatchell Letters, document 63). Undeterred by the animosity of Baker and the competition from Paganini, they continued to display their goods in the hope of improved sales.

However, as Jonathan Wright's letter continues to explain, 'on the 2nd day we lost all hope of auction and continued at private sale' and they placed another advertisement to this effect in the *Hampshire Advertiser and Salisbury Guardian*, which appeared on Saturday 1 September 1832. Interestingly, Baker also placed an advertisement in this paper in which he duly thanked the loyal gentry of the area for their encouragement and emphasized the great reductions he was offering in cut glass.

In a last attempt to remedy the situation, Jonathan Wright set about delivering circulars. He explained that he had

> directed to upwards of 200 of the gentry whose names I got out of the Poor Rate book. These on the 3rd and 4th day I delivered myself principally (Gatchell Letters, document 63).

However, no amount of ingenuity could remedy this situation. Back at home in Waterford, Jonathan Wright's brother John wrote to their other brother Nathan on the 7 September 1832 saying:

> the adventure will turn out poor enough, they met with opposition from the shopkeepers which added to the prejudice against Irish goods, preventing their making sales worth mentioning ... they had concluded if sales did not improve to pack up the glass and return next week. Jonathan writes they have had a toilsome and anxious time of it (Gatchell Letters, document 59).

Nearing the end of his letter, Jonathan Wright resolved that 'it would appear that the grand streets are only partially inhabited and that the gentry there are more migratory than resident' (Gatchell Letters, document 63, 10 October 1832). Before leaving, Jonathan Wright visited Bedhampton where he had arranged to meet a man called Captain Pearce who gave him an order for £60 worth of goods. The remainder of their glass they decided to send to Chichester in the hope that their contact there would be able to sell it (Westropp 1978, 94). The adventure, which had cost them £50 and 7 pence in expenses alone, had ended in disappointment (Account ledger, 1956.139).

THE PERCEPTION OF IRISH GLASS IN ENGLAND

Evidence from the Gatchell Letters shows that those running the Waterford glasshouse were clearly aware that there was a perceived difference in the quality and colour of Irish glass when compared with English or Scottish glass.

In a letter written in November 1832, referring to a potential order for some goods from the glass dealer Edward Eardley of Exeter, the partner Elizabeth Walpole warned Jonathan Wright to choose articles for Eardley 'which will show the colour and other perfections of our manufacture' (Gatchell Letters, document 65 in Westropp 1978, 95). Even more evocatively, Walpole goes on to say in the same letter

> I need not remind George Saunders to choose articles for this market which will bear the keen inspection of an English Eye.

Edward Eardley had apparently told Elizabeth Walpole that 'all the Irish Glass ever he had seen was dark coloured'. However, he gave his word that 'he would judge it as though it were English Glass' (Gatchell Letters, document 69, 7 December 1832).

Whether or not such a disparity really did exist, it is clear that the Dublin glassmaker Martin Crean capitalized on this in his plea for a reduction in duty (Ross 1982, 62). In the evidence he presented to the *Thirteenth Report of Commissioners of Excise Inquiry*, he declared that the difference in the quality of Irish glass when compared with English glass was so manifest that Irish glassmakers should pay duty at a lower rate:

> The coals we get are not equal to those we see in glass-houses in England; we have not the coals I have seen in Birmingham. The great cause of our glass not being so good as theirs is owing to the furnace not being made sufficiently hot to cause the metal to be in a perfect state (*Appendix to the Thirteenth Report*, App. 45, 155)

As emphasized by Ross, the testimonies by English and Scottish glassmakers presented to the *Twelfth Report of the Commission into the Revenue arising in Ireland, Scotland, &c.* of 1825 stressed the fact that large quantities of inferior Irish glass were smuggled onto their shores to the detriment of their trade (Ross 1982, 58–60). The Waterford glass business records illustrate that a large quantity of their sales were met by the demand for plain inexpensive wares. However, it is undeniable that those at Waterford were capable of producing extremely clear and skilfully cut glass. Their skill is illustrated in the service of glass now in the collection of the Provost's House, Trinity College Dublin, which is believed to be the most securely provenanced service of Waterford glass (COLOUR PLATE 82). However, the Gatchell Letters indicate that as the Irish glass industry began to wane, considerable difficulty was experienced in selling their heavily cut glass both in Ireland and England.

An article entitled 'The State of Ireland', which appeared on 1 September 1832 in the *Hampshire Advertiser and Salisbury Guardian*, raises another issue. The article is based on evidence presented by the Irish Commander in Chief, Sir Richard Hussey Vivian, before the committee on the state of Ireland. In this article, Ireland is alluded to as a drain on government resources and the people of Ireland are presented as a race whom no amount of civilizing could remedy. While the approach taken here is more revisionist than patriotic, this article appeared in the very same issue to that in which the Waterford glassworks advertised their sale, and cannot be ignored. Also recorded in the local Hampshire newspapers for that week was a case of cholera in the locality. Considering the fact that cholera was raging across Ireland during that year and there had in fact been an outbreak of cholera in Waterford in the summer of 1832, it is plausible that the Irish visitors were also avoided with matters of health in mind.

If one attempts to explain the failure experienced during this week, one has to consider a range of social and economic factors. The Irish cut glass industry was small and in spite of the posthumous veneration it has received, it is clear that at the time of most consequence, Irish cut glass suffered from what can only be described as an image problem. While the extension of the Excise in 1825 probably curtailed smuggling of poor-quality Irish glass across to Scotland and England, the precedent which this set was detrimental. One could speculate that the English consumers, who were as fickle as their counterparts in Ireland, began to identify this sub-standard smuggled glass as epitomizing the production of Irish glasshouses.

Regardless of the quality of the glass laid out for viewing in Southampton, with such an unfortunate combination of factors working against them, their adventure to Southampton was doomed to failure. However, whatever the reasons or causes underlying the indifference of the Southampton consumers, this research highlights the value of documentary sources in allowing us to recapture not just the risky and competitive nature of the glass business, but also the personal experiences of those who created this history.

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OPAQUE COLOURED GLASS FROM THE HOLYROOD GLASSWORKS: JOHN FORD'S JASPER WARE

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The first glasshouse to be established within the city of Edinburgh belonged to William Ford, a former clerk at a glassworks in Leith. He and a partner set up the Caledonian Glass Company in 1809 on a site almost opposite the Palace of Holyrood. In 1812 William Ford became sole partner, and in 1815 he moved his business to a former iron foundry in South Back of Canongate, still within the old town, where the glassworks remained until its closure in 1904.

After Ford's death in 1819, the factory, known then as the Mid Lothian Glassworks, was run by a partnership which included his nephew John Ford, who assumed sole control in 1835 and renamed it the Holyrood Flint Glass Works. It is under that name that it is probably the best known of the Scottish glasshouses, partly because it is well documented, partly because it lasted a long time, and partly because quite a number of the products still exist and can be seen in museums and private collections.

Many of the papers, pattern books and other artefacts belonging to the Holyrood glassworks are currently in the care of the Museum of Edinburgh, most of them on loan from descendants of the family, and it is on that material, known as the Ford-Ranken archive, that this paper is based. I am grateful to both the owners and the museum for permission to use their material.

The aim of this paper is to present documentary material relating to one of the Holyrood Flint Glass Works lesser known products, jasper ware, and to illustrate glass which has been passed down through the descendants of John Ford, and which is considered by the museum staff to be the jasper ware referred to in the documents. The family have always regarded it as experimental glass, but do not know it as jasper. It is impossible to prove beyond all doubt that the surviving glass is what was called jasper ware at the glassworks – there is no absolute link between the documents and the objects, but there seems to be no reason to doubt it.

The term 'jasper' first occurs in the family papers in 1839, and the last reference to be found so far is in 1879, so we know that it was in the glasshouse repertoire for at least 40 years, although probably never in regular production.

That first reference is among batch lists, beginning in 1836. Coloured glass is mentioned only occasionally in the first two years but by 1839 there were regular references to pots of emerald green and occasionally to other colours. Then on 8 February 1839, the entry reads:

> No 1 charged for Jasper, 4lb [1.8kg] cast iron, 2¾ [1.2kg] brass, 2 lbs [900g] of arsenic (FR15).

There is no explanatory note, so it may well not have been the first occasion on which jasper was made. Brass filings appear in contemporary recipes for emerald green glass, but this is the only reference to the use of brass in jasper metal.

British glass manufacturing was, of course, dominated by the demands of the Excise between 1745 and 1845 – a great trial for the glassmakers, but sometimes useful for researchers when the written records survive. The title of one small volume in the Ford-Ranken archive speaks for itself; it is the *Register of Pots Gauged by the Excise* and it also contains lists of the contents of the eight pots in the furnace for each week it was operating. Accompanying that volume is another, in which comments about the different batches are recorded with the corresponding dates.

This is a transcript of the pot contents on 5 and 14 February 1841:

> *Register of Pots Gauged by the Excise* January 1st 1839
> [the main contents actually start 21 August 1840]
>
> 5 Feb 1841

Pot				
1	Nothing			
2	Moils and ashes batch	5	3	6
3	Jasper mahognie			
4	Batch	12	3	6
6	Batch	13	3	6
7	Moils & ashes batch	5	3	6
8	Washed Cullet & soda batch	12	2	8

> 12 Feb 1841

Pot				
1	Nothing			
2	Moils & ashes batch	5	3	6
3	Jasper of Yellow Green			
4	Batch Montreal ashes	11	3	6
6	Batch S J	12	4	7
7	Moils & Ashes batch	5	3	6
8	Washed cullet & soda batch			

> (FR16)

As the batch lists illustrate, although the content of most of the pots was routine metal, pot 3 contained experimental batches of jasper, which clearly varied considerably in colour from 'mahogany' presumably a fairly dark reddish-brown colour on 5 February, to yellowish green the following week.

The accompanying comments for 5 February, in the second volume, gave the following list of ingredients:

No 3 Pot charge for Jasper 5 Feby 1841

Contents of Pot 1833 lbs [831kg]

Soda Batch Illa Sand	3	0	0	
Jasper moils	2	0		
Blacks	7			
Cast iron turnings				20lb [9kg]
Green verditur				10½ lbs [4.8kg]
Arsenic				1½ lb [680g]

The above turned out remarkable dark owing to so much cast iron about half to much see what was produced from the week ending on the 12th instant 1841 (FR21).

Written along the edge of the page in pencil is:

12oz [340g] cast iron to the hundredweight [50.8kg]
8oz [226g] blue be? " "

The basic metal was a batch of soda glass made with sand from the island of Islay in the Hebrides. Moils were, of course, the remains of the glass left on the blowing iron or pontil rod, while blacks were the same thing but had small particles of iron attached to them. Blacks were normally separated from the rest of the cullet and, according to Apsley Pellat, were used to make inferior glass or glass of a light green colour (Pellatt 1849, 93)

To these basic ingredients was added the considerable quantity of 20lbs of cast iron turnings. These were the shavings of iron removed on a lathe after the cast iron had been taken from its mould, in order to smooth the rough edges. The founder then added the green verditur, usually called copper oxide, and the arsenic.

It is clear from his comments that he later regretted the generous quantity of cast iron he had used and in a subsequent recipe he suggested using about half as much. It is somewhat surprising that he was apparently experimenting with a full crucible of batch; 1833lbs of metal was a large quantity of material to risk if the outcome was uncertain.

The following week another attempt was made, again using no. 3 pot. The bulk of the metal consisted of the remains of the previous week's batch – 12cwt [609kg] of it – to which blacks and green verditur were added, and which was again expected to produce jasper. However, the glass which had been left over the previous week had been ladled into cold water, which had, to quote the notes 'destroyed the colouring properties requisite for the manufacturing of Jasper' – so they finished up with the light yellowish green glass, some of which they made into hock glasses and 'strong, long french shape bottles'.

That batch may have been a failure, but the founder's intentions were quite clear. He wrote:

Provided I had introduced along with the 4lb [1.8kg] of green verditur 8 pounds of cast iron turnings and 6 pounds [2.7kg] of arsenic I am of opinion the metal would have produced a most beautiful variagated jasper but I was afraid to introduce the iron turnings as I had over dosed it on the former week by the 20lb [9kg] .... The green verditur has an effect to make the metal of a greenish yellow. The c. iron turnings will make the glass black green and toward the bottom of the pot the glass turned dark and full of black cords.

NB I proved the above to be correct.

It is clear, then, that Ford's jasper had nothing to do with the famous Wedgwood ceramic product, which tends to spring to mind when 19th-century jasper wares are mentioned, but was intended to provide variegated glass, presumably in imitation of the natural stone, and perhaps referring back to the agate or *calcedonio* wares made in Venice in the 15th century and reproduced in Germany in the early 19th century.

A week later, on 19 February, another attempt was made to produce jasper, using most of the previous week's yellowish green metal, but adding 4lbs of green verditur and 4lbs of cast iron turnings. On this occasion pot 4 was used, and the comments made indicate the level of experimentation which was going on:

No 4 pot charged again for Jasper 19 Feby 1841 contents 1833 lb

Soda ash Batch	168 lb [76.2kg]
Green metal from the former week which produced Jasper	1644 lb [745.7kg]
To the above was added	
Green verditur	4 lb [1.8kg]
Cast Iron Turning	4
	lb 1820

When No 3 was unstoped on the Sunday morning and a proof taken off I was pu? into a Read hot shoe to try to make it change colour but the heat took no effect. I then proceded to the works and caused the person on duty to ladle out nine inches of metal and returned the same into the harbor along with about 56 lb [25.4kg] of batch and 7 lb [3.2kg] of cast iron, 1lb [454gm] of verditur, 3 lbs [1.4kg] of arsenic and returned the whole back into the pot at one charge and opened the pot on the Monday morning but found the Glass not fine & stoped it up again until the Evening when it was again unstoped And the Glass then produced a most beautiful dark marbled Jasper.

NB So far as I can judge before introducing the last quantity of colours about 12 lb[5.4kg] of cast iron and 12 lb of verditur, but it does not answer to put the same quantity of verditur as of cast iron unless you require a Jasper of a variegated Brick Read and to make it of a darkish marble colour about an third less verditur than cast iron should be introduced.

Say for a Pot as no 3 18 lb[8.2kg] cast I. and 1½ [700g] of verditur. If this should not prove effective add in proportion accordingly as formerly (FR21).

Three more batches of jasper were recorded in 1841, but without specific comment.

Among a variety of pieces of Holyrood experimental glass in the Museum of Edinburgh are three reddish-brown rods, each about 250mm long and 10mm in diameter. One of them has a broken end, showing that there are variatons of colour within the rod which corresponds fairly well to the description 'variagated brick red'. The recipes quoted above were for green jasper, and none of the surviving Ford glasses are green – but they do correspond to the descriptions 'variagated brick red' or 'mahogany'.

The small jug in COLOUR PLATE 83, is one of five pieces of jasper ware belonging to the Ford-Ranken family, which were placed in the care of the Museum of Edinburgh in 1958. One hundred years earlier, in 1856, the first Exhibition of the Art-Manufacturers Association was held in Edinburgh. It was an obvious showcase for local products and under the banner 'John Ford of Edinburgh', the exhibits included a range of coloured glass vases, including variations on opal – opal on green, opal on rose with painted figures and opal on flint, as well as pea green, and blue on flint, the latter costing £4 5 0 – an expensive item (Anon 1856, 51). There were five pairs of candlesticks, jug and goblet sets, centre dishes and vases and salts in silvered glass. More relevant to this paper were two jasper claret glasses, costing only 1s 10d each, seven jasper vases ranging in price from 4s to £1 15 0, a sugar basin, a creamer for 12s 6d and a toilet bottle costing 10s 6d.

It seems evident that John Ford was pleased with this particular product, because in 1859 he presented 'a glass rest for a pianoforte in imitation jasper' to the Royal Museum in Edinburgh (Evans 1999, 18). No colour is mentioned in the museum records and, sadly, it was de-accessioned in 1946, along with a lot of other material. According to the museum records, it was given to the St Helens Museum, who unfortunately have no trace of it.

We now move on some 23 years to the Sydney International Exhibition of 1879. The Holyrood Glassworks did a considerable trade with various ports in Australia and John Ford sent a very large selection of glass for the exhibition. Again in the Ford-Ranken archive is a hand-written catalogue of all the 500 items sent to Sydney – and of over 400 articles sent to Melbourne for the exhibition there in 1880. It gives a description of each object, with its price and other details relevant to the company.

Number 189 in the Sydney catalogue is a 'Vase and velvet stand' 15 inches high, 'cut dutch diamonds, fluted stem, scalloped 'Jasper' Ware'. The velvet stand is unusual and at £4 4 0 the vase was one of the more expensive exhibits. A further three items listed were also in jasper ware, but were obviously of more modest form. They were a sugar and cream set with cut flutes and scallops, an urn shaped vase, again with cut flutes and scallops both costing 14s and a toilet bottle with cut flutes and scalloped foot, costing 10s 6d (FR14) (FIG. 1). The cut flutes and scallops are very effective in highlighting the marbled effect of the colour variations in the jasper metal. That only four exhibits from a total of over 500 were of jasper ware would seem to imply very limited production of wares in that metal, although the fact that the costs, apart from the vase in the velvet case, were not particularly high could again indicate that it was not too difficult to produce. No jasper ware is mentioned in the Melbourne list.

Among the jasper ware in the Museum of Edinburgh are two vases of very similar shape, although one is slightly wider and taller than the other (COLOUR PLATES 84, 85). Both are in quite dark metal, cut in long flat flutes, with a turned-over rim cut with regular splits. Apart from the angle of the rim, the shape is not unlike that illustrated in the catalogue for the Sydney Exhibition.

In 1989 a remarkably similar vase, thought to be German lithyalin, was sold by Sotheby's in London (COLOUR PLATE 86). It is the same height as the larger of the two museum

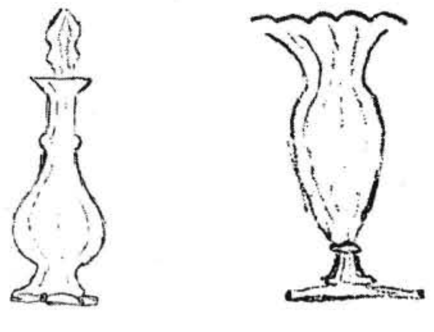

FIG. 1 Illustrations from the hand-written catalogue of exhibits sent to Sydney in 1789 (FR14)

vases, and is cut in the same way. Incised on the base is 'Alexander Cunningham, July 1842'. Although it could, indeed, be lithyalin, it is worth noting that Alexander Cunningham is quite a common Scottish name and there were several men of that name living in Edinburgh in the 1840s. The date also coincides well with the period during which jasper was produced at Holyrood.

Two of the seven pieces of Ford jasper are small wine glasses. One of them, cut to a design recorded in a pattern book in the Corning Museum of Glass, is in the Museum of Edinburgh (COLOUR PLATE 87). The other, an uncut blank, is still in the home of John Ford's 93 year old great-great-grand-daughter. It is of particular interest because it confirms the link between the green and brick red metals, mentioned in the recipes described above. The glass itself is of a variegated brick red colour but a small section of the rim is of clear green glass, although it is obviously part of the same gather. The effect is very similar to that in ceramic copper-red glazes which begin to revert to green when re-oxidized.

There is no doubt that John Ford and his successors produced glass they called jasper ware and his descendants are adamant that the seven pieces of experimental glass they have inherited were made at the Holyrood glassworks, as were the trial rods. It would be unwise to suggest that much of the glass found in Britain which is currently designated as lithyalin and assumed to be German or French, was, in fact, made in Scotland, but the evidence presented above would seem to be sufficient to suggest that at least some of it was.

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THE AUTOMATIC CRYSTAL FOUNTAIN

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On 7 June 1870 Joseph Storer of Hammersmith (a London suburb) obtained Patent No. 1647 from the English patent office for an 'Improvement in Fountains'. He declared the nature of the said invention to be an improvement in that class of self-acting fountain known as Hero's fountain, and that his patent

> relates to the application of means whereby the repeated filling and emptying of the cisterns or reservoirs is obviated.

Storer described the two cisterns and their connecting pipes and went on

> To put the fountain in operation water is poured into the dish or basin until the lower reservoir is filled and the opening is covered. The cisterns are then turned on their axis of motion, so as to place the filled one at the top and the water will flow to a level in the jet pipe and be forced up to the nozzle from which it falls back into the basin and drains down into the lower cistern. When the water has flowed through, a reversal of the revolving cisterns will cause it to start again.

Nothing in the document mentions the material of which the fountains could be made, and there is no evidence that Storer manufactured any examples of the fountain. He is listed as a resident of Hammersmith in the local directories, but he had no business there or anywhere else that I can trace and he appears in the 1881 census as an inventor (Hammersmith and Fulham Archives). However, he received no other patents in the 1870s and 1880s (British Library). The following year, he patented the fountains in the United States, receiving Patent No. 111,697 on 7 February 1871. The text of the American patent is identical to the London one and does not mention glass either. The illustrations are identical as well.

Hero of Alexandria in his *Pneumatica* of about AD 62 described the water-fountain which operated with air pressure and this was illustrated with drawings in several 19th-century encyclopedias. J. Frick's *Physical Technics* of 1861, Knight's *American Mechanical Dictionary* (1880), and *Johnson's Universal Cyclopedia of Universal Knowledge* (1888) all had drawings of various versions of Hero's fountain in all of which the reservoirs were transparent. It was a common piece of demonstration apparatus in the 19th century. In fact, Knight's *Dictionary* refers to 'modern parlor fountains' (Knight 1880, 910) as if they were well known. Storer's innovation was to make the bulbs revolve, which meant that it would play without the need to refill it for as long as the owner wished. What makes it of interest to glass students, of course, is that the existing examples of Storer's fountain have glass bulbs.

Most of the existing examples are American, made by James Tufts of Massachusetts. James W. Tufts (1835–1902) was a manufacturer of soda fountain apparatus who made his fortune as a young man with his Arctic Soda Fountain (Depew 1895, vol. II, 470–6). He owned a drugstore in Somerville, Massachusetts, and desiring to add a soda fountain to it, he designed and patented one in 1863, which was a great commercial success. He abandoned the drug business to manufacture these for nearly 40 years. Fortunately for the researcher, he issued catalogues every few years from 1864 until he sold his company in 1891.

Tufts was an entrepreneurial manufacturer who made and/or sold a variety of related products and he pursued a licensing arrangement with Storer so that he was allowed to make the fountains under the Englishman's patent. The earliest advertisements so far found are from page eight of the 27 July 1876 *Crockery and Glass Journal*. The text refers to it as an 'Automatic Crystal Fountain'. It is self-acting, of ruby glass and mounted on a golden bronze standard with a marble base.

> A little Cologne added to the water makes it a delightful Perfume Fountain, Price Complete $15. More elaborate styles furnished; also fountains for counter use with only silver plated basin and jet in sight.

Tufts exhibited the Arctic Soda Fountain in Machinery Hall at the Centennial Exhibition in Philadelphia in 1876, and he and Charles Lippincott, a rival, had exclusive rights to sell soda water there. He had several buildings scattered around the grounds to dispense this. However, there is no evidence that he showed the Crystal Fountain there. His 1877 catalogue for soda water apparatus (Library, Metropolitan Museum of Art, NYC) has five pages devoted to the Automatic Crystal Fountain and says that he has with considerable effort purchased the patent and is prepared to furnish them.

> The fountain has been received with great favor in England and France, but has never before been introduced in America. The very large sale during the three months I have made them and the very gratifying expressions of satisfaction from the purchasers are ample evidence of their value.

The fountain was available with a silver-plated frame or a gilded bronze one and the catalogue also showed the counter fountain mentioned in the advertisement, which had the revolving cylinders, made of metal, concealed beneath the counter and was meant for a commercial establishment. That page mentions even larger fountains, to be used out of doors in the garden, with the cylinders concealed in the stables. The complimentary letters quoted date from December 1875 and 1876 which must indicate that he had been making them since late in 1875.

A larger brochure, which is only for the fountains, is in the Boston Public Library and this one, which is unfortunately not dated, gives prices and colours. The glass was available in opaque white, plain or with enamelling or gilding, colourless, blue, and ruby glass all with or without acid-etched decoration. The bases were square white Italian marble or Sevier Marble with moulded edges which might mean that it was round. The frames were golden bronze, antique bronze, silver-plate and fancy gold and silver plate. The price range was from $15 for undecorated glass of any colour with the golden bronze frame and Italian marble base, to $30 for those with decorated glass, gold and silver frame and a Sevier marble base. This brochure also included an engraving and prices for the Counter Fountain, at $50 and the Garden and Lawn Fountain at $150 (not including lead pipe and an iron basin). Some of the complimentary letters were different from those in the 1877 brochure, including one from R. H. Macy & Company, a large New York department store, which indicated that they were selling well. This is probably from 1878 or 1879.

The fountain in COLOUR PLATE 88 is the $15 model with undecorated glass and an Italian marble base. It is marked on the frame 'J.W. Tufts, Boston, Pat. Feb. 7, 1871'. It came up for sale in England in 1999 (Wilkinson's, Doncaster, 12 September), the second of two that year. The following year Sotheby's had two colourless ones in a country house sale, both lacking bases (Benacre Hall sale, 11 May 2000, nos 1319, 1320). The fountain in COLOUR PLATE 89 is one of those. At the time, I thought those might be English, perhaps manufactured for Storer. However, I think now they must also be Tufts ones, based on the similarity of the metal work. On the basis of the slightly more ruffled rim and the fancier metal work, these might be from the 1880s. One decorated one is also known, which has the bulbs of red glass over colourless, cut in a pattern. This was probably a special order since the decoration is not listed in the Tufts brochure. It is also missing its base. This decoration is unique as far as I can tell, as it is cased and cut much like the kerosene parlour lamps which were popular at the same time. Several have been found in blue. So far there are eight in museum and private collections in the United States, and I've heard of two or three more in salerooms in the last 20 years. The Lightner Museum in St Augustine, Florida, has a blue one; the Strong Museum in Rochester, New York, has a red one and a red and blue one; the ruby overlay one and a blue one are in private collections. The glass parts for all of these undoubtedly came from one of the several factories in the Boston area, perhaps the Boston & Sandwich Glass Company, the New England Glass Company or the Union Glass Works. Tufts might have purchased the glass from more than one company, but it is impossible to know. In England, several have been for sale in the last five years, but all of the illustrated ones have this same framework and must be American.

No fountains in Tuft's Style 2 have surfaced. This is in both the 1877 and the undated brochure and is 32 inches high rather than 21 inches. It had the gold and silver plated frame, and basins of blue, ruby, opal or colourless glass.

> This fountain has two basins, the upper one is the reservoir for water which supplies the Fountain, and the lower is for flowers, but instead this may be used for gold fish with beautiful effect.

The water shot 12 inches high and the price was $50.

Tufts had been interested in Crystal Parlor Fountains for at least a year. An advertisement (p. 17) from the 21 December 1876 *Crockery and Glass Journal* shows a fountain which Tufts printed a brochure for in 1875 (original in University of Delaware Library). The text in Tufts brochure does not imply that he manufactured it, only that he offers it 'to the trade'. It had a colourless glass bowl and a white glass tulip which concealed the jet and it was made to play by raising a valve in the metal cylinder concealed in the base; as the water came out, the valve lowered and in a couple of hours it was necessary to raise the valve again to make it play. 'Goldfish thrive in it' according to the text and if it was ordered with the stand on which it is sitting, the cylinder went down into the stand and it would play for five hours and cost about $45. By 1876, Tufts was offering the revolving version, but this fountain continued to be advertised by the American Fountain Works for several years more. Unfortunately, I have never seen one of these. Tufts revolving fountains were made through at least 1880, and possibly longer but do not appear in his catalogues from 1884 on.

Some fountains with a different frame and more decoration may possibly be English. One was sold at Sotheby's in 1991 (English and Continental Glass, London, 25 March 25 1991, no. 291) which had red glass globes which were gilded in a floral pattern. A similar one was offered on E-bay fairly recently from New Orleans. Both have lost their bases and have no marking on the metal work. The glass is clearly Bohemian, but the framework may be English. It is not from Tufts and there is no indication that these were being made in Bohemia. The gilding is of excellent quality, judging by the illustrations. Since there is no evidence that Storer ever manufactured the fountains, he must have licensed an English manufacturer who got the glass parts from Bohemia. As several of the Tufts ones have turned up in England, it seems likely that Tufts marketed them there and perhaps was a better marketer than the English manufacturer.

At least one now in a private collection has been found with the same frame and the addition of two 'fairy lamps' attached in the centre. This is clearly from the same manufacturer and fortunately still has its marble base. The glass appears to be Bohemian although the enamelling on this one does not seem as well done as the gilding on the two previous ones. However, the framework is identical. Samuel Clarke patented his fairy lights in 1886 so this variation was not made until then and, on the basis of the decoration, the other gilded ones also date from the 1880s rather than the 1870s.

While it has been possible to identify and document the American version of this apparatus, so far the possible manufacturer in England has been elusive. But all that have turned up with this style of frame have what appears to be Bohemian rather than English glass and stylistically date from a decade after the heyday of the American version.

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BRITISH INFLUENCE ON THE SHINAGAWA GLASSWORKS – JAPAN'S FIRST INDUSTRIAL GLASS FACTORY

Akiko Inoue Osumi

Introduction

Japan's glass industry made a leap forward in the late 19th century after the government turned to Western manufacturing systems in a push to develop a modern glass industry. Among those who played a pivotal role in the process were British engineers and craftsmen, who brought crucial new technology and equipment, trained Japanese workers and helped disseminate Western glassmaking methods throughout the nation. Those people – called *Yatoi* or hired foreigners – were some of the thousands of foreign technicians and teachers who visited Japan on the basis of invitations from the governments, schools and individuals (Umetani 1968).

Britain's largest trade and investment company, Jardine, Matheson & Co, which was looking to expand its trade in east Asia, was also seen playing a vital part in the modernization process, as historic records show they provided funds for running glass plants and importing materials.

This paper establishes the work of British glass engineers and craftsmen using official documents from the Ministry of Industry, Ministry of Finance and Ministry of Domestic Affairs. It also studies how Western glassmaking methods changed Japan's glass industry.

Kogyosha and Erasmus Gower

Japan's first fully Western-style glass factory 'Kogyosha' was set up at Shinagawa, near Tokyo, in 1873, with the assistance of two British engineers, Erasmus H.M. Gower and Thomas Walton. This was only six years after the Meiji Government was inaugurated in 1867, ending Japan's 260 year-long feudal system.

According to the *Nihon Kinsei Yogyoshi* (Modern History of Ceramics in Japan: Dainihon Yogyo Kyokai 1916), Miyonosuke Murai, who was a clerk of the then Prime Minister Sanetomi Sanjo, learned from Gower the advantages of having a modern glass industry and urged his colleague Masatsune Niwa to start a venture. With Sanjo's political backing, they imported manufacturing machines, tools, clay for pots and firebricks from England in an attempt to produce sheet glass and sidelights for ships (Dainihon Yogyo Kyokai 1916, 16).

According to *Erasmus H. M. Gower and His Family*, edited by Toshio Shioi (1979), a grandson of his Japanese wife, Uta, Gower was born in Italy in 1830 the son of the British Admiral of the Fleet, Sir Erasmus Gower, and was educated as a mining engineer in England. Gower arrived at Yokohama, Japan, in 1859 through the good offices of Jardine, Matheson & Co, when the British trading company, which had large operations in China, branched out into the Japanese port city. After serving the Shogunate and the Meiji government, Gower started to work for the Nakakosaka mine owned by Niwa in December 1873 as an engineer. He moved to Kogyosha, also owned by Niwa, in May 1874 and worked there until April 1875 (Shioi 1979, 261–4). During this period, he travelled throughout Japan to conduct research on glass raw materials. He earned 500 yen a month during this period, the highest grade of salary for a privately hired foreigner (Naimusho 1876).

After the government purchased Kogyosha in 1876, Gower was re-employed by the government and helped develop coal mines in the south of Kyushu Island until he left Japan in 1880.

Although there is no clear evidence, it is highly likely that Jardine, Matheson & Co played a key part in the funding for Kogyosha. Kenji Ishii, who made a close investigation of the Jardine, Matheson archive, now in the custody of the Cambridge University Library, writes:

> ... during the 31 months [until the government's purchases of the company], a total of $25,000 was spent on Kogyosha. Using the fund, Jardine, Matheson's Yokohama branch bought cement, bricks and machinery from London's T. Waters and Bristol's A. Robinson. It also bought white alkali from [London's] Matheson & Co. and manganese from Parrot & Co. in San Francisco ... While Murai was responsible for the management of Kogyosha, the Yokohama branch of Jardine, Matheson took various actions deemed necessary – helping Kogyosha hire another British engineer Thomas Walton, importing equipment and machinery with a five percent commission, and providing loans (Ishii 1982, 81–3).

Saburo Ozaki, who was a clerk of Sanjo, states in his *Autobiography* that Sanjo was released from some of the immense debt he owed to Jardine, Matheson, when Kogyosha – then in financial difficulties – was purchased by the government (Ozaki 1976, 217–18).

Thomas Walton began working at Kogyosha in September 1874. After his arrival, a direct combustion-type glass-melting furnace set with six skittle pots, each with a capacity of 240kg, was built under his direction (Dainihon Yogyo Kyokai 1916, 172).

Kogyosha hired experienced Japanese glass blowers to produce broad glass. But the attempt failed due to technical immaturity, deepening the factory's financial trouble. Walton was paid $48 per week between September 1874 and September 1876, and 400 yen per month at the government-owned Shinagawa Glassworks until he was dismissed in September 1878 (Naimusho 1876).

The government-owned Shinagawa glassworks

After the Meiji government, keen on nurturing modern industries, bought Kogyosha's plant in 1876, it was placed under the Ministry of Industry and initially took the name of Shinagawa Garasu Seizosho (Shinagawa Glassworks). It was later renamed Shinagawa Kosaku Bunkyoku (FIG. 1).

FIG. 1 Buildings of the Shinagawa Glassworks. Part of these have been dismantled and reconstructed in the Meiji-mura Museum, Nagoya. By courtesy of the Meiji-mura Museum

The factory's major goal was the production of sheet glass to offset the economic damage to the government of increasing imports. It also aimed at training young glassworkers under foreign masters in order to establish an efficient glassmaking method in Japan. Trainees were sought for from around the country and some new British craftsmen were invited from Britain (FIG. 2).

In January 1877 Elijah Skidmore, a pot-maker, arrived. He was paid £25 a month until June 1881, when his term expired and he left for a private glassworks in Osaka, Japan's second biggest city in central Japan (Kobusho 1876–84).

After Thomas Walton left the glassworks in September 1878, James Speed arrived to take over his post of Chief of Craftsmen in April 1879. His salary was 220 yen (trade silver) a month (Kobusho 1876–84). According to a newspaper article in *Tokyo Shinbun* on 5 May, he was 'more sophisticated in terms of manufacturing technique than his predecessor' (Nakayama 1934). At a date just before or soon after his arrival, clay, various metallic oxides, and moulds were imported from England (Kobusho 1877–81).

In 1881, the second Inter-Japan Industry Promotion Fair in Japan exhibited some 268 pieces of tableware, scientific apparatus, chimneys and bottles from the glassworks (Naikoku Kangyo Hakurankai Jimukyoku 1881). The two brush-holders in FIGURE 3 were probably amongst the factory's products exhibited at the Fair. The manufacturing technique of applying multi-coloured trails on clear glass, unprecedented in Japan, may have been introduced by the British instructor.

It was just after the opening of the Fair that Emanuel Hauptman, a glass engraver, joined the plant to instruct in cutting and wheel-engraving techniques. He was paid 175 yen a month between May 1881 and June 1882 (Okurasho 1889). Various cutting wheels for engraving, cutting and polishing were imported from England (Kobusho 1877–81). But the factory's financial difficulties, stemming from huge investments in the experimental production of sheet glass and slumping sales of utilitarian glass, led to the privatization of the glassworks in 1885. Hauptman was dismissed in 1882 while Speed left in 1883 (Okurasho 1889). Speed moved to the glassworks in Osaka where Skidmore had been working, but their whereabouts after that are not known.

FIG. 2 Photograph probably taken at the farewell of James Speed in 1883. Speed, at the centre left, and Fujiyama, at the centre right, are surrounded by young trainees. By courtesy of the Meiji-mura Museum

FIG. 3 Brush holders probably exhibited at the Fair held in 1881. Ht 168mm (left), 148mm (right); Tokyo National Museum

THE TRANSFORMATION: FROM *JAPAN-BUKI* TO *HAKURAI-BUKI*

Records of the materials imported from England to the Shinagawa Glassworks are found in the Annual Report of the Ministry of Industry kept in the National Archives (Kobusho 1877–81). TABLE 1 shows the extent of new technology and materials brought into the factory. Most of the metallic oxides listed there had not been used in the previous era. According to the recipes published by Tanehiro Fujiyama, director of the factory, these oxides were used in experiments to develop various coloured glasses (Fujiyama 1884a; 1884b). Press moulding, except on a very simple basis, was also a novelty in Japan. Some of the 268 pieces from the factory exhibited at the second Inter-Japan Industry Promotion Fair (1881) are considered to have been made with these colouring agents or moulds.

TABLE 1 IMPORTED GOODS FROM ENGLAND TO THE SHINAGAWA GLASSWORKS, 1879–1881

July 1879–June 1880	July 1880–June 1881
Clay (50 tons)	Engraving machine (2)
Tin oxide (100 pounds)	Stone wheel (rough) (12)
Chromium oxide (100 pounds)	Stone wheel (fine) (12)
Uranium oxide (100 pounds)	Stone wheel to remove pontil mark (12)
Antimony oxide (100 pounds)	Wooden wheel (6)
Nickel oxide (50 pounds)	Bristle brush (6)
Press mould (2)	Cork (5 bundles)
Cup mould (3)	Polishing sand (200 weight)
Dish mould (2)	'*Noshinku*(?)-iron' (1000 weight)
Salt pot mould (1)	
Bottle-mouth press mould (1)	
Bottle mould (6)	

As for cutting methods, practical wheel-cutting and engraving systems were introduced into Japan for the first time. Thereafter they replaced the time-consuming hand cutting using an iron bar and abrasives prevalent in the previous era (Tanahashi 1987). The new Western glass manufacturing system adopted was called *Hakurai-buki* (imported method) to distinguish it from the traditional production system, which was called *Japan-buki* or *wa-buki* (Japanese method).

The biggest problem of the *Japan-buki* was its inefficient manufacturing system, which stemmed mainly from the absence of an effective annealing method. Products were kept in a container filled with hot ash to be annealed (Naikoku Kangyo Hakurankai Jimukyoku 1878, 135). Most of its products lacked strength as a result, except some luxury products.

Shinagawa succeeded in introducing a full-scale modern manufacturing system, including the annealing furnace, thanks to the assistance of hired British engineers and the government's financial support. The major differences between the two production systems are shown in TABLE 2.

THE SHINAGAWA GLASSWORKS USHERS IN CHANGES

The Western glassmaking method, introduced by British engineers and later disseminated by Japanese trainees, drastically changed Japan's glass manufacturing system in a relatively short period of time. Durable utilities of reasonable price began to penetrate the country, while exports soared, making a significant contribution to the economy (Inoue 1979a; 1979b). On the other hand, a rapid increase in production meant a decline in quality. With the arrival on the market of reasonably priced volume products, artistic glassmaking, once a monument to superb Japanese craftsmanship, quickly disappeared. It took a long time before glassmaking was again recognized as an art in Japan.

Although it is clear that the Shinagawa Glassworks played an important role in Japan's glassmaking history, its details remain in the dark. There are only a few historical records of the British engineers, and few glass products are identified as having been produced at the Shinagawa plant. The reason for the continuous failure in sheet-glass production remains a mystery.

For further research, archives owned by Jardine, Matheson and big glassmaking firms, such as Chance Brothers, could provide a clue to the technical backgrounds of the hired British engineers. It would also help clarify the unknowns of the Shinagawa Glassworks.

TABLE 2 MAIN DIFFERENCES BETWEEN TRADITIONAL AND ADOPTED MANUFACTURING METHODS

	Japan-buki	*Hakurai-buki*
Material	Potash-lead glass	Soda-lime glass
Fuel	Charcoal	Coal
Furnace	Small direct-combustion furnace with 1 or 2 pots	Large direct-combustion furnace with several pots
Pot	Skittle pot containing 3–60kg of glass	Skittle or crown pot containing 90–300kg of glass
Annealing system	Ash container	Annealing furnace
Cutting method	Hand cutting with iron bar	Wheel cutting

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SCHLESISCHES GLAS – EINST UND JETZT

SIBYLLE JARGSTORF

Seit dem 14. Jahrhundert ist Glasmachen in Schlesien dokumentiert. Der erste urkundliche Nachweis findet sich in einer Teilungsurkunde aus dem Jahr 1358, in der die Glashütte bei Mittelwald in der Grafschaft Glatz aufgeführt ist. Schon 1366 wird in einer Verkaufsurkunde eine Glashütte bei Schreiberhau im Riesengebirge genannt, in der Region, die in den folgenden Jahrhunderten eine so herausragende Bedeutung in der europäischen Glasproduktion erlangen sollte.

Bereits vor 1500 gab es in Schlesien mindestens 20 Glashütten. Im 16. Jahrhundert förderten die Grundherren dann bereits zum wiederholten Male die Ansiedlung von Glasmachern aus dem Westen, insbesondere aus dem Erzgebirge, um auf diese Weise eine profitable Nutzung für ihre bergigen Wälder zu finden. Nach Kriegen, Pest und Hungersnot begann ab jetzt ein europaweiter, florierender Handel mit schlesischem Glas. Getragen wurde diese Entwicklung von den grossen, schlesischen Glasherrengeschlechtern. Überregional herausragende Bedeutung erlangte dabei die Schürer, als 'Schürer von Waldheim' geadelt, und dann vor allem auch das Geschlecht der Preussler, die fast 250 Jahre die Hütten im Hirschberger Tal betriebenen in diesen frühen Zeiten beschränkte sich das 'Veredeln' der schlesischen Gläser auf 'Kneifen', auf kalte Bemalung, auf Diamantriss und auf Emailmalerei, Techniken, die auch in anderen Glasregionen üblich waren. Im 17. Jahrhundert wurde die Glasmasse in Schlesien dann verfeinert und es setzten sich die speziellen Schnitt/ Gravurbearbeitungen durch, die das schlesische Glas international so berühmt machten. Ein datiertes Schnittglas von 1648 aus dem Hirschberger Tal ist ein wertvolles Beispiel für diesen Gläsertypus, der mit Belegstücken vor allem aus dem 18. Jahrhundert heute weltweit in Museen vertreten ist.

Diese Gläser, in denen Hoch- und Tiefschnitt in üppiger und unnachahmlicher Form verbunden sind, wurden zum Inbegriff der schlesischen Gläser. Die weltweite Bedeutung dieser Gläser liess vielfach vergessen, dass sich das schlesische Glasschaffen auch nach der Epoche dieser Gläser weiterentwickelte und in mancher Hinsicht neue Techniken sogar eher aufgriff als die nahegelegenen böhmischen Glashütten. Dies gilt insbesondere auch im frühen 19. Jahrhundert für die 'venezianischen' Techniken wie Filigran und Millefiori. Die herausragenden Pionierleistungen in diesen Techniken wurden zuerst in den 1830er Jahren auf der Hütte Hoffnungsthal erbracht, geführt von den Brüdem Matterne, und dann in den 1840er Jahren auf den Schaffgottschen Hütten Carlsthal und Josephinenhütte unter der Regie von Franz Pohl. Den Verbrauchern und Händlern in Westeuropa und Amerika fehlte die geographische und politische Detailkenntnis zum Riesengebirgsraum, um zwischen schlesischem und böhmischem Glas zu differenzieren. Deshalb wurden dann insbesondere im 20. Jahrhundert viele, eigentlich schlesische Gläser des 19. Jahrhunderts,die in diesen Techniken gearbeitet waren, und die sich nicht Venedig oder Frankreich zuordnen liessen, ziemlich pauschal als 'böhmisch' eingeordnet. Dieser verführerischen Vereinfachung erlagen/erliegen allerdings auch Fachleute. Es ist fast in Vergessenheit geraten, dass es ein eigenständiges und hochwertiges schlesisches Glas gerade auch wieder seit dem 19. Jahrhundert und dann bis in die Gegenwart gibt. Dies trifft heutzutage ganz besonders auch auf das moderne polnische Studioglas zu, das vielfach andere Wege geht als das moderne tschechische Kunstglas, dem es qualitativ ebenbürtig ist, und in dessen Schatten es dennoch bei dem westeuropäischen Glasliebhaber steht. Die eigenständige Qualität des Glases von der Nordseite des Riesengebirgskamms will ich für die Mitte des 19.Jahrhunderts wie für das Ende des 20. Jahrhunderts nur an einigen wenigen Beispielen andeuten.

DIE WIEDERENTDECKUNG DES MILLEFIORIGLASES IN SCHLESICHEN GLASHÜTTEN

Im Zentrum dieser Betrachtung steht eine Karaffe, die sich in der Sammlung des Victoria and Albert Museum befindet (Vase & Stopper, Acc no. 4479 & A-19011). Dieses Glasgefäss ist in seiner speziellen Machart ein qualitativ herausragendes und einmaliges Belegstück für das nordeuropäische Milleflorigias im 19. Jahrhundert. Es gibt zwar in vielen bekannten Sammlungen, im Corning Glass Museum, , im Metropolitan Museum in New York, im Victoria and & Albert Museum in London, und beispielsweise auch im Kunstmuseums in Düsseldorf (Pokal, no. P. 1929–35 8), eine Vielzahl von kleinen Millefiorigefässen, die ebenfalls entweder Böhmen oder Frankreich zugeordnet werden, die aber auch aus Schlesien stammen. Die schlesische Herkunft dieser Gefässe ist inzwischen durch Bodenfunde zweifelsfrei belegt. (Kordasiewicz 2002, 28–31). Ausserdem gibt es zwei Millefiorivasen von herausragender Qualität (Jargstorf 2003, 29–37), über deren entgültige Herkunft noch debattiert wird, und die eventuell auch aus Schlesien stammen könnten. Nach meinem heutigen Kenntnisstand gibt es aber kein weiteres Belegstück in der Machart und der Qualität der Londoner Karaffe.

Die Karaffe wird Salviati zugeschrieben, ein Irrtum, der unter anderem daraus resultiert, dass sie ursprünglich vom

Museum für angewandte Geologie erworben wurde und die Originalunterlagen zum Kauf verlorengegangen sind. Das Museum wurde in 1901 aufgelöst und seine Bestände wurden auf verschiedene Londoner Museen aufgeteilt. Die Umstände, dass Salviati eine grosse Niederlassung in London hatte und die Technik der Karaffe auf den ersten Blick sehr 'venezianisch' aussieht, mögen zusätzlich zu dem Irrtum beigetragen haben. Die Karaffe stammt aber mit absoluter Sicherheit nicht von Salviati und auch nicht aus Murano/Venedig, sondern mit an Sicherheit grenzender Wahrscheinlichkeit aus Schlesien, und zwar entweder aus der Hütte Hoffnungsthal oder aus der Josephinenhütte.

Meine Zuordnung basiert auf einem relativ differenzierten Indizienbeweis. Die wichtigsten Bereiche der Untersuchung waren:

a) die Handelsverbindungen zwischen England und den schlesischen Glashütten,

b) die Einbindung der schlesischen Glashütten in die preussische Gewerbeförderungsmassnahmen,und die Präsentation von schlesischen Gläsern 'in venezianischer Art' auf Gewerbe- bzw. Industrieausstellungen zwischen 1842 und 1852,

c) die Hüttengeschichte der schlesischen Hütten Hoffnungsthal, Carlsthal und Josephinenhütte, und dabei vor allem ihre personelle und lokale Verknüpfung

d) eine vergleichende Untersuchung zu bestimmten formalen Merkmalen der Karaffe, und

e) eine vergleichende Untersuchung der Murrinen (= Millefioricanes) aus europäischen Glashütten in der Periode 1830–1860.

Aus diesen Untersuchungen resultiert:

a) Der Glashandel zwischen Schlesien bzw. den Schaffgottschen Hütten und England wurde seit der Londoner Weltausstellung 1851 deutlich intensiviert (Steinbeis 1853, 14).

b) Zu den ersten praktischen Arbeiten am Thema Millefioriglas kam es um 1830 in der schlesischen Glashütte Hoffnungsthal (Jargstorf 1991, 31–41; 1993, 513–18). Nur für preussische/schlesische Erzeuger ist nördlich der Alpen ein Angebot von Millefiorigefässen schon VOR 1845 auf verschiedenen Gewerbeausstellungen dokumentiert (Rössler 1843, 275/ *Amtlicher Bericht* 1846, 55).

c) Aufgrund der personellen Verbindungen und der lokalen Nähe konnte es zwischen den Hütten Hoffnungsthal, Carlsthal und Josephinenhütte zu einen direkten Material- und Know-How-austausch kommen, und somit konnte das glastechnische Wissen zum Millefioriglas, dass in der Hütte Hoffnungsthal schon seit den 1830er Jahren gegeben war, vergleichsweise leicht auf die beiden anderen Hütten übertragen werden.

d) Es gibt zwar offensichtlich kein zweites Glasgefäss dieser Machart, das erkennbar denselben Ursprung hat, aber bei Glasauktionen aus den 1980er und 1990er Jahren (Auktionshaus Fischer) tauchten diverse 'Filigran' Karaffen, -Schalen und -Flakons auf, bei denen sich entweder alle an dieser Karaffe vorkommenden formalen Merkmale wiederfinden, oder aber einzelne davon. Betrachtet wurden bei der Untersuchung die Formen des Stöpsels, des Bauches, des Schaftes, des Nodus, des Fusses. Überprüft wurde ebenfalls die Gesamtform, insbesondere der Umstand, dass es sich um ein 'in die Form geblasenes' Glas handelt.Alle diese Stücke wurden in etwa der Zeit um 1850 zugeordnet und mehrheitlich wurde eine Herkunft von der Josephinenhütte angenommen.

e) Für die schlesischen Glashütten kann auf der Basis von Bodenfunden und von Belegstücken (Jargstorf 1991, 35; Kordasiewicz, 2002, 26–7) gelten, dass mindestens die Murrinen aus der Zeit VOR 1850 nicht von Murano/ Venedig inspiriert waren, sondern einer ganz anderen Designlinie folgten. Diese Designmerkmale finden sich an den Murrinen der Karaffe.Vereinfacht kann man sagen, dass die Murrinen der Karaffe alle Merkmale von Prototypen haben, aus denen sich dann etwas später komplexere Murrinen entwickelten, die man heutzutage vor allen Dingen in Briefbeschwerern aus dieser Region findet. Eine vergleichende Überprüfung aller europäischer Murrinen aus der Periode 1830–1860 und der speziellen formalen Merkmale der Karaffe erlaubt es mir, eine Herkunft sowohl aus Frankreich als auch aus Murano/Venedig auszuschliessen. Andere mögliche europäische Herkunftsländer kommen nicht in Betracht. Aus der Summe dieser Untersuchungsergebnisse ziehe ich den Schluss, dass diese Karaffe mit grosser Wahrscheinlichkeit aus den Schaffgottschen Hütten stammt.Ihre herausragende Qualität belegt und bestätigt, warum auf Gewerbeausstellungen der 1840er Jahre das Filigran- und Millefioriglas der Josephinenhütte in den höchsten Tönen gelobt wird (Amtlicher Bericht 1846, 56) Als abschliessendes Indiz für die Herkunft möglicherweise gerade auch dieser Karaffe aus einer der Schaffgottschen Hütten, sei darauf hingewiesen, dass diese Hütten auf der Londoner Weltausstellung von 1851 offensichtlich mit so herausragend guten Gläsern in venezianischer Manier vertreten war, dass der bekannte Glastechnologe Bontemps sie in den höchsten Tönen lobte und dabei insbesondere auf zwei HENKELgefässe hinwies, 'welche die alten venezianischen Glasmeister vor Neid erblassen lassen wurden' (Bontemps 1851, 102) Leider lässt der Kommentar offen, ob es sich bei den angesprochenen Gefässen doch nur um reine Filigran/Netzgläser handelt.

MODERNES SCHLESISCHES/POLNISCHES STUDIOGLAS

Aus den Wurzeln der jahrhundertealten schlesischen Glastradition und in Verbindung mit den Riesengebirgshütten entwickelte sich nach dem zweiten Weltkrieg im jetzt polnischen Schlesien ein äusserst vielseitiges polnisches Glasschaffen, das in seiner künstlerischen und technischen Vielfalt dem böhmisch-tschechischen Studioglas in nichts nachsteht, aber leider ausserhalb Polens ungleich weniger bekannt ist.

In der Vorkriegszeit bzw. in der ersten Hälfte des 20. Jahrhunderts gab es in Polen zwar vielfältige Initiativen im Bereich einer künstlerisch anspruchsvollen Keramik, aber kein Kunstglas von Bedeutung. Nach dem Krieg entwickelte sich dann die Kunstgewerbeschule in Wroclaw (Breslau) zum bedeutendsten polnischen Zentrum für glastechnische Ausbildung und neue glaskünstlerische Impulse. 1953 übernahm Professor Stanislaw Dawski die Leitung der des Fachbereichs Glas, und mit seinem Amtsantritt wurden in enger Zusammenarbeit mit den Glashütten des Riesengebirges die wichtigsten Grundlagen für eine polnische Studioglasbewegung geschaffen.

Anfänglich war das polnische Kunstglasschaffen allerdings noch erkennbar beeinflusst vom Design des russischen Kunstglases und ausserdem stand die Produktion von Gebrauchsglas erkennbar im Vordergrund. Ein internationaler Gedanken- und Künstleraustausch mit dem Westen wurde im kommunistische Polen in keiner Weise gefördert und nur ganz wenigen Künstlern war es möglich, beispielsweise nach Italien oder Skandinavien zu reisen, in die Glasmacherregionen, aus denen in den 1950er Jahren ganz wesentliche Impulse für ein neues Glasdesign und für freies schöpferisches Glasschaffen kamen. Aber schon bei den Werken der polnischen Glaskünstler in den 1960er Jahren kann man eine eigenständige Konzeption erahnen, die dann in den 1970iger Jahren weiterentwickelt wird – auch wenn dieses Glas weiterhin starke Ähnlichkeiten mit dem zeitgleichen russischen Kunstglas aufweist. Schliesslich brachen dann aber die polnischen Glaskünstler in den 1980er und vor allem in den 1990er Jahren mit den alten Bindungen und insbesondere auch mit ihrer Anbindung an die Notwendigkeit, Gebrauchsglas herzustellen. Sie konnten jetzt eigene, private Studios betreiben und konsequent Kunstglas nach ihren persönlichen Vorstellungen schaffen. Einige wenige Künstler aus diesen Jahrzehnten seien hier stellvertretend herausgegriffen. Stanislaw und Pawel Borowski, Vater und Sohn, gehören zu den wenigen polnischen Künstlern, die relativ früh schon ausserhalb Polens bekannt wurden, nicht zuletzt deshalb, weil Stanislaw Borowski 1982 nach Deutschland übersiedelte. Vater und Sohn arbeiten in identischen oder verwandten Techniken. Sie schaffen in mehrschichtigen Überfanggläsern bildliche Darstellungen, die man vielleicht am ehesten mit 'phantastischer Realismus' beschreiben kann. Viele Darstellungen gleichen geradezu alptraumhaften Visionen. Teilweise werden die gravierten Stücke erneut erwärmt und mit farblosem Glas überstochen. Unter der klaren Schicht gewinnen die Darstellungen an zusätzlicher Tiefe (Zelasko 2001, 10–13)

Jerzy und Mateusz Maraj, ebenfalls Vater und Sohn, arbeiten mit der Glashütte in Krosno zusammen, bei der auch Stanislaw Borowski seine Ausbildung erhalten hatte. In ihren Arbeiten dominiert die sehr fein abgestufte Gravur auf Überfanggläsern und bei den bildlichen Darstellungen fallen besonders die karikaturhaft überzeichneten Gesichter auf. Die gravierten Szenen sind sehr komplex und enthalten unendlich viele fein ausgearbeitete Details. Man kann die Darstellungen immer wieder betrachten und auch immer wieder neue Details entdecken (Zelasko 2001, 30–1).

Bei den genannten Glaskünstlern dominiert die 'kalte' Technik der Gravur/des Schnitts, also genau die Technik, die im schlesischen Glasschaffen seit Jahrhunderten eine beherrschende Rolle gespielt hatte. Diese Technik beherrscht ebenfalls das Werk von Maciej Zaborski. Er schneidet zum Träumen anregende Vernetzungen in klares Glas (Zelasko 2001, 54–5) Trotz dieser Verbundenheit mit einer traditionellen Technik stellen diese modernen Künstler in konsequenter Abkehr von den traditionellen, eher rein dekorativen Darstellungen, sowohl mit den herkömmlichen Schneidewerkzeugen als auch mit der biegsamen Welle, äusserst komplexe Inhalte dar.

Im Gegensatz dazu dominiert bei der Glaskünstlerin Barabara Zworska-Raziuk die moderne Technik des 'Fusing', wobei sie die gläsernen Elemente ihrer Skulpturen mit steinernen Komponenten verbindet. Aus ihrer Sicht entsteht erst aus der Verbindung dieses materiellen Gegensatzpaares ein vollständiges Ganzes (Zelasko 2001, 56).

Die teils streng graphischen, teils phantastischen Skulpturen von Stanislaw Sobota bestehen aus vielfarbig in die Form geschmolzenem 'Pate de Crystal', das im Gegensatz zum üblichen 'Pate de Verre' vorrangig transparent bleibt. Die Aussenflächen der Stücke werden teilweise durch Schliff und Politur zusätzlich veredelt (Zelasko 2001, 45–7). In identischer, sehr wirkungsvoller Technik arbeitet auch der polnische Glaskünstler Andrzej Kucharski. Er gehört allerdings nicht zum hier vorrangig angesprochenen Kreis der Künstler aus dem Raum Wroclaw.

Kazimierz Pawlak arbeitet als Glaskünstler und als Dozent, und deshalb schafft er Glasskulpturen in sehr verschiedenen Techniken, wobei er das Glas teilweise auch mit anderen Materialien, wie beispielsweise Metall, verbindet (Zelasko 2001, 34–5)

Diese begrenzte Auswahl an modernen polnischen Glaskünstlern ist sehr stark von meinen persönlichen Vorlieben bestimmt, und deckt bei weitem nicht die gesamte Vielfalt der polnischen Glaskreativität ab. Die gesamte Bandbreite dieses Schaffens kann zur Zeit immer noch am ehesten in den vielen Kunstgalerien von Wroclaw und bei den Glasaustellungen des Museums in Jelenia Gora gewürdigt werden.

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LOST-CLAY MOULDING AND LOW-TEMPERATURE KILN CASTING: TWO REVOLUTIONS FOR *PÂTE-DE-VERRE*

FRÉDÉRIC MORIN AND SALOMÉ

In 1995, when I started to work with *pâte-de-verre* with the aim of producing glass proofs of the works of the famous sculptor Lucien Wercollier from Luxembourg (Philippe 1995, 239–40; Cappa 1998, 342–3, 540–1; Cappa 1999), I was lucky enough to fit my first kiln for *pâte-de-verre* with a 2kw heating element only; and by doing so, made an important discovery. I had left my studio during the first firing and thus had not realised that the actual temperature achieved was not the one I had expected. The element made the process ceiling 740° centigrade for 24 hours. This is usually considered the worst temperature for the Corning optical glass B2359 employed, because of crystallization risks.

This dwell (resting period) at 740°C temperature is only 26°C or 4% above the Littleton Point. Common knowledge tells us that this range of temperature has to be passed across as quickly as possible, otherwise crystallization appears. This is the reason why kilns are usually fitted with 32kw heating elements, and why the kiln is opened after the process to cool the glass inside the plaster moulds.

When my first firing was cold, I was amazed that the enclosed sculptures had not crystallised but were perfectly clear, suitable for optical polishing.

Salomé joined the glass studio in 1998 as a sculptor. She has developed a new process of modelling clay around a core of polystyrene, in a lost-clay process similar to the lost-wax technique employed both for bronze and crystal.

The different attempts we have made since then have made it clear to us that this crystallization temperature can be regarded as a point in the curve, much more than a range. This became evident when we managed, a couple of years afterwards, to avoid crystallization when raising the upper temperature as slowly as possible, in this case 4°C per hour as a maximum for the last 150° before the highest temperature of the process – after that we could maintain the temperature as long as we wished, much more than 24 hours if necessary, without any trouble. Similar experiences have since been conducted with other kinds of glass – barium crystal provided by Philips (The Netherlands) or the soda-lime industrial glass by T.G.I. (Germany) we are employing now – with similar results.

This unexpected original success opened up a wide range of possibilities, which are regarded by Dr Giuseppe Cappa as able to revolutionize the art of statuary if taken with the innovations created by Salomé (Cappa 2001).

We developed a new concept of the process as a whole. First a sculpture is made out of clay pasted onto a polystyrene basic figure. This core of polystyrene (FIG. 1) allows us to approach the form with a low-cost substance,

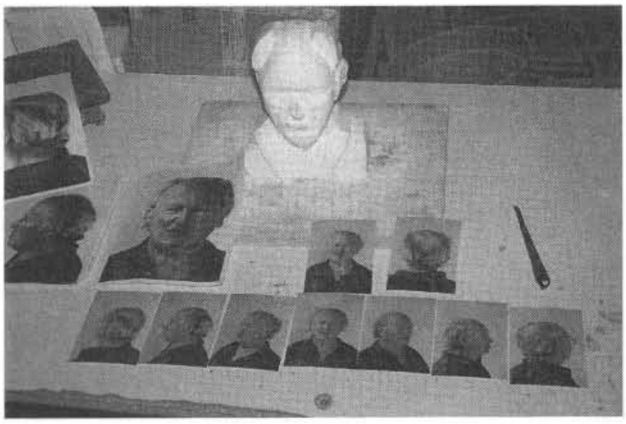

FIG. 1 A low-cost substance, soft and rigid, is moulded on a core of polystyrene; photo Frédéric Morin

both soft and rigid. Clay is pasted on (FIGS 2, 3), kept as wet as possible and modelled with wooden tools, as well as with table knives with different kinds of teeth.

This clay coating is supposed to remain around 10mm thick (FIG. 5), in a way similar to the flexible silicone or elastomere skin around the polyurethane hard-core of a socks-mould. Nevertheless, the sculptor is free to add much more clay than expected as well as to excavate the polystyrene if the sculpture requires it.

After creating about 400 sculptures – including human bodies and animals – we experimented with a portrait which we wanted to be full of living light. We took eight pictures of my father Claude Morin, who created the first independent glass studio in Europe in the year 1970 and had, in Easter 1973, a visit from Harvey K. Littleton and Sybren Valkema together with his students at the Rietvelt Academy. At that time, Claude Morin (whose hobby was previously sculpture) made Sybren's portrait out of clay, made a plaster mould of it and blew glass into this mould (Kermer and Kermer 1993, 43, fig. 16). When attempting a portrait, it was natural, in a way, to celebrate our predecessors (FIGS 4, 12).

When the sculpture made out of clay and polystyrene is finished, the refractory plaster is cast around it and the original sculpture is destroyed inside the plaster. First the polystyrene is scratched into grains with a fork, by hand or using compressed air, until the clay becomes visible. At that point the plaster is near the surface (FIG. 6). The clay is bent into the space left by the polystyrene. Compressed air is useful for cleaning any remaining clay from the plaster. When cleaned and dry (or so regarded), the mould is set

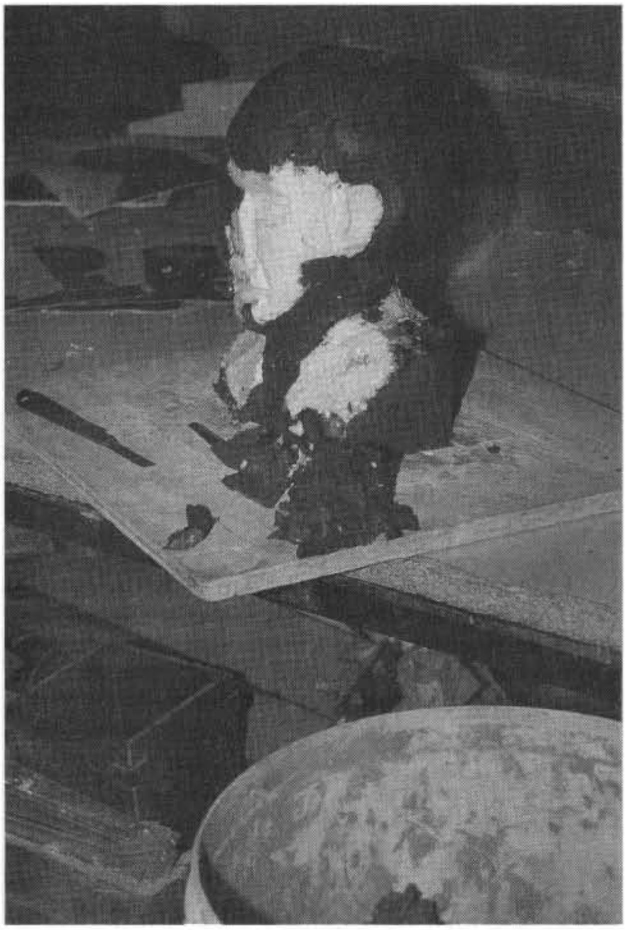

FIG. 2 The clay moulded onto the polystyrene core remains as soft and liquid as required; photo Frédéric Morin

FIG. 4 The finished sculpture before moulding; photo Frédéric Morin

into the kiln with the sculpture upside down. A common clay plant pot is fitted above the opening of the mould (FIG. 7), and filled up with optical glass lenses (from Corning) or rods (from T.G.I.) on which colours are sprayed (FIG. 8).

This technique allows large dimensions (our highest sculpture was 1.5m), and dynamic positions standing out of the vertical – the core of polystyrene stops the wet clay collapsing during the work. Some tricks have been developed to clean the mould where there are thin or inaccessible parts, such as the horns of a bull, or the bill or

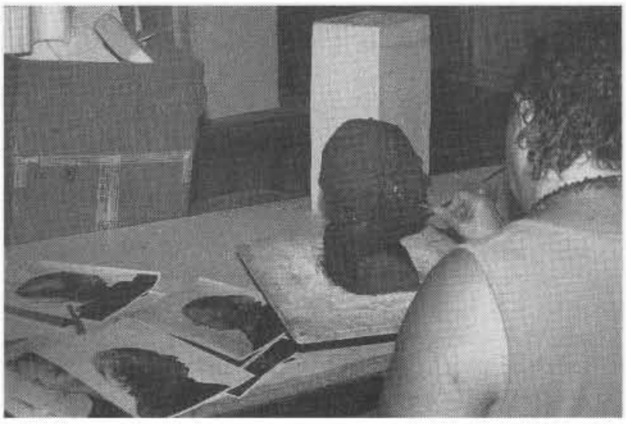

FIG. 3 Salomé finishing the clay from the detailed pictures; photo Frédéric Morin

wings of an eagle. In these cases the polystyrene is left in place, but has been previously polished with the wheel and covered with adhesive tape to give a regular mould, or pasted with lard instead of clay. The final result will appear similar, although these materials will burn into the mould. If the firing is long enough, the glass will form itself into accurate shapes thanks to the air vent-holes, and the burning will not affect the glass with the same reducing effects as would affect lead-crystal.

Although we have now reached 200 firings and 400 sculptures, we continue to note carefully the way we fill the pots and the exact curve followed. A computer takes the temperature up to 740°C at 4°C per hour for the last 150°. Then the glass collapses from the pot through the enlarged hole and fills the mould during the 10–20 hours dwell. The annealing temperature (545°C with Corning optical glass) is reached two days later at a similar speed of 4°C per hour when the dwell will be one day long.

The present curve we employ now with the TGI glass is shown in TABLE 1.

In total our process is 15 days long – 5 days to reach 750°C, 16 hours dwell, followed by 10 days cooling. When cold, the empty pots are removed, the moulds lifted out of the kiln with a crane, and the plaster moulds destroyed with a wood saw and hammer (FIG. 9). The glass-sculpture is then cleaned with water and the feeding cone cut with a diamond saw, this forms the base of the final sculpture.

TABLE 1 CURRENT STUDIO FIRING DATA

desired temperature (°C)	length ramp	speed	length dwell
150°	6h	25°/h	12h
600°	30h	15°/h	0
752°	36h	4°/h	16h
562°	48h	4°/h	24h
462°	48h	2°/h	0
362°	36h	3°/h	0
200°	30h	5°/h	10h
10°	30h	6°/h	END

Only the most careful cleaning, using different bronze or plastic brushes, will achieve the high standards we require of our sculptures.

The low-temperature process discovered by Frédéric Morin (750°C with optical or industrial lead-free glass) produces amazing results in the high quality of the moulds, showing the finest details of the original skin of the clay sculpture such as, for instance, the impression of the cracks of the clay made by a wooden tool that reproduces the detailed effect of a feather (FIG. 10). The medium viscosity of the glass stops it wetting the plaster – glass is in contact with the plaster but does not mix with it as can be seen in FIGURE 10. Consequently, there is no skin to remove as is usual with high-temperature lead-crystal. The light shining through the glass also produces different shades of grey between white and black from each tooth mark of a knife blade, in a way that enhances the relief (FIG. 10). Such effects were managed in lead-crystal at some cost by cutting and polishing, and have never previously been achieved with *pâte-de-crystal* and its common mechanical polishing or acid softening.

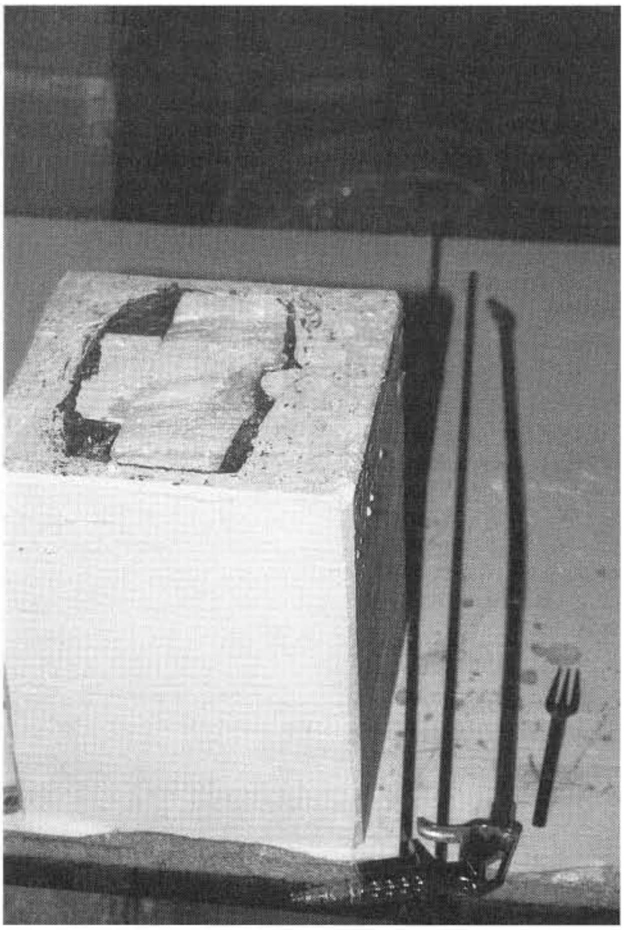

FIG. 5 The clay is just a skin around the polystyrene which is first destroyed. The sculpture is still within the plaster; photo Frédéric Morin

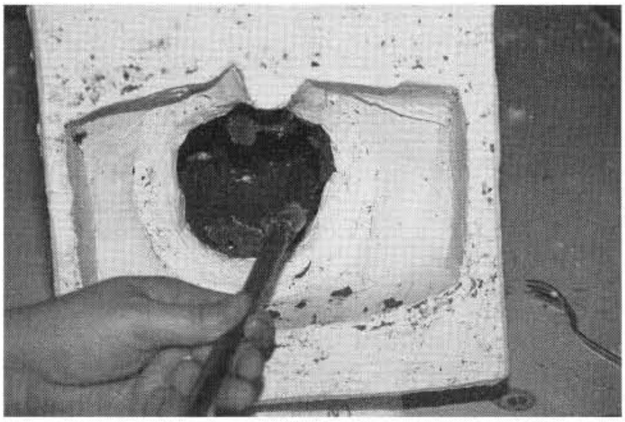

FIG. 6 Compressed air is useful in remove the remaining clay particles from the sculpture; photo Frédéric Morin

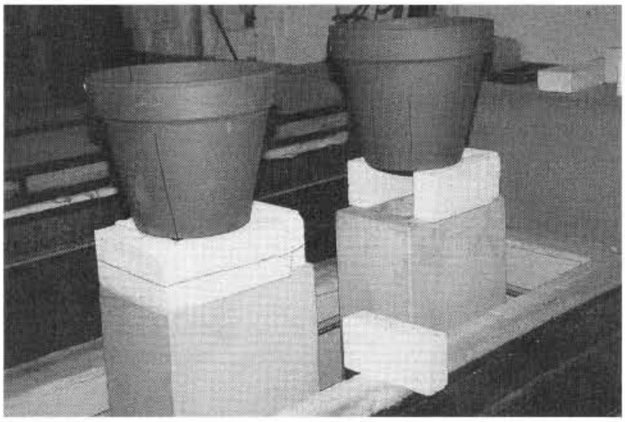

FIG. 7 Plaster moulds and the upper plant-pot for the uncoloured glass rods and colours are placed in one of our electric kilns – note the bricks that give additional volume to offset any retraction; photo Frédéric Morin

Space is lacking here to develop how our process differs from the tradition that everyone knows, but we wish to point out several specific results.

First our process ensures that it is possible to employ lead-free instead of lead-crystal glass for kiln-casting at temperatures suitable for normal moulding plaster. Usually, artists using lead-crystal have 880°C as a minimum for the process, sometimes much more to obtain a very low viscosity (we mean liquid). This is much higher than the blowing temperature with lead-crystal, and a similar viscosity would need 1200°C as a minimum with glass – plaster cannot stand such a high temperature. This first point about the use of lead-free glass leads on to other advantages, in addition to safety. The lead oxide in lead-crystal means that the reducing oxide of copper cannot be used because all the reducing colours would turn black. Using glass, we are now able to produce sumptuous reds, both strong, transparent and luminous, some 100mm thick. Frédéric Morin's sculpture entitled *Red Isis* (N°F-2001-116, ht.

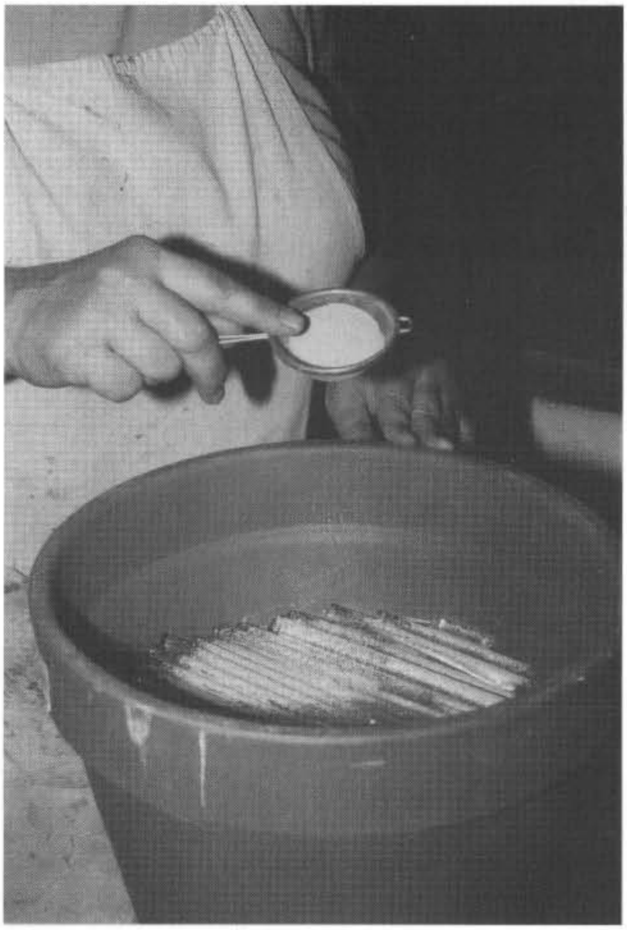

FIG. 8 Powdered coloured glass is sprayed onto the rods to colour the additional casting; photo Frédéric Morin

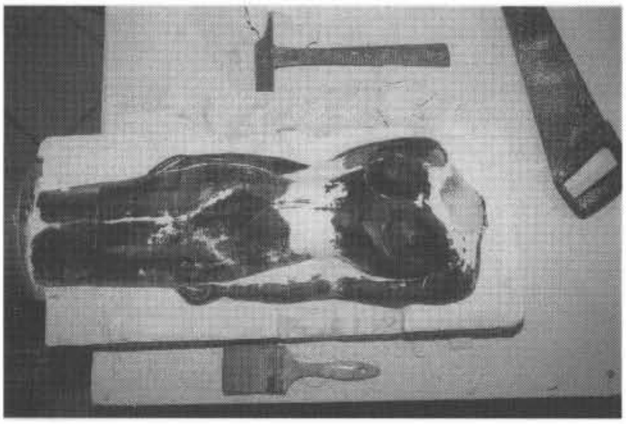

FIG. 9 Dismantling the plaster mould is easily done with a wooden saw and hammer, brushes are used on the final surface of the sculpture; photo Frédéric Morin

0.58m, wt. 20.2kg, now at the Musée du Verre in Sars-Poterie) provides a good example of what has never been seen before (COLOUR PLATE 90). Our oranges and yellows are bright with an unusual strength for glass.

Secondly, as noted above, the medium viscosity of the glass stops it wetting the plaster. Consequently, there is no skin to remove as is usual with high-temperature lead-crystal, and no mechanical or chemical cleaning and/or polishing. This saves money and is beneficial for health.

FIG. 10 Detail of the feathers of Salomé's sculpture *Grand Duc* (N°S-2002-300) – although the surface has not been polished it nevertheless produces a strong effect of alternating dark and light; photo Frédéric Morin

This second point about the medium viscosity leads to another major consequence. Since there is no need for polishing or carving, such as is necessary with bronze, the moulded glass is a perfect reproduction of the original sculpture out of clay created by the sculptor (FIG. 10). This allows the sculptor to play with details of the clay such as the rubbed surface left by a wooden tool and the regular variations in light and dark created by the point of a knife on the clay. A softened clay will provide a satin-skinned glass, and a temperature limited to 736°C will increase its viscosity so that the glass will not be liquid enough to enter the thinnest details of the plaster. Thus the glass will stay bright for it has had no contact! The mastery of the lost-clay process that Salomé has developed in our studio has brought a major contribution to the expressive sculpture we are producing.

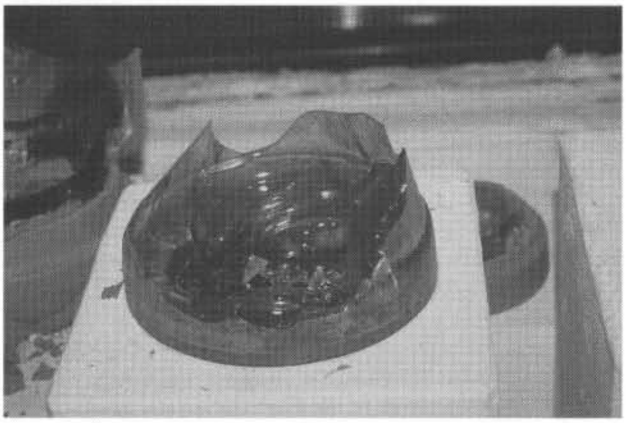

FIG. 11 Following the process in which the glass contained by the plant pot has fallen into the mould, the glass undergoes a *c.* 20% retraction between 750°C and 560°C. In this instance the process temperature (750°C) was much higher than the final temperature (562°C) and *c.* one litre was lost; photo Frédéric Morin

Thirdly, the low-temperature process below the crystallization point allows us to cool the works as slowly as possible – some 4°C per hour to the annealing temperature. We are far from those who open their kiln to cool its contents! During this cooling, a 20kg sculpture

FIG. 12 *Portrait of Claude Morin* by Frédéric Morin & Salomé (N°FS-2003-396, ht. 260mm, wt. 12.7kg). Claude Morin (b. 1932) started the Studio Glass Movement in Europe in 1970 in his studio at Dieulefit, France. Since no further carving or polishing is required after our low-temperature process, this *pâte-de-verre* portrait is one of the numerous new directions opened up by the discoveries of the authors; photo Frédéric Morin

will lose a volume measured as one litre (FIG. 11), and this loss has to be fed by an extra charge of glass. The temperature must remain high enough to allow this, and that is the reason why we never open the kiln at that moment. Our process brings improvements – there is no longer local retraction (usually located on buttocks and breasts) and the plaster has no reason to break. Thus it may stay as fragile, light and thin as possible (though not less than 8mm). Hence this plaster may be used and reused a great number of times, simply adding 20% of new material after grinding. This third point means that, as the evidence suggests, our low-temperature process limits us to strong sculptures since we have to deal with shape effects and viscosity. We cannot produce slim items such as *biscuits de Sèvres*. On the other hand, there is no limit to size other than what we are able to move and the dimensions of the kiln. Our larger kiln is 0.5m wide, 1.55m long and 1.2m high (FIG. 7) – we are among the few people in the world who are able to produce 75kg sculptures without any breakage.

Fourthly, there is no thermic movement in the mould after casting – the glass falls down from the upper flower pot and will remain like that. This allows us to employ colour inside the sculpture in different ways, opening a range of meaning much more interesting than the mixed and soft colours which are ordinarily available. We are able to strengthen a body with an inside column of colour, either to distinguish two bodies of a dancing couple with two different colours, or to bring life into the thick glass with dancing flames of colours. This fourth point allowed us to make a new observation. Everybody knows that a mix of blue and yellow pigments produces a green colouration, and that a yellow light and a blue light will cover each other to produce a red; but no one has ever seen and described the transformation of a white light passing through our colours *AltGold* and *DunkelBlau* from Kugler, Germany. This can be seen on a picture of a couple Salomé made (*Tout-Contre*, N°S-2000-67, ht. 0.56m, wt. 20kg) where the resulting lighting is purple from the two lenses one yellow the other blue, or on the little bowl blown with two colours we showed during the Congress. Where colours are soft, the crossing lighting appears as green, where the colours are strong the crossing lighting appears as red. This opens wide a new and virgin field for science.

Referring to science, our experience of low-temperature processes will lead some of the archaeologists specialising in glass to use this new knowledge in the interpretation of remains and the recovery of ancient techniques. The temperature of 750°C is easy to reach with wood even in a direct-flame kiln, whatever the period and technology. This means that the process may stand long enough at this temperature. Is it possible to imagine a low-temperature blowing, or rather a high-temperature blowing but a low-temperature decoration, in a way similar to lamp-work? This may explain the virtuosity of past blowers.

As another scientific result, we have provided the evidence that the different constituent elements of glass may be affected by movements below the temperature of crystallization. Atoms remain mobile for the glass is still in the state of a liquid. This sheds a new light on the necessity for a quick cooling to obtain glass instead of crystallized quartz after a high-temperature firing, such as is illustrated by Dr Pascal Richet (Richet 2000, 105). It must be remembered that variations of temperature in our process are 4°C per hour or 2°C per hour, as compared to the 1° or 10°C per minute mentioned by Dr Richet between 800°C and 500°C, and that makes a great difference between the two concepts.

This matter may be of interest in the interpretation of the process employed at Bet Eli'ezer, Hadera (6th–7th century AD) in Israel where different melting kilns were discovered (Foy and Nenna 2001, 37–9). The enormous weight of one of the batches recovered, almost 9 tons, is such that it is not possible to imagine that it could be cooled quickly enough, even if doused with water, without breaking the batch. Yet, on the contrary, one of these batches, 3.8 x 1.95 x 0.45m, was recovered whole at Bet She'arim, and the remains discovered at Bet Eli'ezer show that they have been broken by dynamic shocks and not by shrinkage. Based on our experience with heavy sculptures exceeding 60kg, our low-temperature process contradicts the present view which is based only on scientific experiments on small quantities sometimes little more than 5g.

In conclusion, we consider that technique is nothing if not employed to express feelings. As far as we are artists, we act as a sponge – not of alcohol but of human sentiments. We feed our work with the humanism that brings a careful attention to what happens every day, attention to what life is made of, most often as a general perception rather than in individual behaviour. In opposition to the laws of fashion, we give expression to those feelings we are afraid may get lost, that is tenderness, gentleness and sweetness, generosity, happiness, a caressing pride and strength, and also deference, including the right to be different, as well as an interest in complementing one another. Our caressing sculpture is regarded as a gift by those who know a little about life. And our strongly coloured transparent glass sculpture, luminous due to this low-temperature process, enlightens our everyday life.

We would not like to end this paper without giving special thanks to Joseph Philippe, Giuseppe Cappa and Ger Maas who have done so much to support our work, and also to Lucien Wercollier and François Wagner who trusted in our abilities and have supported our enterprise.

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BEADS AND OTHER ORNAMENTS

MOSAIC GLASS NECKLACES FROM PTOLEMAIC EGYPT: GIFTS FOR DEITIES AND THE DECEASED

SUSAN H. AUTH

This paper presents two Egyptian broad collars of fused mosaic glass (COLOUR PLATE 91), places them in the history of this type of jewellery and discusses how they might have been used. Multi-strand broad collar bead necklaces, called *wesekh*, were worn by the ancient Egyptians as adornment during life, and fashioned in less durable form for the use of the dead (Hayes 1953, 306–7, fig. 198). They were painted onto the gesso of anthropoid coffins, and later onto cartonnage mummy decorations. In religious rituals they were given as gifts to deities and to the Pharaohs.

HISTORY AND USE OF BROAD COLLARS IN ANCIENT EGYPT

Men and women, both commoners and royalty, wore broad collars and they also adorned deities and sacred animals. Like many everyday objects in ancient Egypt the form and colours of the broad collar were thought to have protective and magical powers. It was called 'great in magic' and 'master of eternity' (Feucht 1977, col. 933).

Broad collars were worn for many centuries, from the Old Kingdom *c.* 2500 BC, through the Ptolemaic period, 305–30 BC (Wilson 1997, 260). By the Ptolemaic period, however, broad collars were not the style of jewellery worn by the living, but were reserved for funerary and religious use (Andrews 1990, 199–200).

These necklaces were originally made of cylindrical and round beads of green or blue faience (Friedman 1998, 220, no. 100, 123, top pl.). By the Middle Kingdom the Egyptians were able to make faience beads in brilliant colours, such as the blue used in the broad collar of Wah, made about 2000 BC (Andrews 1990, 27, fig. 18). Beads of gold and semi-precious stones were worked into broad collars for royalty and the wealthy (Aldred 1971, col. pl. 10). The stones were chosen for the symbolic power of their colour. Thus cornelian signified life-giving blood, turquoise the regenerating green of new vegetation, and lapis lazuli, the sky and water (Andrews 1990, 37).

Although they were cheaper to produce, necklaces of faience beads were not considered inferior to those of more 'precious' materials. To the Egyptians it was their regenerative and amuletic qualities which mattered (Patch 1998, 42–3). The luminous and sparkling surface of faience was also associated with the sun god (Bianchi 1998, 24). When glass came into use in Egypt its brighter colours and increased shine must have made it even more desirable than faience as a symbolic material.

During the New Kingdom, in the 14th century BC, a new type of broad collar came into fashion using beads of bright multi-coloured faience shaped like flowers and fruit (Friedman 1998, 221, no. 103, 8–9, pl.). Some of the finest examples are products of the royal workshops at Malkata and Amarna (Nicholson 1998, 59–61). Petals of the lotus flower, a symbol of rebirth (Wilkinson 1994, 182), are often included in these necklaces (Friedman 1998, 221).

These faience necklaces are thought to be more permanent ornaments modelled after pectorals made of fresh petals, leaves and fruit. A well-preserved example (FIG. 1), made of leaves, cornflowers, withania nightshade berries and faience beads sewn to a papyrus backing, was worn at the funerary banquet of Tutankhamun, and ritually buried after use (Hayes 1959, 188).

FUNERARY USE

Coffins depicted broad collars as adornment on the deceased and offerings to them. Funerary offerings painted onto the interior of Middle Kingdom rectangular wooden coffins, *c.* 1938–1775 BC include broad collars among the possessions and gifts of the dead (Hayes 1953, 314–15, fig. 205).

During the New Kingdom Egyptian wall paintings inside the tombs depict the deceased and his family wearing broad collars along with their best clothes as they observe scenes of daily life or participate in ritual activities (Shedid and Seidel 1996, 34–6, pls). The same theme is transferred onto a painted panel from a linen shroud made for a man named Hori (FIG. 2). The deceased sits in front of a table piled with offerings. He is dressed in party clothes: a long linen kilt, wig with cone of perfume, and multi-coloured broad collar.

Body-shaped anthropoid wooden coffins replaced the rectangular type shortly before the New Kingdom and

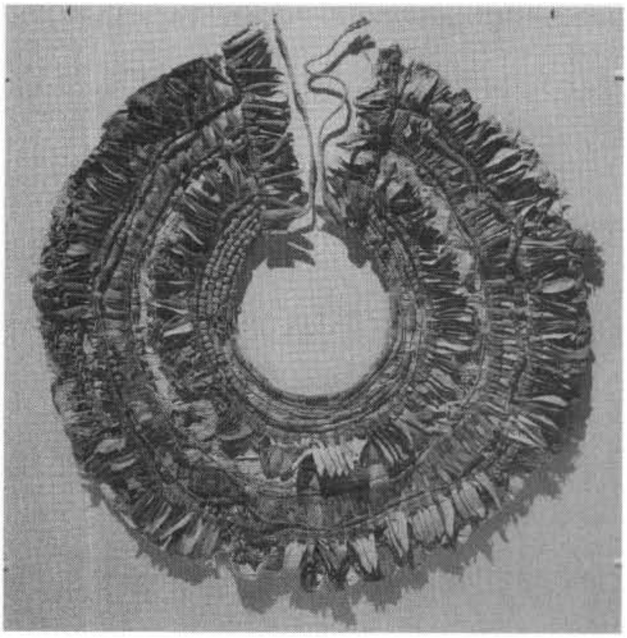

FIG. 1 Floral wreath from Tutankhamun's burial cache. The Metropolitan Museum of Art, Gift of Theodore M. Davis, 1909, 09.184.216 Photo courtesy of The Metropolitan Museum of Art

continued in use for many centuries into the rule of the Ptolemaic Greek kings (1600–200 BC). Now the collars were part of the symbolic images painted onto the wood of the coffin or onto a layer of gesso applied over the wood. A typical 21st-dynasty anthropoid coffin from The Newark Museum, *c.* 1070–1000 BC, depicts the deceased, a singer of Amun, wearing the broad collar. Although the multiple strands of the collar are sketched in a summary fashion, its falcon-headed terminals are clearly depicted (COLOUR PLATE 92). Falcons representing the god Horus were especially used in funerary contexts (Wilkinson 1992, 83, 167).

The size and placement of the broad collar on coffins changes through the centuries, but as protection for the

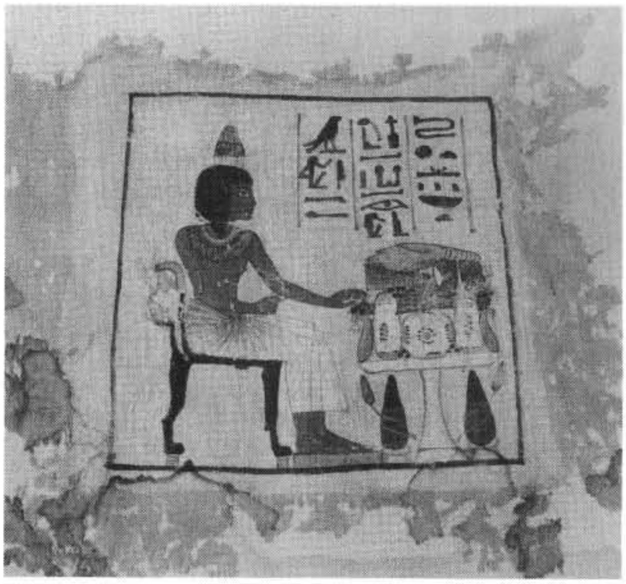

FIG. 2 Painted shroud of Hori. The Metropolitan Museum of Art, Rogers Fund, 1944, 44.2.3 Photo courtesy of the Metropolitan Museum of Art

mummified body it remains an essential element of their decoration (Ikram and Dodson 1998, 209–37, figs 267–314, 324–7).

When wooden anthropoid coffins went out of use, designs were painted onto large pieces of cartonnage. These were attached as separate elements over the linen mummy wrappings. The Ptolemaic-period mummy of Nesumin illustrates the type (FIG. 3). Beneath the gilded mask of the deceased a broad collar with falcon-headed terminals rests over the chest and shoulders. The necklace strands are painted in dark and light blue and muted red with white. Although the beads are rendered as conventional designs, the strand with open lotus flowers is clearly depicted, an indication of the importance of this plant as a symbol of regeneration for the dead.

BROAD COLLARS IN RELIGIOUS CONTEXTS

Broad collars were presented as protective gifts to the deities in Egyptian temples, a practice memorialized by

FIG. 3 Broad collar on mummy of Nesumin – The Metropolitan Museum of Art, Funds from Various Donors, 1886, 86.1.50 Photo courtesy of The Metropolitan Museum of Art

reliefs on the temple walls. From such carvings we know about the broad collars of gold presented by Tuthmosis III to the god Amun at his Karnak temple for use in the daily rituals of dressing his statue (Aldred 1971, 14, pl. 119).

Carved scenes from the Ptolemaic-period temple of Horus at Edfu, built between 237–57 BC, depict offerings of a number of broad collars (Wilson 1997, vii). Some are of semi-circular form with falcon-head terminals (Wilson 1997, 261). Others are long and U-shaped (Steindorff 1945, 41, fig. 2) with nine strands symbolizing the Ennead, the nine gods of Egypt's cosmogony (Riggs 2001, 59–62, fig. 2).

Three disparate objects from the Ptolemaic period have survived by chance to provide a glimpse of broad collars made for temple offerings. The smallest is a pectoral for a small statue. Only 102mm wide, it is made of a sheet of gold with cloisonné inlays of cornelian, feldspar and lapis lazuli (Aldred 1971, 241, fig. 146: Metropolitan Museum of Art). The motifs include pointed and rounded petals and rosettes.

The second example is a fragmentary pectoral with a wood and plaster ground onto which silver and gold cloisons have been inlaid with multi-coloured glass in dark blue, turquoise, red and white. The designs consist of rosettes, papyrus umbels and lotus flowers and buds. It is though to be a funerary collar from a gilded sarcophagus (Aldred *et al.* 1980, no. 179, pl. 193: Louvre Museum).

The third collar is almost complete and very large (Bianchi 1983, 17–18, fig. 11: Brooklyn Museum). At nearly 0.5m in height, it is made to a super-human scale. It is fashioned of wood and plaster, with inlays of gilded plaster and glass. The deep red, turquoise, blue and white colours of the glass are strong and harsh. However, they may have looked different in the dim light of an Egyptian temple sanctuary. The damaged hieroglyphs on the borders may be epithets of King Ptolemy V Epiphanes, 205–180 BC (Bianchi 1983, 17, n. 32). These three offerings give a tantalizing glimpse of the richness of temple offerings even at a late date in Egyptian history.

The mosaic glass broad collars

The use and significance of broad collars through time in ancient Egypt has been discussed to provide a background for the two fused mosaic glass broad collars which are the subject of this paper.

The first mosaic-glass collar belongs to the Corning Museum of Glass (COLOUR PLATE 91 – hereafter Collar Number One). Part of the right side and half of the lowest two rows of decoration are missing. On the right side the collar has sagged inwards and darkened, presumably from fire damage. Its maximum width is now 170mm. Nine rows of fused mosaic plaques survives, each separated by a narrow band of opaque white glass. From top to bottom the designs of each row are as follows:

- Greek-style palmette and ivy leaf design of white, turquoise and red on a black ground
- 4-petalled flowers in yellow with red tips on a dark green ground
- White 8-petalled rosettes with red centres on a black ground
- Egyptian uraeus cobras in medium blue with black details on red ground
- Off-white 8-petalled rosettes with red centres on turquoise ground
- Yellow buds and green leaves on a red ground
- White 8-petalled rosettes with red centres on a red ground
- Black 8-petalled rosettes with red centres on yellow ground
- Alternating groups of three red and three yellow petals on khaki-coloured ground.

Under close scrutiny, it can be seen that plaques with individual motifs were fused together into units before placement on the collar. For example, there is a strip of four yellow and red flowers from row 2, and a repeat of three red and three yellow petals in row 9.

Since the collar is quite deep, it may retain its original number of rows. The finishing border (as in COLOUR PLATE 92), and the falcon or lotus terminals must have been made separately. A miniature mosaic glass falcon on a flat plaque gives an idea of the possible appearance of the missing terminals (Christie's 1993, 58, pl. 157).

The second fused mosaic broad collar comes from a private collection (hereafter Collar Number Two). Since no photograph is available for publication, a description follows. Since both top edges are straight and smooth, this example may be complete in width up to the now-missing terminals. It has seven rows of decoration. As in Collar Number One, the rows of decoration are separated by narrow bands of opaque white glass. The colours are very clear and bright. The designs from top to bottom are as follows:

- Alternating red and blue 8-petal rosettes on white ground. In the course of shaping the collar, the designs have been squashed in from the sides so that many of the rosettes are elongated vertically.
- A dense series of yellow olive leaves in bunches of five, with stems bound together; on a black ground. Twenty three-leaf bunches on the left side of the collar face to the right, while 23 bunches on the right face to the left, meeting in the middle. The colours and design of this band look like a Greek-style gold diadem.
- There are a number of individual plaques similar to the bound-leaf motif, but with three leaves and two red stamens (Christie's 1993, 29, fig. 57).
- Small 8-petal white rosettes with blue centres on red ground
- Yellow 8-petal rosettes with red centres on turquoise ground
- White 5-pointed stars with red centres on black ground
- Small black 8-petal rosettes on yellow ground
- Delicate yellow and white lotus flowers with blue tips and red buds, on a blue ground. There is a narrow opaque white band below.

Both of the mosaic collars show a mixture of Egyptian and Greek motifs. In Collar Number One the palmettes in the top row are clearly Greek in origin. Just as clearly Egyptian is the unusual band of uraeus cobras in the fourth row (COLOUR PLATE 93). Uraeus cobras are placed on the forehead of the pharaohs as a protective and defensive motif. They also appear in pairs on the shoulders of Ptolemaic-period images of the goddess Hathor in mosaic glass (Auth 1999, 58, fig. 5), bronze and faience (Friedman 1998, 215, no. 91, pl. 102).

On Collar Number Two the wreath-like elements are Greek. The lotus flowers in their traditonal position on the lowest strand of the collar are an Egyptian motif. Also Egyptian are the stars on a dark ground, which are used in Egyptian offering scenes of glass as an indication of the heavens (see an earlier inlaid glass example in Auth 1999, 55, fig. 4). Here they seem out of context. Interestingly, the miniature glass mosaic plaque of the goddess Hathor mentioned above (Auth 1998, 58, fig. 5), wears a broad collar with a row of the same star motif and another row of 4-petal rosettes identical to those from Collar Number One.

Each collar uses four rows of rosettes of different colours and backgrounds, stylizations of the daisy-like cornflower of Egypt (Hepper 1990, 14–15, pl. 5). There are many mosaic-glass examples in museum collections. For example at The Newark Museum there is a composite mosaic bar, not yet cut into plaques, with four yellow rosettes on a red ground (Acc. No. 50.985). In The British Museum's Greek and Roman collection there are two examples of red and blue rosettes on white, the motif of the first row of Collar Number Two (GR Reg.1868, 5-1.98).

Comparison with other mosaic glasses

Composite inlay figures combining separate opaque glass body elements with mosaic-glass clothes and jewellery (Christie's 1993, 66, fig. 180), have similar motifs of rosettes and lotus flowers on their broad collars and kilts. The glass workshops clearly used similar mosaic elements for different purposes.

The mixture of Egyptian and Greek motifs on the two glass mosaic collars seems to bear little relationship to traditional pectoral designs. Rather it reflects the mixed culture of Ptolemaic Egypt, and the glass mosaic designs produced by late Ptolemaic glass workshops. The designs themselves and the accomplished technique used to shape and join the narrow curving bands, put them in the ambience of 1st-century BC to 1st-century AD glass production in Egypt (Auth 1999, 69).

Use of mosaic glass collars

How were these mosaic glass collars used? The admittedly tiny sample of three Ptolemaic votive broad collars known to me consists of a very small example suitable for a small statue of a deity or pharaoh, a medium-sized collar thought to be from a coffin, and a large 'display collar'. The two mosaic glass collars, of medium dimension, are sized to a human scale.

Composite plain and mosaic glass figures were inlaid onto small gilded wood shrines (Auth 1999, 53–4, fig. 4). The numerous parts of these figures in private and museum collections have been thought to come from similar shrine scenes. However, 20 years ago Bianchi published a now-destroyed cartonnage sarcophagus with rows of glass figure inlays (Bianchi 1983, 14–16, fig. 6).

Were glass mosaic collars also used on coffins? A gilded stucco coffin from the Siwa Oasis, now in the Alexandria Museum, has groups of brightly coloured figures separated by horizontal bands, and a small broad collar at the neck (Acc. No. 27808). However, only parts of the horizontal bands are composed of mosaic glass, with plain glass separators and possible plain glass sun disks on the falcon-head collar terminals (Aidan Dodson, pers. comm.).

The original function of the two mosaic glass collars under discussion remains uncertain. Further excavation, both in museum store rooms and in the ground of Egypt, may give an answer.

Acknowledgements

My thanks to Yasuko Fujii for providing a photograph of the mosaic bands in The British Museum collection and to Aidan Dodson for information and a photograph of the stucco coffin from the Siwa Oasis in the Alexandria Museum.

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PENDENTIFS EN VERRE SUR NOYAU – NOUVELLE CONTRIBUTION

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PRESENTATION

La présence dans notres musées de pendentifs en verre façonné sur noyau procedents ou non des fouilles systématiques, on fait l'objet des études typologiques générals trés importants.

Les fouilles archéologiques réalisées dans la colonie grecque d'Empúries (Girona), dans les oppida de Sant Julià de Ramis (Girona) et de El Turó del Montgrós (El Brull, Barcelona), et dans la nécropole du Puig des Molins (Eivissa) ont mis en évidence la présence assez nombreux des importations des pendentifs en verre sur noyau produits en Méditerranée orientale principalement par phéniciens, rhodiens et chypriens et plus tard par puniques. Ils sont distribués par le commerce des phéniciens, grecques, et carthaginois en Méditerranée occidentale.

Dans ce travail nous étudions des exemplaires inédites trouvés dans ces sites archéologiques, dans les contextes des IV-III siècles av.-J.C., et aussi un pendentif de l'ancien collection Espona provenant des marchés des antiquités du XIX siècle, que se conservent au Museu d'Arqueologia de Catalunya a Barcelona et Girona (FIG. 1).

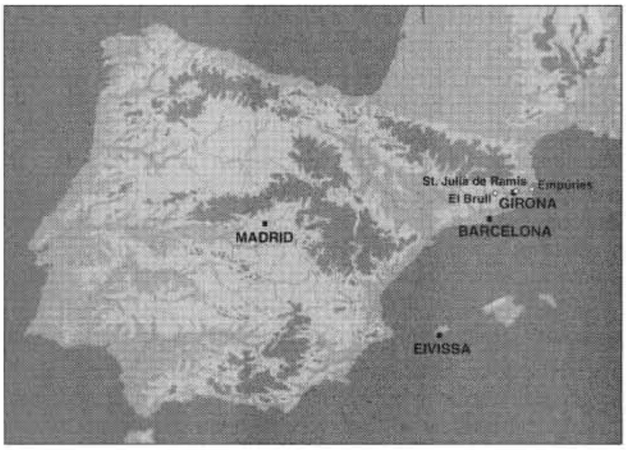

FIG. 1 Carte de la Péninsule Ibérique avec situation des sites

GÉNÉRALITÉS

Ce genre de masques n'est pas particulièrement répandu dans la péninsule ibérique, on les trouve aussi bien dans des sites de *faciès* puniques que grecs ou ibériques, et pratiquement tous proviennent de nécropoles. Le gisement possédant le plus grand nombre de pièces est la nécropole du Puig des Molins à Eivissa (site archéologique fondamentalement punique et romain, comprenant plusieurs périodes s'étalant sur dix phases datables à partir du VIIe siècle avant J.C., avec des restes de la période Phénicienne-archaïque, jusqu'à la fin du XIIe siècle – début du XIIIe siècle après J.C., avec des éléments de l'époque médiévale islamique), la suit avec un nombre plus faible d'exemplaires celle de Empúries (Girona), et de manière sporadique avec un, deux ou trois exemplaires, nous pourrions citer les masques trouvés à Villaricos (Almería), Tortosa (Tarragona), Covalta (Valencia), Son Cresta et la Grotte del Morro (Mallorca), Cancho Roano (Badajoz), La Oseŗa (Avila), La Albufereta (Alicante), Pajares (Cáceres), Castellones del Ceal (Jaen), El Turó del Montgròs (Barcelona), Sant Julià de Ramis (Girona), ces deux derniers ont été trouvés avec certitude au niveau occupé d'une habitation.

L'intérêt de ce travail se situe dans le fait de faire connaître des séries de pendentifs inédits ou uniquement référencés dans des inventaires archéologiques où aucune étude typologique de la pièce n'a été réalisée. Les masques de Empúries, qui sont conservés au Musée de Girona, de même que celui de Sant Julià de Ramis, sont inédits et le pendentif trouvé à El Brull, possède une référence d'inventaire de fouille.

Pour les masques provenant de Puig des Molins conservés dans la collection de verres que Santiago Rusiñol a constituée grâce a ses acquisitions ou des fouilles, au Musée du Cau Ferrat de Sitges, nous avons publié récemment ceux que nous souhaitions présenter ici (Carreras et Domènech 2003), c'est pour cette raison que nous ne nous étendrons pas sur leur description et étude, bien que nous désirions les mentionner en raison de leur importance; il s'agit de quatorze exemplaires, dont un seulement a été répertorié et publié auparavant (Haevernick 1977, 208, no 484). Selon la classification de M. Seefried ils ont les types suivants: type A: trois exemplaires (Carreras et Domènech 2003, 45, no 31,a, b, c), type B II: un exemplaire (Carreras et Domènech 2003, 47, no 35), type C I: deux exmplaires (Carreras et Domènech 2003, 43, nos 29, 47, no 36), type C II: un exemplaire (Carreras et Domènech 2003, 48, no 40), type C IV: un exemplaire (Carreras et Domènech 2003, 48, no 38), type D II: quatre exemplaires (Carreras et Domènech 2003, 47, no 37, 48, nos 39, 45, no 31e, f), et type E I b: deux exemplaires (Carreras et Domènech 2003, 40, no 25a, 49, no 41).

Nous n'avons pas l'intention ici de réaliser une étude des pendentifs en forme de masque, puisqu'il existe déjà des travaux de grande qualité où sont analysés les détails de ceux-ci : les types, techniques de fabrication, chronologie, origine, provenance, diffusion, usage, destination, signification. Nous renvoyons au magnifique travail de Monique Seefried (Seefried 1982) que nous avons utilisé pour la classification de nos masques, ainsi qu'à celui de Thea E. Haevernick (Haevernick 1977) entre autres.

CATALOGUE

Sant Julià de Ramis (Girona)

1 MAC-Girona, no. inv. 2.371 (COLOUR PLATE 94).
Ht: 22; L: 18mm
Visage de couleur beige clair, yeux et sourcils bleu foncé. Correspond à le type Se. C I, 450-300 av. J.C.
Fragmenté, il reste seulement la face, on lui manque la partie supérieure de la tête, les oreilles et la barbe.
Inédit.

Ce masque a été trouvé en 1936, au cours de prospections archéologiques réalisées dans le *oppida* ibérique situé au sommet de la montagne de Sant Juliá de Ramis près de Girona (début du IVe siècle - fin du IIe siècle av. J.C.). Le lieu de la découverte était une zone d'habitations domestiques située près d'une rue et proche de la muraille, cette petite tête a été trouvée près d'autres matériels caractéristiques des villages ibériques du Nord-Est péninsulaire: Une grande quantité de céramiques de production locale (céramique ibérique de tradition hallstattienne et peinte), face à un groupe plus réduit de matériels d'importation (céramiques de type gréco-italique), et une certaine quantité d'objets en fer (lances, épées, couteaux, clous), en bronze (pointes de flèches, fibules) et en argent (fibules, torques) que nous pouvons dater du IVe siècle av. J.C. La situation stratégique de ce village entouré de champs cultivés et sa proximité de la rivière du Ter, qui communiquait directement avec la ville grecque de Empúries rend possible la présence de produits d'importation et, d'autre part, rendent évident le rôle actif de ce village au début de la romanisation.

Empúries (Girona)

2 MAC-Girona, no. inv. 14.640 (FIG. 2).
Ht: 16; L: 12mm
Anneau de suspension, visage et sclérotique de couleur blanche, sourcils bleu foncé, contour des yeux bleu cobalt, iris noir et bouche marron. Correspond au type Se. C IV, 350–200 av. J.C.
Son état de conservation est médiocre, il lui manque les boucles de cheveux et la barbe.
Ce masque fait partie d'un collier formé de 26 perles de verre de différentes sortes, formes et couleurs.
Inédit.

3 MAC-Girona, no. inv. 23.387 (COLOUR PLATE 95).
Ht: 23; L: 18mm
Pâte bleue. Visage, sclérotique et oreilles de couleur blanche, cheveux, barbe, iris et contour des yeux bleu foncé, sourcils bleu cobalt, bouche et boucles d'oreilles jaune. Correspond au type Se. C IV, 35–200 av. J.C.
Fragmenté et restauré, il lui manque l'anneau de suspension et une partie de la barbe du côté droit.
Inédit.

FIG. 2 Masque de Empúries (Girona) no. inv. 14.640

4 MAC-Girona, no. inv. 111.973 (FIG. 3)
Ht: 28 ; L: 13mm
Pâte de couleur turquoise, visage et sclérotique blanc, barbe bleu turquoise, cheveux, bouche, boucle d'oreille jaune, iris et contour des yeux bleu cobalt. Correspond au type Se. C I, 450–300 av. J.C.
Son état de conservation est médiocre, il lui manque l'anneau de suspension et une partie des cheveux.
Ce masque fait partie d'un collier composé de 49 perles de verre de différentes sortes, formes, et couleurs.
Inédit.

Le gisement gréco-romain de Empúries a fait l'objet pendant des années – en particulier avant le début des fouilles officielles en 1908 – de pillages systématiques et fouilles clandestines qui étaient destinés à alimenter en objets les marchés de l'art. Le Museu d'Arqueologia de Catalunya - Girona conserve dans ses fonds une intéressante collection de verres formée par l'achat direct, par la Comision Provincial de Monumentos de Girona, et parfois par le propre Musée, d'objets en verre aux pilleurs qui saccageaient les nécropoles de Empúries, ce qui permet parfois de connaître les circonstances de leur découverte.

Les trois masques de Empúries que nous présentons ici, proviennent possiblement de à l'entour de la nécropole de incinération Bonjoan, cimetière situé au sud de la ville grecque dont la chronologie va de la seconde moitié du VIe siècle au IIIe siècle av. J.C., sur les tombes apparaissent de riches ornements funéraires en matériel d'importation phéniciens, grecs et carthaginois.

El Turó del Montgròs (El Brull, Barcelona).

5 MAC-Barcelona, no. inv. 29.203 (COLOUR PLATE 96).
Ht: 33 ; L: 21mm
Pâte de couleur turquoise, visage, oreille et bouche jaune, sourcils et contour des yeux bleu foncé, sclérotique et

FIG. 3. Masque de Empúries (Girona) no. inv. 111.973

boucles d'oreille blanches, barbe et iris bleu cobalt. Correspond au type Se. C II, 400–300 av. J.C.
N'est conservée que la moitié droite du visage qui est fissurée dans sa partie supérieure.

Ce masque a été trouvé en 1987 dans le *oppida* ibérique de Turó del Montgròs (El Brull, Barcelona – Molist et Rovira 1989)). Il s'agit d'un site ibérique avec présence d'occupation à la fin de l'Âge de Bronze (X–IXe siècle av. J.C.) qui peut être daté depuis le VIe av. J.C. jusqu'au début du IIe siècle av. J.C., avec deux périodes d'occupation et d'abandon.

Le village se trouve au sommet d'une montagne à versants escarpés et protégé par une muraille, son urbanisation interne est peu connue car le sédiment conservé est rare. Les vestiges des habitations trouvés se situent près des zones de défense intérieures ou adossés à la muraille. La tête a été trouvée à un niveau d'occupation du IVe siècle av. J.C., sous le secteur 3, dans un sol de terre avec des cendres, du charbon et d'abondantes céramiques, principalement d'importation (attique de figures rouges) qui coïncide avec la première période d'abandon de l'enceinte fortifiée après un incendie vers le milieu du IVe siècle av. J.C.

Provenance inconnue

6 MAC-Barcelona, no. inv. 17.218 (COLOUR PLATE 97).
Ht: 28; L: 25mm
Pâte de couleur turquoise, visage, bouche, oreilles jaune clair, sourcils, boucles des cheveux, iris et contour des yeux noir, boucles d'oreille et sclérotique blanc. Correspond au type Se. C I, 450–300 av. J.C.
Toute la pièce est recouverte d'une patine de couleur beige clair nacré. Fragmenté et restauré, il lui manque un partie des boucles des cheveux, l'anneau de suspension et la barbe.
Inédit.

Cette pièce à été donnée au musée de Barcelona par José Espona, collectionneur d'art, en 1958, d'après ses informations, il l'acheta à Chypre.

Conclusions

Mis à part le masque du MAC-Barcelona provenant du marché d'antiquités et qui ne peut nous apporter aucune information scientifique sinon celles de la pièce et la réalité de son existence.

Les masques trouvés à l'ancienne ville grecque de Empúries, et à les *oppida* ibériques de El Brull et Sant Julià de Ramis attribuables aux types Se. C I, et CI, trouvés avec matériels d'importation grecques nous croyons qu'ils sont des produits non carthaginois amenés par des commerçants phéniciens et aussi grecs à Empúries. Ils canalisaient une partie de ce commerce vers les centres indigènes proches, où ceux-ci pouvaient les redistribuer dans leur zone d'influence. Ce serait le cas du pendentif trouvé à El Brull.

Pour ce qui concerne les pièces trouvés à Empúries et répertoriées comme Se. C IV, de claire empreinte carthaginoise, il faudrait voir et définir le rôle joué par Eivissa (Espagne) dans ses relations commerciaux avec Carthage et la péninsule ibérique.

Reconnaissances

Nous remercions pour les images le Museu d'Arqueologia de Catalunya.

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PRE-ROMAN GLASS BEADS IN BELGIUM

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Introduction

This paper focuses on the preliminary results of the inventory of pre-Roman glass beads undertaken as part of an inventory of pre-Roman and Roman glass beads and bracelets from Belgium. This inter-university and interdisciplinary project, involving the universities of Brussels (ULB), Gent (UGent) and Leuven (KUL), brings together archaeological, historical and chemical research. Its aim is to obtain a wide-ranging and up-to-date description of all glass beads and bracelets found in Belgium – their shape, decoration, colour, manufacturing technique and dimensions together with chemical and contextual analyses.

With a few exceptions, only published information is used. No research has yet been undertaken in the different collections, institutional or private, and so only an overall picture can be provided.

Chronology

Late Bronze Age

The oldest glass beads in Belgium dating from the late Bronze Age are almost exclusively from Trou de Han at Han-sur-Lesse in South Belgium. The extensive cave of Han-sur-Lesse is one of the most important late Bronze Age sites in Belgium, if not in North-western Europe (Warmenbol 1996a). Underwater archaeology in the river Lesse has produced hundreds of artefacts, most of bronze, some of gold and a few in quite exotic materials. A dozen glass beads dating from the late Bronze Age were identified and might be classified as the oldest glass objects in Belgium and the Southern Netherlands. They have been briefly described (Haevernick 1978; Warmenbol 1996b), but have not been the subject of a detailed academic report.

The beads of interest are the barrel-shaped ones in bluish glass, from turquoise light blue (FIG. 1.1–3) through dark blue (FIG. 1.4, 6) to purplish (FIG. 1.5), with opaque white spirals. Dated to the end of the 11th and the beginning of the 10th century BC they were most probably imported from the Mediterranean. The length of these beads varies between 10 and 15mm and their diameter between 7 and 9mm (Warmenbol 1996b, 54). Known as 'Pfahlbauperlen', they are very well represented in the Swiss lake-dwellings, like Concise, Corcelletes, Cortaillod and Estavayer-le-Lac (Haevernick 1978, 151–2), but also appear at their French counterparts, like Châtillon, Conjux, Grésine and Le Saut, and in the hoard of Réallon, Hautes-Alpes (Haevernick 1978, 155). Up to now the village of Hauterive-Champréveyres has yielded the greatest number, where 86 of the 190 beads discovered came from layers 5–3 dated dendrochronologically from 1050 to 1030 BC. One bead was found in layer 03, dated 990–980 BC (Rychner-Farragi 1993, pl. 115, 13–120, 4). The oldest barrel-shaped beads are to be found in Italy or in Switzerland and belong to 'Bronze final II b' (Ha A2), the youngest are to be found in France and in Germany and belong to 'Bronze final III b' (Ha B2/3).

Five other beads from Trou de Han are spheroid (FIG. 1.7–11), two of them knobbed (FIG. 1.7–8). Four were made of light blue glass, with white spots or eyes, and one is of dark blue glass (FIG. 1.10). These beads, to which we add a possible fragment of a sixth bead (FIG. 1.12), come from the bottom of the Lesse at the Trou de Han. Their diameter varies between 8.2 and 10.4mm and their thickness varies between 5 and 5.8mm except A 70-161 which has a thickness of 8.9mm (FIG. 1.10).

Sites yielding barrel-shaped beads such as Auvernier (Rychner 1979, pl. 100.13–16) and Hauterive-Champréveyres (Rychner-Farragi 1993, pl. 121.1–7) produce knobbed beads as well (i.e. 'Pfahlbaunoppenperlen'), although the latter are much rarer. Five of the 26 triangular or quadrangular beads found were in layer 5 and only one in layer 03. These beads would thus be at least in part contemporary with the barrel-shaped ones, although most of them would be rather later (Ha B2/3), like those from the hoard of Allendorf which contained two quadrangular beads (Uenze 1950, 216, pl. 14.5–6) of a type unknown in the lake dwellings. This type of bead is perhaps not unknown in Han-sur-Lesse (FIG. 1.15).

It is very probable that the glass beads of Han-sur-Lesse were imported from Western Switzerland or Eastern France, like most bronzes found at the bottom of the Lesse. Since no chemical analysis has been done on the Han-sur-Lesse beads, conclusions about the origin of the knobbed beads at least seems premature as they are so widespread (Henderson 1989a). Nevertheless barrel-shaped beads are found in great quantities in Northern Italy, in settlements, such as Montagnana (Chieco Bianchi and Tombolani 1988, fig. 96), as well as in cemeteries such as those around Bologna and Este (Haevernick 1978, 154; Müller-Karpe 1959, pl. 97). In the current phase of the inventory project no chemical analyses have yet been carried out, but when they are made it will be worth checking if all the late-Bronze Age glass beads from Trou de Han and Trou del Leuve at Sinsin (unpublished) are of the group recently distinguished (Brill 1992, 16–17) which consists of mixed-alkali glass and seems to appear from the 11th century BC onwards

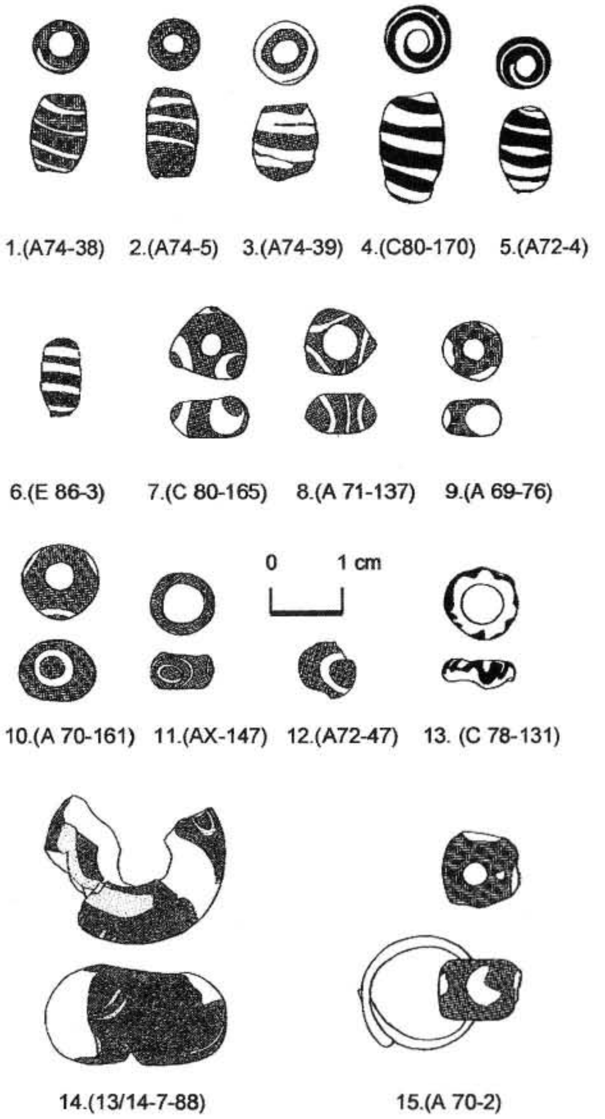

FIG. 1 Glass beads from Trou de Han in Han-sur-Lesse (scale 1:1); drawings by Françoise Roloux

and disappears during the 8th century BC (Gratuze and Billaud 2003, 13). The only production workshop for mixed-alkali glass known up to now is the Protovillanova site at Frattesina in Northern Italy (Bietti Sestieri 1981, 143–8; Nava 1984, 162–3), since recent chemical analyses have provided enough information to prove the North Italian origin of barrel-shaped beads (Brill 1992, 16–17; Gratuze *et al.* 1998, 17–18). These beads must have reached Trou de Han via traders of the Urnfield culture *groupe Rhin-Suisse-France orientale* as there is also the presence in the cave of imported bronze objects from the Swiss-French Alpine region (Warmenbol 1996a) and at least two of the gold ornaments, decorated with filigree and granulation (Warmenbol 1999, 59–61) which are to be identified as imports from the Italian peninsula. The south of Belgium might therefore be seen as a north-western offshoot of the Urnfield culture *groupe Rhin-Suisse-France orientale*.

Early Iron Age

Although Urnfield sites are very frequently attested all over Belgium (Desittere 1968, 133–46) and are almost exclusively cemeteries, only the Ha B/C tomb 50 at Achel-Pastoorbos (Beex and Roosens 1967, 25) (FIG. 2.1), the Ha B tomb 17 at Neerpelt-Achelse Dijk (Roosens *et al* 1975, 19–20) (FIG. 2.2) and the Ha B tomb 1 at Court-Saint-Etienne (Mariën 1958, 148–53) (FIG. 2.3) are known to have contained glass beads. Rather than indicating that glass was rare in Belgium during this period, this might instead suggest only that glass beads were uncommon as burial gifts in the Urnfield culture. Moreover as these three tombs are dating from the Ha B and Ha B/C-period, they may rather be seen as late Bronze Age instead of early Iron Age (Warmenbol 1996b, 55).

Up to now only small undecorated annular beads (diam <15mm) in blue or bluish glass have been found within the urn and they are always limited to one specimen in each burial. As can be deduced from their deformation by heat, the beads of Neerpelt and Court-Saint-Etienne must have been a primary burial gift. The thesis might be advanced that glass beads, like a large number of bronze objects, were most probably worn when the body was put on the funeral pyre. As the deceased might have worn a number of beads there might have been an Urnfield tradition or ritual whereby the bereaved thought it appropriate to gather and deposit only one bead at the burial. Further research and more archaeological evidence are needed to find out why only one bead was collected. If the bead was worn individually and no correlation is noticeable between the presence of glass beads and burial wealth, beads might have been seen as amulets and not just as ornaments or commodities (Venclova 1990, 106). As the context of the three discussed tombs gives no reliable information on the use and significance of the beads, one might only suppose the glass beads were part of a necklace and had significance as an amulet or talisman.

The anthropological study of the cremated bone fragments attributes the tomb from Neerpelt to a child (Roosens *et al.* 1975, 34, no. 17). And although the Achel tomb is that of a woman younger than 25 years old, the remains of a foetus were also found within the urn (Beex and Roosens 1967, 25, no. 50). Given this evidence, the glass beads might have been a typical burial gift for children. Venclova has already stressed that the majority of the wearers and owners of beads were women and children (Venclova 1990, 104).

Middle Iron Age

Up to now the very important early La Tène (LT A) stronghold of Kemmelberg in south-western Flanders has produced almost no glass. Only two small undecorated annular beads are recorded, a round deep-blue bead (FIG. 2.4) with a diameter of 13mm and an irregular olive-green bead (FIG. 2.5) with a diameter of 13–15mm (Van Doorselaer 1987, 40, no. 14-15, fig. 108-4/5). In comparison with the glass beads from Kemmelberg, those from the LT B2 chariot grave II,1 found in Neufchâteau-le-Sart are worth mentioning. The 24 undecorated beads are defined as a necklace (Cahen-Delhaye 1997, 73–4, fig. 17.44), but the calculated length of 235mm is insufficient to go around the neck. As all the beads were concentrated in an area of 170mm between two bronze brooches on the breast near the head, it might rather be that the beads together with the bronze brooches were used to fasten a cloak.

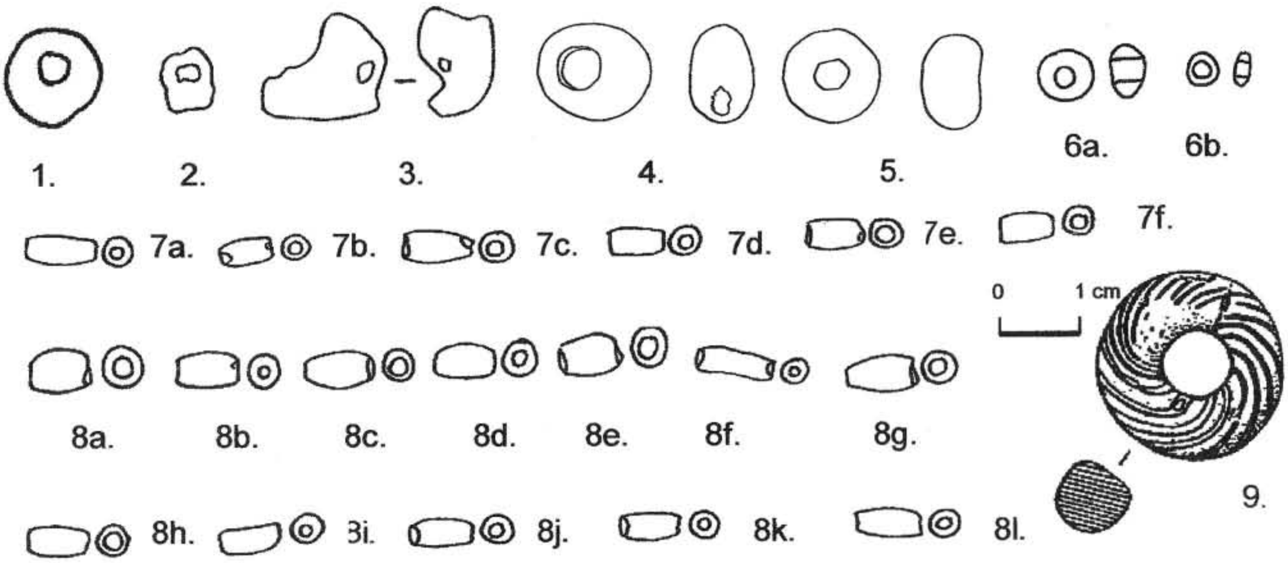

FIG. 2 Glass beads from 1: Achel, 2: Neerpelt, 3: Court-Saint-Etienne, 4 and 5: Kemmelberg, 6–8: Neufchâteau-le-Sart, 9: Trou del Leuve, Sinsin; 6a–b, blue, 7a–f, brown, 8a–l, black

Besides the two very common annular beads (diam 9 and 5mm) in blue glass (FIG. 2.6a–b), the 22 beads are in brown (10) (FIG. 2.7a–f) or black glass (12) (FIG. 2.8a–l) (Cahen-Delhaye 1997, 26, no. 44). The brown and black beads have an oblong shape with a thickened middle. The length varies between 9 and 12mm. The body of the beads is of olive-stone shape, but the colour is presumably an imitation of beads in amber and lignite/jet for, respectively, the brown and the black glass beads. In contrast to the intact black glass beads, the brown beads are crumbly (and therefore impossible to draw). The presence and absence of certain oxides probably contributes to the difference in preservation of the two different coloured glass beads. The chemical composition of these middle Iron Age beads in black and brown glass has still to be analysed.

In general brown-coloured glass beads and bracelets are from the La Tène C2/D transition period (125–100 BC) onwards and remain in production until the La Tène D2 period (end 1st century BC–early 1st century AD) (Zepezauer 1993, 95–7). Nevertheless honey-brown beads are also attested in central Europe during Ha C (Venclova 1990, 98). Radiocarbon dates the chariot grave from Neufchâteau-le-Sart to between 400 and 205 BC, but typologically this tomb is dated in general between 300 and 180 BC and more specifically in the second quarter of the 3rd century BC (Cahen-Delhaye 1997, 25, 64, 87).

The so-called black glass from the pre-Roman period is in reality a very dark opaque glass in blue, purple or brown colour though in contrast the black beads from Neufchâteau-le-Sart are made of very dark olive-green opaque glass. A dark-green glass appearing black is considered to be typically Roman, yet the chariot grave II,1 from Neufchâteau-le-Sart dates from the 3rd century BC. As the Ardennes in Belgium and/or Ardenne/Champagne in France can be seen as the area(s) where black glass is produced one might consider that the black glass beads from Neufchâteau-le-Sart were produced locally in the broad sense of the word.

Late Iron Age

Due to the paucity of publications the study of the late Iron Age glass beads from Belgium is in a very preliminary stage. What causes most difficulty is the context as many of these beads are found in early-Roman ones. An investigation in depth of context is essential for a better understanding.

From a sub-aquatic context in Trou de Han (Warmenbol 1999) comes a badly preserved large annular bead (FIG. 1.13) in dark, almost opaque, blue glass with marvered opaque white spirals (alternating one large and two small). This type of bead can be catalogued as an Oldbury type of Guido's class 6 (Guido 1978, 53–7) and as type Zepezauer IV.1(.1) (Zepezauer 1989, 113). In Great Britain a date is given between 150 BC and the first decades of the 1st century AD with a peak during the later 1st century BC (Guido 1978, 54–6). On the continent the Oldbury type is attested from the transition of LT B2 and LT C1 (270–250 BC) until LT D1 (50 BC). No example is known from a LT D2-context (Zepezauer 1989, 118).

As well as functioning as an ornament, this type of bead is also supposed to have had the function of an amulet (Zepezauer 1989, 119). The cult connotation of Trou de Han with ritual depositions from the Bronze Age onwards are noteworthy.

Another late Iron Age glass bead from the same sub-aquatic context in Trou de Han is a colourless bead with yellow opaque zigzags (FIG. 1.14). This small annular bead can be catalogued as a Meare variant of Guido's class 11g (Guido 1978, 81–4). A similar bead is found in Ekeren (Verbeeck *et al*. 2004, 169). Both beads have an outer diameter of 10mm. These beads are dated between the 1st century BC and the 1st century AD (Guido 1978, 83). Of British origin, they are considered to originate from Meare (Henderson 1989a, 64–7).

Near Trou de Han another cave, Trou del Leuve at Sinsin, yielded a late Iron Age glass bead (Warmenbol 1984, 7, pl. 2, no. 1). This large annular bead (outer diameter 26.6mm) in brown glass has a ray design in yellow opaque glass (Haevernick 1960, type 23) (FIG. 2.9). It comes from central Europe and seems to originate from Stradonice although other local production centres might have existed (Venclova 1990, 140–1). This type of bead is dated to the LT D1 period (100–50 BC) (Zepezauer 1993, 59).

This tentative and preliminary research of a limited number of sites with glass beads has already resulted in new findings. The present state of affairs only strengthens the need for an exhaustive inventory of pre-Roman glass beads in Belgium.

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JAVANESE (JATIM) BEADS IN LATE FIFTH TO EARLY SIXTH-CENTURY KOREAN (SILLA) TOMBS

JAMES W. LANKTON, IN-SOOK LEE AND JAMEY D. ALLEN

INTRODUCTION

As early as 1921, when schoolchildren were seen to be playing with glass beads exposed by grading for railway construction (Nelson 1993, 251), archaeologists began to excavate a number of the over 150 mounded tombs in the centre of Gyeongju, Korea, uncovering remarkable gold crowns, belts, earrings, rings, and bracelets, as well as tens of thousands of glass beads and other ornaments. These mounds are now known to be the elite tombs of the Silla Kingdom (*c.* 300 to 668 CE), with at least some of the tombs being the burial places of Silla kings.

Close inspection and scientific analysis of the glass beads suggests several possible bead making sites and techniques, both local and foreign (Lee 1994; 1997; Lee and Wypyski 2002). This paper will focus on five polychrome glass beads found in four different graves in Gyeongju. Four of these beads appear to be identical to beads thought to have been made in eastern Java, and the fifth, while unique in the archaeological literature, is sufficiently similar in technique of manufacture to suggest a similar origin.

ARCHAEOLOGICAL EVIDENCE

The Silla Kingdom developed rapidly during the late 3rd to 4th century from its origins among the Chinhan peoples of the south-eastern Korean peninsula. From the 4th to the early 6th century, the most obvious evidence of social stratification was the construction of large mounded tombs in the Silla capital at Gyeongju (Barnes 2001, 208). The tombs appear to be of at least two types, one with a single wooden burial chamber containing a wooden coffin and a separate box for grave goods, and the other with multiple smaller chambers containing either burials or grave goods (*ibid.* 214–15). These inhumation graves were covered by stone mounds, which were in turn covered by an earth mound with a typical height from 10 to 15m. Because the stone mounds usually collapsed, closing off the wooden chambers, the mounded tombs were very difficult to plunder, and most of those excavated have been intact. The single chamber tombs generally contain richer grave goods, including, in some cases, glass vessels, gold crowns, and thousands of monochrome glass beads; at least some of the single chamber tombs are thought to be the burials of Silla kings and queens or nobles. Many of the other mounded tombs also contain prestige objects, including gold jewellery and glass beads. The soil conditions are such that little skeletal material has been recovered, and, with

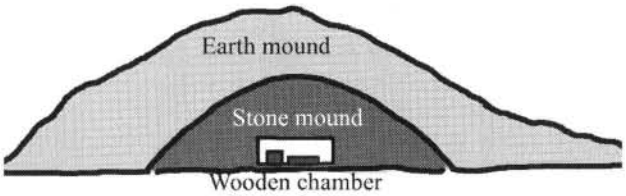

FIG. 1 Structure of Silla wooden chamber, stone-mounded tombs; mid 4th to early 6th century; adapted from Barnes 2001, 209

rare exceptions, it is not known whether the graves were male or female. All of the wooden chamber tombs are thought to predate the mid 6th century, when stone chamber tombs become more common (*ibid.,* 208, 211). The structure of a typical mounded wooden chamber tomb is shown in FIGURE 1.

FIGURE 2 shows the location of several tomb clusters, indicating the approximate find-spots for the beads in this report. We have designated these five beads as follows:

1 Noseo-ri A (COLOUR PLATE 98.1a): A small glass bead covered with a mosaic layer of alternating green and yellow stripes, which have been combed into a festoon pattern; L. 12mm, diam. 14.5mm. This bead, on display in the Seoul

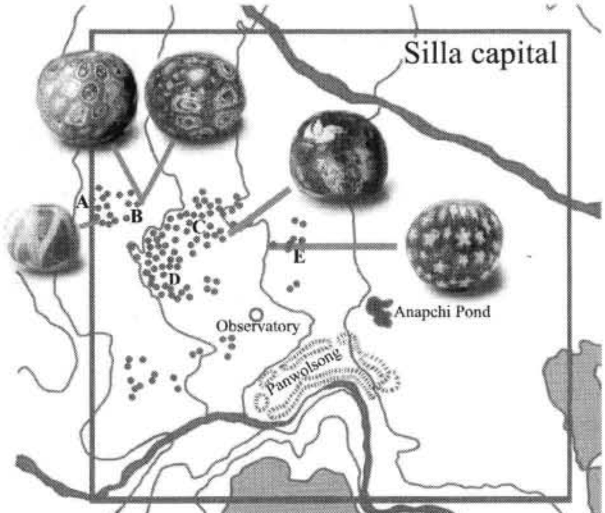

FIG. 2 Mounded tomb clusters in Gyeongju, with excavation sites of beads included in this report; map adapted from Barnes 2001, 225; A Noseo-ri, B Nodong-ri, C Hwango-dong (includes King Michu Tumuli District), D Hwangnam-dong, E Inwang-dong

National Museum along with cornelian, amber, jasper and monochrome glass beads from the same grave (COLOUR PLATE 98.1b), was excavated in 1933, with an estimated date from the late 5th to the early to mid 6th century. Distinctive characteristics of the bead Noseo-ri A include the bright yellow diagonal stripes, and the more complex bands with multiple thin stripes. These patterns appear to be pulled toward the perforations of the bead, suggesting formation by segmenting a glass tube. Because of the elite nature of the excavated beads, the Noseo-ri A burial is thought to be from a large mounded tomb whose mound had been lost over time (pers. comm. Dr B. Pak, Curator at the Gyeongju National Museum, June 2002).

2 and 3 Sikrichong A and B are *millefiori* mosaic glass beads found during the 1933 excavation of Sikrichong, the Ornamental Shoes tomb, a large, late 5th to early 6th-century, mounded royal tomb.

2 Sikrichong A (COLOUR PLATE 98.2a–c): A *millefiori* mosaic bead with an underlying monochrome glass core; diam. 21.3mm, perforation diams 2.9mm and 3.1mm. The superficial mosaic canes show two different patterns: blue and white concentric circles built up by applying successive layers of glass to a blue centre, and a more complex cane with a layered yellow and red centre surrounded by blue and white spokes formed by manipulating either cold or hot strips of glass into position. The cane segments appear to be distorted toward the perforation at one end of the bead, best illustrated in COLOUR PLATE 98.2c, while the other end does not show this distortion.

3 Sikrichong B (COLOUR PLATE 98.2d–g): A *millefiori* mosaic bead with five different mosaic cane designs; diam. 21.5mm, perforation diams 3.8 to 4.5mm and 3.7 to 3.8mm. Although the thin mosaic slices would have been circular in cross-section when applied to the bead, when partially melted together they assume the polygonal shapes most obvious in COLOUR PLATE 98.2d and e. The simplest, layered, cane is similar to the blue and white cane on Sikrichong A, and can be seen in COLOUR PLATE 98.2e. There are two versions of canes with a central star surrounded by glass of a contrasting colour – white and blue, and yellow and green. These cane designs are best seen in COLOUR PLATE 98.2d. In both cases, the stars appear to have six points. The other two cane designs on Sikrichong B are more complex: the first has a dark green core surrounded by alternating strips of red and white to form a ring pattern with six parts, which is then surrounded by layers of dark green, white, and finally red. The second complex cane has a monochrome white centre surrounded by a ring made up of twelve sections of alternating red, yellow, and green, all of which is then layered with white. This cane is best seen in COLOUR PLATE 98.2d. COLOUR PLATE 98.2f and g show the two ends of Sikrichong B. One end has clear evidence of distortion of the canes toward the perforation, while the other does not.

4 Inwangdong A (COLOUR PLATE 98.3): A *millefiori* mosaic bead with one mosaic cane design; L. 19.5mm, diam. 22.7mm, perforation diams 4.2 and 4.2mm. This bead was found in Inwangdong tomb number 6, excavated in 1977 by a team from Yeungnam University. Inwangdong 6 is thought to be late 5th century, and certainly no later than the very early 6th century, thus preceding Sikrichong, and making Inwangdong A the earliest bead in our series. With the exception of a relatively large area showing the rough basal glass visible in COLOUR PLATE 98.3d, the surface is covered by cane segments with a white star surrounded by greenish blue. The diameter of the star patterns varies slightly, although all of the stars clearly have five points, with a design otherwise similar to the six-pointed stars on Sikrichong B. The cane distortion at one end matches that on the Sikrichong mosaic beads.

5 National Treasure 634 (NT634) (COLOUR PLATE 98.4): A *millefiori* mosaic bead with three different figural canes; diam. 18.4mm; excavated in 1973 by a team led by Lee Eun Chang from what appeared to be a wood chamber, wood coffin, stone-mounded tomb with a separate area for grave goods, although the mound had been lost over time. The grave is one of over 50 located in the King Michu Tumuli District to the north of the large mounded tomb known traditionally as that of King Michu. The mosaic bead was found together with the additional beads shown in COLOUR PLATE 98.4a, along with an elaborate pair of gold earrings of the type associated with royal graves. The entire group is on display in the Gyeongju National Museum (Gyeongju National Museum 2001, 132). The suggested date for this tomb is late 5th to early 6th century (Pak 2002, 101), and certainly no later than the mid 6th century, when, as noted, the wood chamber tombs were no longer used.

The three mosaic cane patterns on NT634 are a white face, including the neck and part of the shoulders, a white bird and a branching shape interpreted as a tree or flower. Four colours of glass were used to produce the mosaic designs – white, red, yellow, and dark blue. There are four faces on the bead, and in spite of some distortion, it appears that they all originate from the same cane. Prominent features include round eyes; slightly arched, continuous eyebrows; a blue hairline above the forehead; a long, straight nose; red lips; two blue lines on the neck, one of which may indicate the chin; rather long ears applied separately as the composite cane was produced; and the suggestion of three shapes in red and yellow rising from the top of the head at the 10, 12, and 2 o'clock positions. Three of the cane segments show the bridge of the nose to the right, while the fourth shows the bridge to the left, indicating that this cane section had been flipped over prior to being applied to the bead.

The bird image, with its long beak, large feet, short neck, and squat body, has been interpreted as a duck in Korea. The round eye, in blue and white, is identical to the eyes on the human face, suggesting that the bead maker used a similar prefabricated cane for both images. The wing is a separate unit, and the feather markings along the trailing edge are similar to the star patterns on both Sikrichong B and Inwangdong A, suggesting a common manufacturing technique. The four birds on NT634 appear to be slices of the same cane, and again, one of the slices was flipped over to show the bird walking toward the left, rather than toward the right as in the other three sections.

There are also four examples of the flower or tree cane (COLOUR PLATE 98.4c) interspersed over the surface of the bead, appearing to be sections of the same cane. Like the other designs on the bead, this one also is a hybrid of composite and layered construction, with an outer layer of dark blue glass. The central stem has three sets of branches to the sides, of which two end in flower patterns. The other two branches are quite short, and the end of the stem also has a flower, giving a total of five. Each flower has four petals around a red centre. As with Inwangdong A, there are no obvious borders between the cane segments, since all of the canes were cased in dark blue.

NT634 has a number of important features in common with the other *millefiori* mosaic beads in this report: the shape and size are roughly similar, and the construction of the bead appears to be that of thin slices of mosaic cane laid over a core of glass. Most importantly, the cane sections are distorted toward the perforation, as shown in COLOUR PLATE 98.4b for one end of the bead, and in a photograph published by Yoshimizu for the other (Yoshimuzu 1993, 56).

JAVANESE ORIGINS

These five beads found in Korean tombs share many characteristics with a group of glass beads known as *Jatim* for their strong association with eastern Java, or *Jawa timur*. Jatim beads may be monochrome or polychrome; the two groups which concern us are the *pelangi*, or rainbow, beads, and the *millefiori* mosaic beads. Although few Jatim beads have come from controlled excavations, and none, with the exception of those reported here, from well-dated contexts, the association with eastern Java is very strong, leading Francis to conclude that Jatim beads 'likely originated in or around Jember' (in eastern Java) (Francis 2002a, 136), basing his opinion on the following points:

1. At the turn of the 20th century, Dutch archaeologists reported these unusual beads in megalithic graves near Bondowoso and Besuki (also near Bondowoso) in far eastern Java (Adhyatman and Arifin 1996, 65). The vast majority of Jatim beads have been found in that same area (Francis 2002a, 135), with very few from western Java or neighbouring parts of South-east Asia (Adhyatman and Arifin 1966, 67). Exceptions include small numbers of beads, usually of the less diagnostic twisted stripe variety, found in Malaysia, Sumatra, Kalimantan, Johore, the Philippines and possibly Oc-eo and Japan (Francis 2002a, 135). Francis reports a surface find of one *millefiori* mosaic bead of Jatim type at Berenike, Egypt, possibly dating to the mid 6th century (Francis 2002b, part 3). The known exception to this limited spread of Jatim beads is their use as heirloom currency on the Pacific island of Palau, 1600 miles north-east of Java, which may be the result of early maritime contact (Francis 2002a, 190).

2. Surface finds of misshapen and partially melted *pelangi* and *millefiori* beads at Jatiagung, near Jember, in far eastern Java, are taken as evidence for local bead making (see Adhyatman and Arifin 1996, 71, for two of the large *pelangi* beads found near Jember). In contrast, there is no other evidence for the manufacture of Jatim beads, either in Java or elsewhere.

With no well-supported dates for Jatim beads based on scientific excavations in Indonesia, Adhyatman and Arifin have suggested a manufacturing period between the 7th and the 10th century based on local reports that Tang Dynasty (618–906 CE) ceramics have been found in the same graves (Adhyatman and Arifin 1966, 41). There are many important and unanswered questions regarding the origin and early history of glass bead making in Java, as well as the integration of eastern Java with contemporaneous South-east Asian sites, including Mantai, Oc-eo, and Khlong Thom, thought to be involved in the manufacture of Indo-Pacific glass beads. Although some, but not all, of the mosaic patterns on Jatim beads are similar to those on beads made in Egypt or possibly western Asia, the developmental relationships are not clear. The nature of any contact, whether in terms of trade in mosaic glass canes or in terms of actual travel of bead makers from Egypt, western Asia, or Java, is not known.

The special technological aspects of Jatim beads are important in making the case that the five beads excavated in Korea are in the Jatim tradition. *Pelangi* beads come in a variety of sizes and colours, with the most common combinations being blue and white; red, yellow, blue, and white (the same combination of colours as on NT634); and green and yellow, as in Noseo-ri A. All are characterized by a surface pattern of rows of festoons joined by bands of multiple fine lines. Allen has suggested the following process for making such beads as Noseori A – a drawn tube of glass with a mosaic surface layer of alternating green and yellow longitudinal stripes was twisted to produce a pattern of spiral yellow stripes; these stripes were then combed into festoons, with each combing motion extending the full length of the tube. Each combed stripe will contribute two thin lines of yellow to the band cross-cutting the diagonal festoon pattern. By the time five stripes have been crossed, this band will consist of ten thin lines, which may in fact begin to blend together. Similar patterns may be seen on small glass vessels with a combed trail decoration (Tait 1991, 95). The entire construction was then segmented, or hot-pinched, into individual beads. Although each individual bead may have only one or two rows of festoons, the bands between will reflect the multiple stripes that have been combed on the surface of the parent tube. Occasional examples of doublet beads remaining conjoined are further evidence for the segmenting process. Both the appearance of the finished beads, and the use of segmenting for decorated beads, appear to be unique to eastern Java (Allen 1998, 107, 138–9). Large *pelangi* beads have many rows of festoons, while such small beads as Noseo-ri A may show only part of a row, making the festoon pattern less obvious. However, Noseo-ri A's pattern of bright yellow stripes alternating with broader bands containing multiple thinner stripes, coupled with the appearance of segmenting at the perforations, would only be found on a bead made by the *pelangi* technique, and, in fact, such small yellow and green *pelangi* beads are rather common among beads found in eastern Java. Because the manufacturing technique is thought to be unique to eastern Java, we conclude that Noseori-A is a Jatim bead.

Jatim *millefiori* mosaic beads are also unusual, and the four *millefiori* mosaic beads in our sample reflect some of the same special bead making technologies used in eastern Java. During the 1st millennium CE, the two principal techniques for making *millefiori* mosaic beads were the formation of a bead by fusing together thick mosaic sections, without an underlying core, and the use of thinner slices of mosaic cane to cover a prepared glass bead; neither technique can be considered necessarily early or late (see Lankton 2003, 77–81 for discussion). Jatim *millefiori* mosaic beads are unusual in that the thin layer of mosaic sections appears to have been applied in some way to a tube, rather than to an already formed bead. In a method analogous to the *pelangi* beads discussed above, this decorated tube would then have been segmented, or hot-pinched, into individual beads. At least one end of the finished bead will show evidence of the mosaic canes being distorted toward the perforation. If the tubes were short, many beads would show pinching at one end only, as is the case for Sikrichong A and B and Inwangdong A. This combination of segmenting with *millefiori* decoration is very unusual, and the authors are not aware of any other bead making industries exploiting the hot-pinched method for the production of intricately patterned beads. In addition, the two most complex cane designs on Sikrichong B have been found only on Jatim beads (Adhyatman and Arifin 1996, 49; Allen 1998, 102, 108).

While beads such as Sikrichong A and B and Inwangdong A (Adhyatman and Arifin 1996, 56) resemble known Jatim examples, NT634, with its figural mosaic patterns, is unique among published beads. The only comparable bead we have found (COLOUR PLATE 98.5) is in the collection of The Bead Museum in Glendale, Arizona. This bead, with an unknown provenance but thought to be from Java, shares similar bird and face canes with NT634, along with three other canes consistent with Jatim designs. On the basis of overall construction, and in particular the combination of segmenting with a thin surface layer of mosaic cane slices, we would identify NT634 as a Jatim bead as well. The Arizona example suggests that others might be found, which could help to strengthen the case for NT634's Javanese origin.

Summary

We have presented five polychrome glass beads scientifically excavated from late 5th to early 6th-century Silla tombs in Gyeongju, Korea, and propose the following conclusions:

1. These five beads found in Korea were made in the Jatim tradition, most likely in eastern Java, and provide evidence for at least indirect contact between Korea and Java during this period. It is also conceivable that bead makers familiar with Jatim techniques were established at another site, although the very strong preponderance of such beads found in eastern Java would argue against this possibility.

2. The late 5th to early 6th-century date of the Korean beads provides the best and earliest date for the production of Jatim beads.

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THE USE OF GLASS IN BYZANTINE JEWELLERY – THE EVIDENCE FROM NORTHERN GREECE (FOURTH–SIXTEENTH CENTURIES)

Anastasios Antonaras

During the late Roman and early Byzantine period, northern Greece was in the centre of the Roman world and Via Egnatia was one of the most important roads connecting the eastern and western parts of the empire. Thessaloniki was the main urban centre and it even hosted one of the tetrarchs during the early 4th century.

According to the archaeological finds from the thousands of graves excavated in the necropolis of Thessaloniki it is evident that only a very few of the deceased were buried adorned. It is equally probable, that very few people wore jewellery when alive. From the surviving finds the following can be inferred concerning the use of glass in jewellery.

A wide variety of beads were used at the time. They were mostly small monochrome creations, dark blue and green being the prevailing colours. They were made in spherical, ovoid, biconical and tubular shapes – both plain and with oblique ribbing. Occasionally, multicoloured beads appear, decorated with specks or trails in different colours (Makropoulou 1997, 63–5, table 2; Antonaras 2003, illus. 48–50th week). Mosaic beads have also been found in the region but they are very sporadic. Smaller beads were used in large groups, as necklaces, while bigger ones were used either singly or in small numbers flanked by smaller ones hanging from cords or threads made of organic material.

Glass had been used for the production of discoid amulets bearing stamped representations since Hellenistic times. This practice continued during the medieval period. The amulet belongs to a well attested Syro-Palestinian type dated to the 4th century (Philippe 1970, 37–8; Spear 2001, 179–84, pls 29–30). It represents a lion with the sun and moon over its head. The lion represents the celestial protective power while the sol-luna motive over its head, which was used throughout the Byzantine period, denotes that God was the ruler of time.

Another glass find, which is part of a private collection from an unknown find spot, presents Saint Symeon the Stylite (Antonaras in Zafeiropoulou 2001, 29, no. 39). It has the usual form of these glass amulets, which is a disk folded at the top in order to aid suspension. On the one side is stamped the figure of the saint, who is flanked by two small figures of venerating angels in very low relief. The back is flat and undecorated.

Glass bracelets are found only occasionally, they are not dated very firmly, but it seems that they appear after the 3rd century (Makropoulou 1997, 65, table 3). They are almost always made of dark purple or green glass, which due to its thickness appears black. It has been considered that they were made as imitation of jet jewellery, which was quite popular at the time. They appear in circular, semi-circular and flat, band-like cross-sections. They were made using two techniques – there are seamed examples, from drawn out canes of glass, and seamless ones, made with centrifugal rotation of a hot mass of glass (Spear 2001, 193). They are either plain or they bear relief decoration in the form of oblique ribbing. They were usually quite wide, *c.* 60–70mm, but it is not attested, archaeologically, if they were worn around wrists or at the upper part of the arm.

Glass gems were used in many cases as substitutes for semi-precious stones in rings, both in cheaper creations and in golden elaborate examples as well (*cf.* Makropoulou 1997, table 4).

Northern Greece from the 7th to the 12th century suffered a lot from the invasions of Slavs and other Barbarians, some of whom eventually settled there. Many ancient cities ceased to exist and new ones were founded in more protected sites – usually in the form of castles. Commerce and communications as a whole became more difficult and products tended to be locally made. Archaeological finds are very scarce, and we can merely assume the products of that time and the changes that occurred during this period based on fragmentary finds and the innovations that appear after the 12th century.

There is not much published material concerning beads, but finds from neighbouring northern countries together with the picture from as yet unpublished local excavations lead to the following conclusion. Necklaces, made mainly of plain spherical beads (Deriziotis 2002, 9) with a few bigger ones among them (Maneva 1992, 116, 123–4), were used sporadically during these turbulent times. It seems that the struggle of the Christian church against the custom of embellishing the deceased, assisted by the difficult economical situation, has deprived us of the valuable source of information that graves supply.

Rings, which present the most numerous group of surviving Byzantine jewellery, were used equally by both sexes. Some of them were simple decorative objects, while simple and more elaborate examples of wedding rings are also a well-attested group. Middle Byzantine glass rings are rare finds and the few known examples are made of a small, plain circular rod, which is curved to create the hoop. The bezel is made out of a small disk, which was attached, while still hot, over the ends of the hoop (Traikovski 1990–91, 245, t. V/17).

With regard to metal rings with glass gems in the bezel we present the following classification:

1 (COLOUR PLATE 99) The first type is embellished on the bezel with a piece of flat, transparent, greenish or pinkish glass roughly cut and embedded in a metal frame (Papanikola-Bakirtzi, 2002, 445).

2 The second group consists of rings embellished with lentoid gems. They can be divided into:

a) Lentoid plain ones (COLOUR PLATE 100) The majority of the preserved examples are decorated with dark-blue coloured gems (Kypraiou 1997, 220; on the excavation see Kourkoutidou-Nikolaidou 1996; on the date of the cemetery, 11th–12th century, *ibid.* 1988, 412). Byzantines appear to have followed the belief in the apotropaic forces of blue gems, which is well attested among Eastern Mediterranean people from the prehistoric period up to modern times.

b) Lentoid with impressed decoration (COLOUR PLATE 101) The majority of the preserved examples are also decorated with dark-blue coloured gems and they bear apotropaic motifs or zodiac signs. Two examples of rings with glass gems, dated to the late 10th to early 11th century, are found in the central Macedonian medieval castles in Edessa and Chrysi respectively.

The hoop of the first example consists of four wire rings soldered together at the apex. The bezel is inlaid with a red and dark blue lenticular glass gem (Papanikola-Bakirtzi 2002, 444). This type is well known from a few examples found in medieval necropolis of the 10th, 11th and 12th century (Davidson 1952, nos 1830–3; Ercegović-Pavlović 1976, pls viii.3, xv.4).

The second ring is a cast bronze one (Papanikola-Bakirtzi 2002, 444). It consists of a circular hoop and elliptical bezel inlaid with an oval bluish green glass gem bearing the intaglio representation of what is probably a mounted male figure.

A better preserved example, with the same representation on the gem, can be found in a private collection from Thessaloniki (Antonaras in Zafeiropoulou 2001, 84). Both for typological and stratigraphical reasons the ring type is dated between the late 10th and early 11th century (Maneva 1992, 62; 1993–95, 195, figs 5–6, 12; Evgenidou 1988, 15–19).

Two more intact cast finger-rings (COLOUR PLATE 102) were found in central Greece and are dated also to the 11th–12th century. On one, a blue glass gem set in a raised, oval bezel is adorned with a herringbone pattern, most probably depicting the zodiac sign of Pisces. The gem of the second example is adorned with the representation of an animal (Papanikola-Bakirtzi, 2002, 445) which could be interpreted as the sign of Capricorn.

It seems that blue-coloured glass was preferred for the embellishment of earrings, probably for apotropaic reasons. In one case a single bead (*cf.* Maneva 1992, 221) has been used while in another case four beads embellish every earring.

Glass bracelets were already quite popular from the Roman imperial period (Kypraiou 1997, 150, 171–4) and obviously represented a cheap form of adornment for the lower classes and younger girls. In the middle Byzantine time they were given a new impetus and so are found in great numbers. Examples of more complex sections become usual as well. Only seamed examples are found dating to this period. They usually bear a punty-scar on the opposite side of their seam, a result of being shaped during their final reheating.

New methods of decoration are now used (Kypraiou 1997, 219). Apart from flat band-like ones, there are twisted examples made of one cane or sometimes of two or more canes of different colour and size. Decoration with canes of various colours in varying sizes was applied on straight, non-twisted bangles as well. Among the quite common plain-glass bracelets some stand out because of painted decoration, consisting of simple geometric motifs (spirals and zigzag lines), or schematized floral ones or even birds (COLOUR PLATE 103). A typical example is the deep blue one of the 11th–12th century, flat on the inside and convex on the outside. Its decoration consists of six panels separated by sets of three vertical lines. The panels are alternately adorned with a depiction of a bird, and have two gold zigzags painted along their long sides with a yellow zigzag in the centre (Kypraiou 1997, 215). This decoration is made using a different technique to that of the enamels. The colour is incorporated in the body, is surrounded by a very characteristic aura and is probably executed using the silver stain technique (Whitehouse *et al.* 2000).

Glass bracelets appear mainly in two sizes, 40–50mm and *c.* 70–80mm. The diversity of their diameters along with the archaeological evidence indicates that glass bracelets were used equally around the wrists and the arms. Also, it seems that they were used singly and in groups, as they are still used in middle and far Eastern countries. A quite interesting suggestion about the reasons that led to the increase of their use from the 9th to 12th century connects this to the changes in clothing that occurred at the time (Parani 2003, 73–4). According to the iconographic evidence clothes of the time had very long and wide sleeves, which were usually folded and fastened behind the neck, leaving the arms of women uncovered up to the shoulder and encouraging them to further adorn their arms.

There are several examples found at different sites in Macedonia and Thrace. In middle-Byzantine graves at the slopes of the fortress of Rendina (for the excavation see Moutsopoulos 1996) bangles were found decorating the deceased in pairs and in bigger groups (Kypraiou 1997, 171–2, 174).

Glass bracelets were found above the ruins of the so-called 'Museum basilica' (Kourkoutidou-Nikolaidou 1996) at Philippoi, among the grave goods of the 11th to 12th-century cemetery (Kourkoutidou-Nikolaidou 1988, 412). They are of dark blue glass and the majority have circular cross-sections. One of them has flat sides and bears painted geometrical motifs, barely visible today (Kypraiou 1997, 218–19).

A child's cist grave was found at Maronia's Paliochora in Thrace, in the cemetery of a settlement dated between the 10th and 13th century (Papanikola-Bakirtzi 2002, 419). Amongst the other grave goods, five monochrome glass bangles were uncovered (COLOUR PLATE 104), attesting the well known habit of their use in large numbers. Two glass bangles were found in a cemetery of the 12th or 13th century at the town of Pherres, located next to the Evros River – nowadays the border between Greece and Turkey. They are pale green decorated with additional red thread, which in one case is straight while in the other is twisted (*ibid*, 418–19).

A pair of golden armbands, exhibited in the Museum of Byzantine Culture in Thessaloniki, are amongst the best examples of Byzantine goldsmithing. Byzantine jewellers used glass in many ways to embellish metal objects. One of the most delicate techniques was inlaid enamel, known at the time as *chymeutice*. Enamel and especially *cloisonné* is one of the achievements the Byzantine goldsmiths were famous for. In this technique metal strips that adhered to the surface so that closed fields are created, make the design. In each one of these fields pulverized glass is set, and in the end, after firing, a colourful outcome is achieved.

These two exceptional examples of this technique were found at Thessaloniki (Pelekanides 1959) in a 9th to 10th-century golden jewellery hoard. It has been supposed that these *pericarpia* – i.e. armbands or bracelets – were part of the imperial court costume of a lady. They are decorated with inlaid *cloisonné* enamel of green, dark blue, cobalt blue, turquoise and white. Each one of them is covered with 20 rectangular fields, in two rows, in which alternately appear a rosette, a bird and a palmette (Papanikola-Bakirtzi 2002, 411–12). These armbands are not an isolated example as far as the use of enamel in this period – 10th to 11th century – is concerned, and other examples of *cloisonné* enamel are also known from other parts of the empire.

Representations in wall paintings and manuscripts reveal that a lot of glass was also used in the adornment of the official clothes of wealthy people and aristocrats and also in the bindings of holy books and other votive objects (Evans and Wixon 1997).

During the late Byzantine period, while the dynasty of Paleologoi was on the throne of Constantinople (mid 13th to 15th century), Macedonia and Thrace, together with the rest of the remaining empire, were suffering from invading enemies and internal dynastic wars. In contrast to the political instability and the fear of the inevitable fall of the empire into the hands of enemies, spiritual life was given a new impetus and a classical renaissance was expressed in every field of art.

Though the use of glass in jewellery during this period is better attested because more burials with bodies wearing ornaments have been found, it is not yet possible to draw final conclusions. Starting with beads it can be assumed that necklaces were used in late Byzantium but not many of them are preserved. The cemetery of the basilica of Ayios Achilleios on the Lesser Prespa Lake (Moutsopoulos 1989), which is dated between the 12th and 14th centuries (Paisidou 1998, 532; Papanikola-Bakirtzi 2002, 404), yielded, apart from glass bracelets, evidence for the use of glass beads as necklaces in that period. The evidence comprises 99 small, dark glass and pale bone beads, annular and circular in section, found in a child's grave. Apart from the numerous metal examples, glass buttons are preserved from the same necropolis, demonstrating another rare use of this material during the late Byzantine period (Paisidou 1998, 532, fig. 5).

Another Palaeologan find comes from a cemetery in Thermi, near Thessaloniki, and consists of a necklace made of plain spherical, greenish beads (Ignatiadou and Hatzinikolaou 1997, 65, photos 16–17).

Evidence for the use of glass gems in the embellishment of earrings is offered by a few surviving examples dated between the 14th and 16th century. Likewise, larger, green, pinkish and blue glass gems were used to embellish finger rings (exhibition – Museum of Byzantine Culture at Thessaloniki).

Although there are some 13th-century finds of Paleologan bracelets, it seems that their use was fading by then and that they had gone out of use by the second half of the 13th century. This conclusion is based not only on the scarcity of the archaeological finds but also on the iconographic evidence. In the rare cases where ladies, almost exclusively maids, are shown with uncovered arms they are no longer wearing arm bands any more, unlike the case during the middle Byzantine period.

Two small, blue bangles decorated with a twisted white stripe (Papanikola-Bakirtzi 2002, 420) have been found in Thessaloniki, probably dating to the late middle Byzantine or early Palaeologan period. A group of four dark blue bangles were found in a cemetery also in Thessaloniki dated between the 13th and 15th century. Two of them have a plain surface while the other two are twisted (exhibition – Museum of Byzantine Culture at Thessaloniki).

The use of glass in the form of enamel – not *cloisonné* this time but more like a mosaic – can be seen in a crescent-shaped earring with curving sides covered with geometrical motives. Cubic glass pieces of three different colours had been used in its decoration and two and a half blue lozenges with a red central tessera on white background can be seen on each side of the body of the earring (exhibition – Museum of Byzantine Culture at Thessaloniki).

The remains of a dress dated between the 14th and 16th century comprise another interesting find from late-Byzantine Thessaloniki. The dress was decorated with 1400 glass beads of three kinds (exhibition – Museum of Byzantine Culture at Thessaloniki). Most of them have twelve facets, some completely decolourized and others of dark blue colour. They are made of clear glass with no impurities or pinpricks. They are cut very roughly and unevenly. Only 31 spherical beads are preserved, probably due to their fragility. They are made of very thin decolourized glass, coated in their interior with a thin layer of lead. The use of lead has transformed the beads to small mirrors, which would have reflected the wonderful colours of the rich cloth they were decorating. The use of semi-precious stones and their glass substitutes was very widespread among the wealthier social strata and Byzantine nobility as wall paintings, mosaics and book illuminations show. The use of beads is unique in the region and probably indicates that the dress was imported to Thessaloniki from a (Western?) commercial centre.

This short journey over the Byzantine material from northern Greece possibly raises questions rather than answers them. But glass in Byzantium is still quite an obscure field and a lot more material needs to be published in order to start drawing conclusions on the origin, the extent of the distribution of certain types of jewellery and the overall picture of glass production and its place in Byzantine society.

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EARLY MEDIEVAL GLASS BEADS FROM PRAGUE CASTLE AND ITS SURROUNDINGS – TYPOLOGICAL AND CHEMICAL CLASSIFICATION OF THE FINDS

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INTRODUCTION

The history of Prague Castle from the last third of the 9th century to the 12th century AD is connected with the origins and growth of the early medieval Czech state. A study of the glass beads from this significant place in 2002/3 was one of the completed elements of a research project entitled 'Prague Castle, centre of the Czech state, mirrored in cemeteries and tombs at the time of the Přemyslied and Luxembourg dynasties' (GAČR-Nr.404/01/0853). Our study grew out of a database of 192 beads deriving mainly from necklaces deposited in the graves of women and children. Most of them (189 pieces) did not originate directly from the area of the castle, but rather from the cemeteries situated to the north and west (FIG. 1: Royal Garden; Riding School; Lumbe's Garden, Jelení Street; Strahov's brickfield; Panenska; Strahov). In the 9th and 10th century and into the 11th, its inhabitants preferred to bury close by the castle but outside its inhabited area. To this period probably belong 110 glass beads. From the same period only two beads were recovered from settlement contexts associated with the castle. In spite of the increasing burial intensity in the area of the castle in the 11th and 12th century, this proportion of beads found outside and within the castle area did not essentially change. From the castle sites one bead came from the burial-ground, ten from settlement layers (7 from 11th to 12th and 3 from 10th to 16th-century contexts), and 69 from the cemetery in Loreta Square (FIG. 1.9).

Some beads from burials in the surroundings of the castle were not available for analysis while others whose existence was known but which had not been conserved or published were excluded from the database.

CHARACTERIZATION OF THE FINDS

All finds were classified from two points of view – typological and chemical. Typological analysis of the whole collection has shown that nearly all the basic types of beads known from the milieu of early medieval Bohemia are

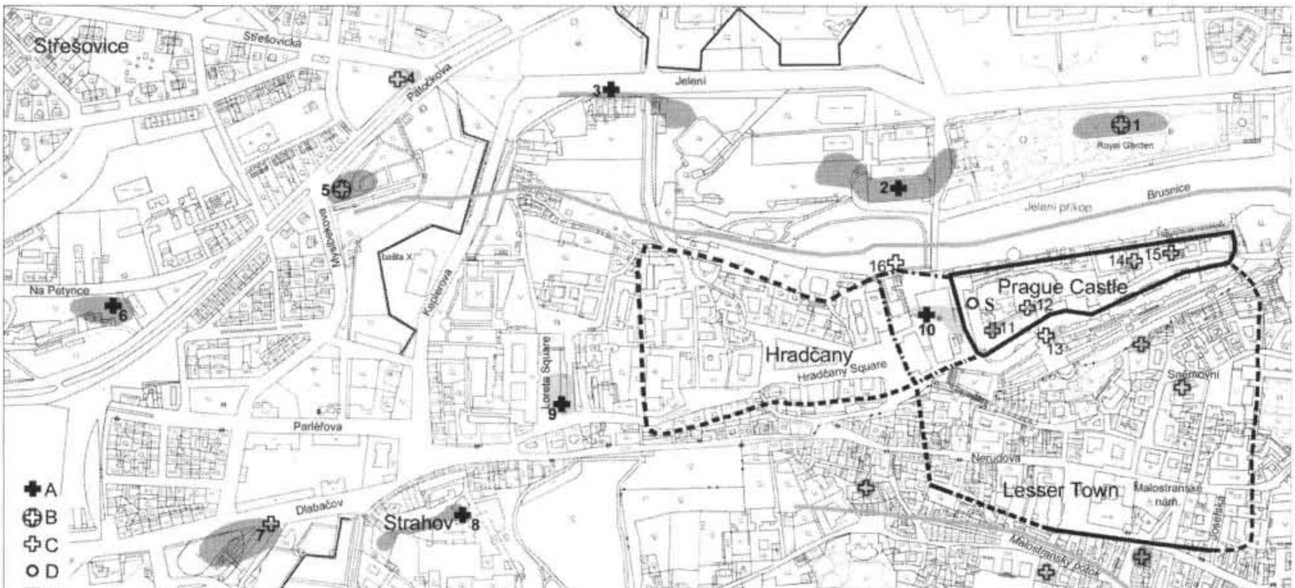

FIG. 1 Glass beads and the cemeteries at Prague Castle and its surroundings. A Cemeteries with beads with partial chemical analysis; B Cemeteries with beads without chemical analysis; C Cemeteries without beads; D Settlement layers with beads with partial chemical analysis; E Site with beads from the 9th–10th century; F Site with beads from the 11th–12th century. SITE KEY: 1 Royal Garden; 2 Riding School; 3 Lumbe's Garden, Jelení Street; 4 Patočkova, Střešovická Street; 5 Strahov's brickfield; 6 Panenska; 7 Malovanka; 8 Strahov; 9 Loreta Square; 10–16 and S Prague Castle

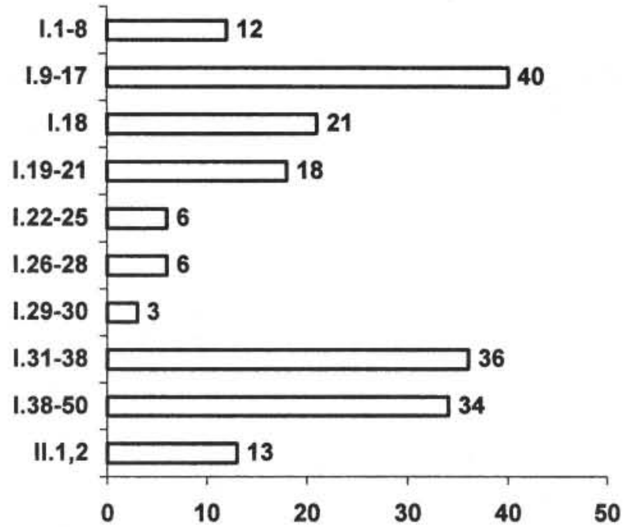

FIG. 2 Number of beads of a bead type

present (COLOUR PLATE 105). This analysis derived from the classification published by Krumphanzlová (1965, 161–88) in which beads were divided into two basic groups – simple monochrome beads and polychrome beads. Simple monochrome beads predominate in the castle collection and are represented by various shapes – globular, annular, cylindrical and barrel (COLOUR PLATE 105, group I.1–28). Melon beads are present in only two varieties (COLOUR PLATE 105, group I.29, 30). The olive beads in our collection (COLOUR PLATE 105, group I.31–8) differ in size and colour. Segmented beads are present in a modified form (COLOUR PLATE 105, group I.39–50). The second group – polychrome beads – is not so numerous and can be divided into eight individual types according to their decoration (COLOUR PLATE 105, group II.1–8): beads with *millefiori* eyes, with *millefiori* eyes and trails, with layered eyes and so on. More details about the frequency of occurrence of individual types of beads will be published shortly (Tomková and Černá forthcoming).

The chemical composition of the beads was investigated. Twenty-eight beads were selected with respect to their shape and date so that the set of analysed beads would be as representative as possible. The group included beads from the six burial-grounds and three settlement areas (FIG. 1). It comprised nearly all the basic types of beads found in the hillforts, but not all the types from the complex of burial grounds (FIG. 2). Representatives of both of the groups mentioned above – simple monochrome and polychrome – were included. The first group is represented by simple globular beads (COLOUR PLATE 105, group I.2, 3, 5), annular (COLOUR PLATE 105, group I.12), barrel (COLOUR PLATE 105, group I.27, 28), cylindrical (COLOUR PLATE 105, group I.25), melon (COLOUR PLATE 105, group I.29), olive (COLOUR PLATE 105, group I.31–4, 36, 38) and segmented (COLOUR PLATE 105, group I.39–41, 44, 46, 48–50). The last two types of beads (olive and segmented) were included in the group in larger numbers than the others for two reasons. Both types have been excavated in many shape and colour variations in our territory and predominate in the majority of our burial-grounds (Tomková and Černá forthcoming). The occurrence of olive beads is relatively well defined geographically and chronologically and is limited to a narrow area of central Europe including Bohemia, Moravia, Slovakia, further Saxon-Thuringia, Bavaria (Krumphanzlová 1974, 63–6) and recently also Polish Silesia (Rzeźnik 1997, 279–82).

Only three beads with different decoration represent the second – polychrome – group: 1. a globular bead with *millefiori* eyes (COLOUR PLATE 105, group II.1), 2. a globular bead with *millefiori* eyes and trails (COLOUR PLATE 105, group II.2) and 3. a globular bead with raised monochrome eyes (COLOUR PLATE 105, group II.6).

ANALYSIS OF GLASSES

The chemical composition of the glass of 28 beads was analysed with a scanning electron microscope Hitachi S-4700 equipped with EDX analyser Thermo-NORAN D-6823. The results are given in TABLE 1.

From this table it follows that we can divide all glasses according to their chemical composition into five chemical types – A, B, C, D and E. Group A is further subdivided into two individual subgroups A1 and A2.

Subgroup A1 Na_2O-CaO-SiO_2

This represents Roman-type natron soda-lime glasses with the content of K_2O<1wt% and MgO<1wt%. This subgroup is the most numerous of all the groups.

Among A1 glasses there is a small further subgroup of beads (A.1.2.: Nr. 79, 80, 76, 65), which differs from the other members of A1 by their small lead oxide content (0.09–2.25wt%). Similar soda-lime glasses containing low proportions of lead oxide are presented by Wedepohl (2003a, 209, tab. 19A) as glasses from the 7th to 10th century of Franconian, Carolingian and Anglo-Saxon provenance.

The group A1 natron glasses from Prague Castle are represented by the black circles in FIGURE 3. This is based on the triangular diagrams constructed by Wedepohl (Wedepohl 2003b, 94, fig. 2) showing the chemical composition of Roman soda-lime glasses. The dark grey areas on the diagram represent 780 analyses of Roman glasses from different authors together with his own compilations. As can be seen with the exception of only one bead all our finds of natron glasses fall within this area. The exception (bead no. 5) belongs to the type I.27 and has unusually low sodium oxide and a high calcium oxide content. Moreover this bead is coloured by high-level copper oxide. Glasses of the subgroup A1 are also documented at other Czech sites (Černá *et al.* 2001; Hulínský and Černá 2001).

Group A2 Na_2O-CaO-SiO_2 plant ash glass

The second most numerous group A2 presents the beads made of plant-ash glass with the content of K_2O>1.5wt% and MgO>2.5wt%. It seems that these glasses have a slightly lower C1 content in comparison to natron glasses from the A1 group. There are actually three minerals in the lake of Wadi el Natrun – sodium chloride crystals (common salt), sodium sulphate crystals (thernardite) and sodium carbonate crystals (soda). Grey thernardite is easy to

TABLE 1 CHEMICAL COMPOSITION OF BEADS. PH-JIZ: Riding School; PH-VUS, PH-TN, PH-SD: Prague Castle S; PH-LZ/JEL: Lumbe's Garden, Jelení Street; PHS-PAN: Panenska; PH-IIN: Prague Castle 10; PHY-STR: Strahov; PHY-LN: Loreta Square

Site	PH-JIZ	PH-VÚS	PH-JÍZ	PH-JÍZ	PH-JÍZ	PH-JÍZ	PH-JÍZ	PH-TN	PH-JÍZ	PH-JÍZ	PH-JÍZ	PH-JÍZ	PH-JÍZ	PH-LZ/JEL
Number	16	5	42	21	13	24	23	3	79	80	76	65	45	96
Type	I.28	I.27	I.2	I.36	I.38	I.32	I.31	I.36	I.33	I.34	I.31	I.32	I.29	I.40
SiO2	72.08	69.78	68.65	69.01	69.97	69.18	68.16	71.87	69.86	65.72	66.80	69.51	70.54	74.18
Na2O	15.67	9.09	17.48	16.35	14.59	17.67	19.21	15.05	19.39	20.76	18.89	15.86	11.67	7.64
K2O	0.36	1.01	1.09	0.92	0.00	0.59	0.84	0.75	0.34	0.58	0.89	1.66	2.62	2.85
CaO	6.54	12.31	7.39	7.59	9.91	6.30	5.41	6.32	5.31	5.16	5.56	6.86	4.97	8.61
PbO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	2.25	2.16	0.72	0.00	0.00
Fe2O3	0.35	2.93	0.73	1.34	0.87	1.11	0.74	0.40	0.40	1.08	1.08	1.36	1.51	0.56
Al2O3	2.95	1.75	2.20	2.34	2.21	2.84	2.56	2.83	2.13	2.69	2.90	2.97	2.59	0.94
SO3	0.00	0.00	0.36	0.00	0.00	0.00	0.60	0.37	0.00	0.00	0.00	0.00	0.54	0.00
Cl	1.05	0.84	1.01	1.13	1.06	0.99	0.95	1.08	1.54	0.97	0.92	0.70	0.58	0.87
MnO	1.01	0.38	0.64	0.98	1.39	0.65	0.59	0.80	0.91	0.78	0.82	0.00	0.65	0.59
MgO	0.00	0.85	0.44	0.07	0.00	0.67	0.94	0.54	0.00	0.00	0.00	0.19	4.34	3.77
P2O5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO2	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CoO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
CuO	0.00	1.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00
SnO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Group	A1	A1	A1	A1	A1	A1	A1	A1	A1	A1	A1	A1	A2	A2

Site	PHS-PAN	PHS-PAN	PHS-PAN	PH-IIN	PH-TN	PHY-LN	PHY-LN	PH-SD	PH-SD	PHY-LN	PH-LZ/JEL	PH-LZ/JEL	PH-LZ/JEL	PHY-STR
Number	130	124	136	1	2	324	323	8	10	362	85	86	87	Strahov
Type	I.50	I.46	I.44	I.41	I.49	I.12	II.6	I.3	I.5	I.25	I.48	I.39	II.1	II.2
SiO2	72.73	73.88	69.45	71.66	66.43	25.64	22.45	49.21	19.28	35.91	53.84	66.90	51.73	69.49
Na2O	9.26	9.28	10.21	7.20	12.82	0.00	0.00	0.43	0.29	0.07	7.19	10.78	9.66	10.71
K2O	3.37	1.99	2.53	3.38	4.20	0.00	0.00	0.51	0.00	5.57	2.00	1.92	2.35	6.43
CaO	7.14	6.94	6.33	8.54	8.73	0.00	0.43	2.14	0.47	0.79	5.42	4.99	4.59	4.04
PbO	0.00	0.00	0.00	0.00	0.00	72.68	73.17	32.99	77.38	56.02	22.15	6.39	22.00	0.00
Fe2O3	1.04	0.33	3.07	2.99	0.51	0.00	2.47	0.47	0.57	0.00	0.59	0.36	0.10	2.69
Al2O3	1.14	1.20	2.89	1.26	1.37	1.51	0.89	1.50	1.36	1.65	2.15	2.49	0.82	3.15
SO3	0.00	0.00	0.61	0.34	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.11
Cl	0.69	0.41	0.50	0.77	0.78	0.00	0.00	1.75	0.00	0.00	0.54	0.62	0.57	0.89
MnO	0.46	1.02	1.04	0.59	0.52	0.00	0.00	0.00	0.00	0.00	0.31	0.48	0.97	0.11
MgO	3.95	4.95	1.94	3.28	4.35	0.17	0.00	0.31	0.00	0.00	3.50	4.76	3.98	1.15
P2O5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.84	0.23
TiO2	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CoO	0.00	0.00	0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CuO	0.23	0.00	0.00	0.00	0.00	0.00	0.59	2.00	0.65	0.00	0.00	0.00	0.00	0.00
SnO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.69	0.00	0.00	2.32	0.30	3.28	0.00
Group	A2	A2	A2	A2	A2	B	B	B	B	C	D	D	D	E

separate from soda, but salt could contaminate soda crystals to some extent and could possibly have been introduced into the batch together with soda crystals. This might be the reason why the natron glasses have more chlorine than the plant-ash glasses.

In FIGURE 3 the Prague Castle A2 glasses are shown as open circles. The pale grey areas are from Wedepohl's triangular diagrams (2003b, 94, fig. 2) and represent the composition of plant-ash glasses using 167 analyses of glasses from Mesopotamia, Egypt and the Sassanian empire undertaken by Brill (1999). Four of our samples lie slightly outside these areas indicating that they have more potassium, but all our finds of this type of glass are located near to the highest potassium content boundary of the ancient glasses.

Group B PbO-SiO2 binary glass

Group B represents four binary glasses from the system $PbO-SiO_2$. Three samples have nearly identical composition with PbO contents varying from 72.68 to 77.38wt% and two are coloured with copper oxide. The last sample (no. 8) differs from the others in its concentrations of major and minor elements. It has a substantially lower PbO content (32.99wt% only), a much higher CaO content (2.14wt%), high chlorine (1.75wt%), some magnesium oxide, and 8.69wt% of tin oxide and 2wt% of copper oxide. In this glass tin oxide creates $PbSnO_3$ crystals that cause opacity. The finds of binary lead oxide early medieval glasses in Bohemia and Moravia are discussed with the finds from Northern Europe, Poland and Kiev Russia in Černá *et al.* (2001).

Group C K2O-PbO-SiO2 ternary glass

Only one glass (no. 362) from Prague Castle is of group C. This type of ternary lead, wood-ash glass ($K_2O-PbO-SiO_2$) is quite common among the early medieval glass finds in our country (Černá *et al* 2001; Hulínský and Černá 2001) and in northern and eastern Europe (Wedepohl 2003a). However the composition of our sample differs from other published ones in that there are no magnesium and manganese oxides present in the bead and also no iron oxide.

Group D Na2O-PbO-SiO2 opaque glass

Group D consists of three opaque yellow glass beads made of plant-ash glass with the addition of lead oxide and tin oxide. The lead oxide reacts with the tin oxide giving crystals of $PbSnO_3$ causing the yellow colour and the opacity of the glass. Samples 85 and 87 are made of nearly identical glass while sample 86 has a much lower addition

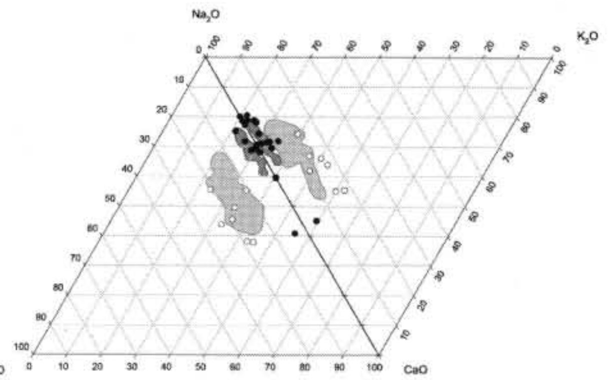

FIG. 3 Triangular diagrams comparing the composition of soda-lime glasses (dark grey areas) and of plant-ash glasses (pale grey areas) with the finds from Prague Castle (black and open circles)

of both Pb and Sn oxides. This type of glass is documented by Wedepohl (2003a, 202, tab.12A) on samples from 1391–1348 BC.

Group E Na2O-K2O-CaO-SiO2 glass

Group E is represented by only one find. It is probably a mixture of soda-lime glass and wood-ash glass. The content of potassium oxide is about 6.43wt% and sodium oxide is 10.71wt%. The composition of this glass is similar to Carolingian glass presented by Wedepohl (2003a, 211, tab. 21A).

Discussion

Here we examine whether there is any linkage between the shape of the beads and their chemical composition (TABLE 2). To do this it is necessary to analyse which chemical groups of glass belong to individual shapes of beads, and what is their frequency and dating.

In subgroup A1 (natron soda-lime glass) there are twelve beads with three different shapes: olive (9 examples), barrel (2 examples) and globular (1 example). All beads come from the end of the 9th century to the 10th century and none is later than the 10th century. Previous discoveries can be used to verify our understanding of these glasses in our area (Černá *et al* 2001, fig. 6; Hulínský and Černá 2001).

Three samples of olive beads from this subgroup, which come from the Prague Riding School, contain lead oxide absent in the remaining beads. They are from graves dated to the end of the 9th to 10th century. The presence of lead oxide in beads of this date is surprising. In our area finds of lead-oxide glasses occur later and are dated to the late hillfort period (11th to 12th century). From our previous research we know of only two beads from subgroup A1 where a small content of lead oxide was identified. One is a melon bead from Dolánky (which is not precisely dated) and the second one is an olive-type bead from •atec.

The A2 group included seven beads represented by two basic shapes: melon and segmented. Our previous research has documented the presence of this type of glass to the middle hillfort period only (9th to 10th century). In the collection from Prague Castle, we can now note the occurrence of this glass into a later – 11th to 12th century – period as well.

Glass type B is represented by four beads. In three cases they are simple monochrome globular or annular shapes while the fourth bead represents a polychrome type. This type is decorated by three raised eyes in another colour (COLOUR PLATE 105, group II.6). All beads forming this group are dated to a late period of 11th–12th century that is not in contradiction with the older finds of lead-silicate glasses in our territory (Černá *et al.* 2001, 77; Hulínský and Černá 2001, 119).

Glass type C – lead-potash – is represented by only one monochrome bead of cylindrical shape (COLOUR PLATE 105, group I.25) dated to the 11th to 12th century. The occurrence of this glass type in this period in our territory has been observed before but only in connection with rings from Olomouc (Černá *et al.* 2001, 80–2; Hulínský and Černá 2001, 119). The sample from Prague is the first evidence of the application of this type of glass to the production of beads. A more detailed comparison of the composition of the rings and of the cylindrical bead highlights some important differences. For instance there are no magnesium and manganese oxides in the bead, and also no iron oxide. It seems to be made from a very pure batch which suggests another provenance for the glass of an origin as yet unknown. We can quite safely say that this bead from Prague was not made in the same glass workshop as the rings from Olomouc. It is not certain if this bead came from Poland where this glass was often produced at that time (Olczak 1968, 223–8). The glass of our bead has a substantially higher content of lead oxide than all the analysed Polish samples so far.

Glass type D – lead-soda glass – is represented by three beads from our collection. Two of them are segmented beads (COLOUR PLATE 105, group I.39, 48), and the third, decorated with *millefiori* eyes, belongs to the polychrome glass group (COLOUR PLATE 105, group II.1). All the beads come from a grave dated to the 10th century. This type of glass occurs very rarely in Bohemia, and other than these beads, it is only known from one find from the hillfort at the village of Dolánky (Černá *et al.* 2001, 83).

Glass type E – soda-potash-lime glass – is a newly defined group. Only one globular bead decorated with *millefiori* eyes (COLOUR PLATE 105, group II.2) from Strahov

TABLE 2 TYPES AND FREQUENCY OF BEADS REPRESENTING CHEMICAL GROUPS A–E

	End C9th–C10th		C11th–C12th		C10th–C16th	
Group	**type**	**no.**	**type**	**no.**	**type**	**no.**
A1.1	I.2	1				
	I.27–28	2				
	I.31–33, 36, 38	6				
A 1.2	I. 31, 32, 34	3				
A2	I.29	1	I.41	1		
	I.40, 44, 46, 50	4	I.49	1		
B			I.5	1	I.3	1
			I.12	1		
			II.6	1		
C			I.25	1		
D	I.39, 48	2				
	II.1	1				
E	II.2	1				

is represented. Similarly decorated beads are very rare in our territory. It is interesting that another bead of similar decoration with *millefiori* eyes and trail (COLOUR PLATE 105, group II.2) has a similar composition. This comes from grave 160 in Prague-Motol (Kovářík 1991, tab. 81). According to Wedepohl (2003a, 211, tab. 21A) our bead could be made of 60% soda-lime glass and 40% wood-ash glass.

CONCLUSIONS

When we compare the shape of the beads with their chemical composition we can establish certain linkages. The variations of one basic shape are usually connected with only one type of glass and only exceptionally can we find identical shapes in two chemical types – as for instance simple globular or annular beads made of soda-lime glass (A1.1) or of lead binary glass (B). In this case the beads are from different time periods and different production sites.

The research on the beads from Prague Castle and its surroundings has proved the accuracy of previous conclusions about the chemical composition of Bohemian early-medieval beads. The current study has helped us to clarify our knowledge of the chemical variability of glass composition. It has shown that our finds do not differ substantially from other early-medieval European finds.

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STUDIES IN WINDOW GLASS AND GLAZING

EVOLUTION OF FRENCH STAINED GLASS COMPOSITIONS DURING THE MIDDLE AGES – ANALYSES AND OBSERVATIONS MADE ON THE CLUNY COLLECTION

SOPHIE LAGABRIELLE AND BRUCE VELDE

A total of 189 micro-samples from the very rich stained glass collection at the Cluny Museum have been taken for electron microprobe analysis (TABLES 1–4). These analyses can be compared with the corpus of information on blown glass published by Barrera and Velde (1989) and that for stained glass made by Brill (1999) on material from Germany, Switzerland and France. These combined data will allow us to draw some first conclusions concerning stained window glassmaking in France during the Middle Ages.

FRENCH WINDOW GLASS DURING THE 12TH CENTURY: A TRIAL PERIOD

The stained glass panel from the royal Abbey of Saint-Denis (1140–1144) (COLOUR PLATE 106) belongs to the Ile-de-France glass composition group which is potassic and calcic. However its blue glass pieces, which are much thicker than the other colours, contain sodium as the major fusing agent, as is the case for some samples from York (Cox *et al.* 1979) and Chartres (Brill 1999, 282–97). That means that they were still obtained from the Middle East as was the case during Antique times.

FRENCH WINDOW GLASS DURING THE 13TH CENTURY: SOME REGIONAL RECIPES

Stained glass work began its development in association with large architectural projects in the second half of the 12th century. At that time, glass compositions in the northern part of France are characterized by a high level of magnesium – more than 4% in the Ile-de-France (the Grand Louvre site) and Normandy regions. French glassmakers used beech wood and fern or other shrub ashes, as described by Heraclius in the 13th century. Contemporary German production is by contrast generally of a rather low magnesium content (FIG. 1) probably because German glass makers preferred, as Theophilus reported, the use of tree wood ash alone.

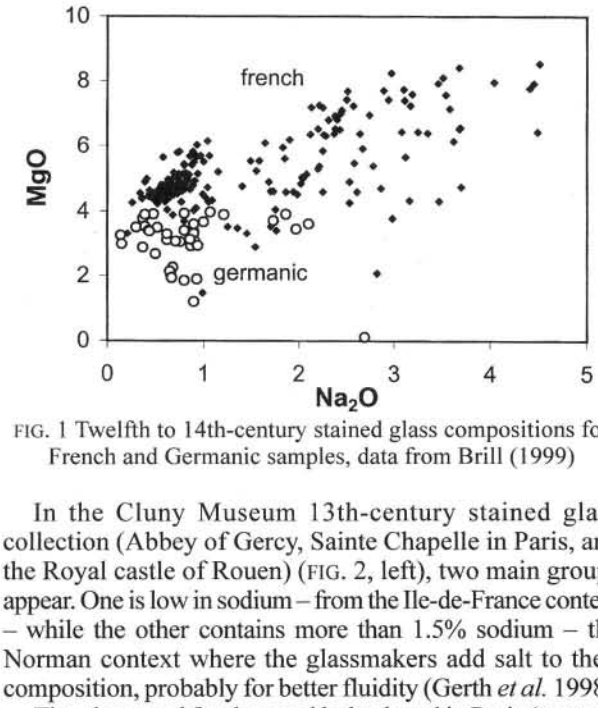

FIG. 1 Twelfth to 14th-century stained glass compositions for French and Germanic samples, data from Brill (1999)

In the Cluny Museum 13th-century stained glass collection (Abbey of Gercy, Sainte Chapelle in Paris, and the Royal castle of Rouen) (FIG. 2, left), two main groups appear. One is low in sodium – from the Ile-de-France context – while the other contains more than 1.5% sodium – the Norman context where the glassmakers add salt to their composition, probably for better fluidity (Gerth *et al.* 1998).

The glass used for the royal holy chapel in Paris (COLOUR PLATE 107) comes from both of these origins (FIG. 2, lower) – from the Ile-de-France glass factories as expected, and from Normandy since the Ile-de-France glass producers were unable to provide such a large quantity of glass in such a short time (650m² for the period 1250–1255). One can find compositions from both areas in the same panel, indicating that the glass painters did not obtain their material directly from the producer but from an intermediary, probably a specialised merchant.

The numerous concentric ringed marks left behind on the glass correspond to the crown-glassmaking procedure (around 0.4m in diameter). This kind of process, normally attributed to the Normandy factories, is rather characteristic of the north and centre of France (Paris, Rouen, Tours, Poitiers etc). In 15th-century manuscripts, it is actually known as 'French glass'.

TABLE 1 SAINT CHAPELLE: 13TH-CENTURY STAINED GLASS ELECTRON MICROPROBE ANALYSES

Inventory/ sample no.	Na_2O	MgO	Al_2O_3	SiO_2	Cl	P	K_2O	CaO	TiO_2	MnO	FeO
Cl. 14477											
1 red	0.5	4.38	1.96	50.47	0.27	4.85	16.09	18.39	0.23	0.92	0.7
2 rose	0.69	4.5	1.86	49.82	0.31	4.82	15.11	17.63	0.31	1.48	0.44
3 flesh	0.76	4.62	1.54	51.13	0.2	3.99	18.51	12.93	0.23	1.71	0.58
4 blue	0.63	4.74	1.94	51.11	0.35	4.78	15.1	18.31	0.21	1.43	0.43
Cl. 14480											
5 light blue	0.51	4.45	1.98	50.62	0.28	4.88	16.4	16.79	0.27	1.2	0.75
6 dark blue	0.72	4.72	1.33	51.7	0.33	3.75	19.12	11.71	0.24	0.67	0.28
7 rose	0.6	4.59	2.31	52.49	0.34	3.68	14.85	15.88	0.34	1.39	0.68
8 red	0.81	4.67	1.69	51.7	0.25	4.41	18.78	13.58	0.21	0.77	0.51
9	0.9	5.49	1.24	51.5	0.34	5.07	15.39	14.91	0.18	0.76	0.37
Cl. 14478											
1 blue	2.26	6.35	1.76	52.55	0.32	4.7	14.16	14.88	0.19	1.4	1.12
2 flesh	0.74	4.63	2.25	55.21	0.33	4.3	14.17	15.4	0.25	1.44	0.55
3 rose	0.6	4.29	2.05	51.06	0.23	4.1	16.32	18.59	0.28	1.17	0.66
4 green	0.82	5.16	1.97	54.83	0.38	5.3	16.74	10.9	0.36	0.59	0.7
Cl. 23711 (D.S. 1883)											
5	0.66	4.95	1.67	52.02	0.31	5.5	15.55	15.71	0.21	1.09	1.07
6 greenish	0.89	5.82	1.51	48.45	0.34	5.5	17.7	16.16	0.13	1.71	0.38
7 red	2.2	5.29	1.47	53.4	0.44	5.4	13.6	15.36	0.22	0.8	0.57
8 dark green	0.82	4.92	1.4	52.22	0.37	4.7	18.1	14.13	0.2	0.58	0.38
9 rose	1.58	5.54	1.53	50.51	0.27	5.34	13.93	17.54	0.18	1.78	0.4
10 yellow	0.94	5.14	1.41	52.69	0.33	3.48	16.76	15.06	0.2	0.96	0.38
11 light green	2.74	6.96	1.45	52.63	0.24	4.6	14.24	14.23	0.14	0.73	0.74
Cl. 23720 (D.S. 1892)											
2 blue	1.9	6.19	1.19	55.69	0.47	3.5	14.37	13.68	0.1	1.14	0.63
3	2.08	5.13	1.55	51.52	0.48	4.25	12.85	15.62	0.29	0.94	0.7
4 green	0.72	4.79	1.39	52.82	0.46	3.45	17.8	13.52	0.12	0.74	0.34
5 red	1.06	5.69	1.43	51.84	0.55	4.39	15.7	15.66	0.2	0.9	0.51
6 red	0.79	4.8	1.54	53.2	0.46	3.71	19	12.2	0.16	1.01	0.52
7 yellow	0.36	4.39	1.8	50.1	0.52	4.76	18.53	15.73	0.2	1.07	0.57
8 rose	0.43	4.45	1.77	49.24	0.42	4.9	15.54	17.62	0.24	2.02	0.55
9 rose	0.58	4.4	1.78	50.16	0.41	4.92	15.97	17.16	0.19	1.67	0.69
10 rose	0.73	4.82	1.41	53.58	0.47	3.77	18.59	12.67	0.15	2.18	0.45
Cl. 23718 (D.S. 1980)											
1	0.93	5.67	1.81	56	0.5	2.98	15.32	13.41	0.14	0.89	0.52
2 rose	0.44	4.63	1.71	49.53	0.4	5.21	15.68	18.31	0.24	1.51	0.36
3 green	0.52	4.23	1.81	49.31	0.38	5.16	17.69	16.75	0.18	1.04	0.8
4 blue	0.81	4.81	1.38	52.88	0.48	3.82	18.51	12.76	0.19	0.97	0.8
5 blue	0.65	4.69	1.36	52.91	0.47	4	18.64	12.6	0.18	1.14	0.8
6 blue	0.63	4.96	1.62	51.7	0.43	4.14	19.36	14.2	0.22	0.89	0.68
7 blue	1.15	5.2	1.5	50.61	0.58	4.56	16.72	15.15	0.17	0.89	0.55
8 red	0.75	4.92	1.48	52.49	0.41	3.84	17.65	14.44	0.2	1	0.62
9	0.97	5.69	1.28	49.73	0.46	4.18	17.98	15.16	0.12	1.96	0.41
10 green	2.03	5.03	1.43	50.72	0.49	4.49	12.96	15.61	0.2	0.89	0.64
11 rose	0.51	4.35	1.81	49.5	0.48	4.69	16.18	18.06	0.22	1.83	0.53
Cl. 14474											
1 blue	2.44	7	1.82	53.45	–	3.72	13.97	14.2	0.13	0.95	1.01
2 red	2.37	6.38	1.92	55.81	–	4.16	11.56	12.14	0.13	0.83	1.43
4 red	0.44	4.47	1.83	48.1	–	5.6	16.11	17.63	0.28	1.53	0.43
5 rose	0.48	4.36	1.84	49.2	–	5.06	15.86	18.24	0.26	0.83	0.31
6 flesh	0.47	4.57	1.86	51.4	–	4.48	16.36	16.89	0.34	0.9	0.75
7	0.52	4.32	1.96	51.3	–	4.42	16.72	16.41	0.3	1.63	0.54
8 yellow	1.64	6.09	1.16	50.8	–	4.45	13.91	18.11	0.18	0.98	0.43
Cl. 14475											
1 green	0.85	5.11	1.79	55.9	0.32	2.68	18	14	3.4	0.55	0.53
2 rose	0.76	4.7	2.04	53.4	0.33	3.46	16.3	16	0.24	1.14	0.59
3 flesh	0.77	4.28	1.97	50.34	0.32	3.7	17.14	18.45	0.23	0.93	0.39
4 yellow	0.72	4.65	1.74	52.9	0.22	3.12	19.6	14.7	0.23	0.62	0.61
5 blue	1	5.51	1.84	55.8	0.33	2.66	17.8	12.1	0.23	0.83	0.9

TABLE 1 (CONTINUED)

Inventory/ sample no.	Na_2O	MgO	Al_2O_3	SiO_2	Cl	P	K_2O	CaO	TiO_2	MnO	FeO
Cl. 14472											
1 blue	0.69	5.17	1.54	52.1	0.34	4	17.1	17	0.2	0.94	0.93
2 yellow	0.78	4.62	1.36	53.8	0.34	2.91	20	15.7	0.2	0.68	0.45
3	2.21	5.37	1.66	54.1	0.32	3.32	14.2	16.1	0.2	0.84	0.5
4 green	2.45	7.1	1.44	53.6	0.28	3.46	15.4	14.7	0.13	0.7	0.46
Cl. 14471											
8 blue	0.74	5.12	1.47	52.7	0.29	4.04	17.5	16.6	0.18	1.06	0.68
Cl. 14470											
9 blue	2.4	6.82	1.63	53.5	0.26	3.57	14.2	15.3	0.18	0.72	0.8
Cl. 23717 (D.S. 1889)											
1 flesh	1.02	4.42	1.13	49.52	0.26	5.46	19.51	16.7	0.1	0.96	0.44
2 violet	1.04	4.72	1.37	49.11	0.31	5.02	19.65	15.11	0.22	0.92	0.62
3 green	1.4	4.76	1.02	50.94	0.28	4.56	18.1	17.6	0.1	0.63	0.36
4 red	0.86	4.66	1.07	49.05	0.25	4.96	19.4	18.24	0.11	0.65	0.33
5 blue	0.89	4.78	1.26	48.9	0.27	5	19.6	18.2	0.1	0.5	0.94
6 light blue	1.85	5.61	0.95	55.21	0.27	3.73	14.2	17.6	0.13	0.46	0.53
Cl. 32712 (D.S. 1884)											
1 yellow	2.51	7.68	0.65	52.41	0.34	2.45	14.61	15.09	0.08	0.9	0.47
3 green	2.57	7.23	0.93	54.55	0.34	2.66	12.73	15.43	0.11	1.1	0.58
4 purple	1.49	5.53	2.12	53.1	0.22	2.89	15.81	15.17	0.19	2.05	1.11
5 blueish	2.94	7.42	1.1	55.1	0.31	2.61	13.53	14.5	0.09	1.01	0.48
6 blue	2.38	6.53	1.17	53.8	0.26	2.45	14.35	15.47	0.09	0.83	0.71
7 blue	2.43	6.51	1.28	54.35	0.25	2.28	14.32	15.85	0.11	1.22	1.04
9 flesh	3.51	8.1	0.73	54.12	0.31	2.86	12.81	14.32	0.1	1.69	0.53
10 flesh	3.17	7.24	0.71	54.25	0.22	3.27	17.5	11.52	0.12	1.43	0.54
11 red	0.21	3.3	1.86	51.21	0.07	1.35	20.58	18.9	0.09	1.43	0.21
Cl. 14481											
1 blue	0.8	5.43	1.5	54.32	0.29	4.33	16.39	14.8	0.09	1.55	0.73
2 green	0.75	5.11	1.48	51.81	0.22	4.72	17.12	15.21	0.07	1.02	0.49
3 red	0.93	6.03	1.07	52.43	0.33	5.44	16.55	14.95	0.29	1.27	0.61
4 yellow	0.75	5.05	1.8	55.02	0.27	4.63	15.8	14.8	0.29	1.12	0.62
5 rose	0.64	4.46	2.02	52.04	0.32	5.22	15.39	18.4	0.34	1.12	0.42
6 flesh	0.39	4.89	2.35	57	0.25	4.27	15.86	13.12	0.06	1.25	0.54
7 greenish	0.68	4.78	1.51	55.3	0.28	4.06	16.5	13.52	0.22	2.87	0.58
Cl. 14473											
1 violet	0.41	4.98	2.9	45.77	0.04	2	20.3	20.9	1.46	1.29	0.37
2 flesh	2.31	6.8	0.51	54.34	0.26	3.17	13.8	15.9	0.1	1.03	0.23
3 red 14–15	0.47	4.52	2.12	54.5	0.2	2.72	17.77	15.45	0.11	0.82	0.53
4 green	0.73	4.53	1.38	54.41	0.25	3.29	19.6	13.4	0.14	0.71	0.4
5	1.73	4.61	0.87	54.5	0.27	2.7	15.9	14.1	0.05	0.68	1.4
6 blue	0.62	4.53	1.51	55	0.31	3.15	18.9	13.1	0.22	1.55	0.37

TABLE 2 GERCY ABBEY, ILE-DE-FRANCE: 13TH-CENTURY STAINED GLASS ELECTRON MICROPROBE ANALYSES

Inventory/ sample no.	Na	Mg	Al	Si	P	Cl	K	Ca	Mn	Fe
Cl. D. 23677										
1	0.9	4.02	0.98	55.84	3.23	0.26	15.05	16.63	0.47	0.47
2	0.61	4.83	1.35	51.08	4.44	0.19	15.94	18.83	0.77	0.67
3	0.56	4.53	1.61	55.32	3.25	0.21	16.68	14.85	1.13	0.87
4	0.79	5.13	0.92	53.37	2.77	0.27	18.09	16.07	1.13	0.39
5	0.73	5.05	1.21	53.23	3.52	0.23	16.85	16.16	1.03	0.56
Cl. D 23644										
10 blue	0.59	4.66	1.13	50.9	0.29	3.87	16.86	16.29	0.13	0.98
11 green	0.8	3.69	1	53.9	0.28	4.03	15.48	15.35	0.15	0.43
12 red	0.62	4.04	0.9	51.82	0.29	4.55	16.5	16.35	0.91	0.81
Cl. D. 23665										
1 green	0.68	3.88	0.91	50.19	0.33	4.29	17.06	16.96	0.09	0.55
2 blue	0.92	4.1	0.95	50.25	0.41	4.72	18.24	16.86	0.21	0.51
3 red	0.93	5.66	1.49	52.85	0.41	4.33	16.4	16.59	0.28	1.01

continued over

TABLE 2 (CONTINUED)

Inventory/ sample no.	Na	Mg	Al	Si	P	Cl	K	Ca	Mn	Fe
Cl. 23666										
4 light blue	0.83	4.99	1.5	47.95	0.37	4.72	17.59	17.62	0.22	0.94
5 red	0.64	4.4	1.36	50.91	0.25	4.4	17.79	15.48	1.96	0.61
6 purple	0.52	4.49	1.2	48.6	0.26	4.8	18.7	17.05	0.27	1.45
7 colourless	0.53	4.65	1.47	49.1	0.31	5.06	18.02	16.22	0.41	1.17
8 dark blue	0.44	4.52	1.32	51	0.25	4.25	18.06	15.32	0.17	1.08
Cl. D. 23679, Cl. 23680										
1 red	11.59	0.13	0.71	70.89	0.74	0.24	0.18	13.9	0.2	0.07
2 red	1.04	6.15	1.26	51.63	5.22	0.51	18.47	13.5	0.1	0.91
3 blue	0.73	5.79	1.22	53.19	2.86	0.54	17.05	15.24	0.13	1.39
4 green	0.66	4.86	1.5	51.13	4.97	0.41	18.07	15.05	0.15	0.15
5 purple	0.58	4.78	1.39	48.2	5.17	0.34	19.12	16.87	0.18	1.45
6 red	0.68	5	1.12	49.2	4.59	0.47	21.27	15.54	0.1	0.93
7 blue	0.53	4.54	1.6	51.45	4.24	0.46	19.04	13.78	0.07	1.09
8 yellow	0.61	4.76	1.62	49.17	5.03	0.46	19.56	16.13	0.25	0.65
9 green	0.56	4.8	1.51	50.64	4.89	0.55	18.58	15.06	0.08	0.85
Cl. D 23719										
1	0.9	4.02	0.98	55.84	3.23	0.26	15.05	16.63	0.47	0.47
2	0.61	4.83	1.35	51.08	4.44	0.19	15.94	18.83	0.77	0.67
3	0.56	4.53	1.61	55.32	3.25	0.21	16.68	14.85	1.13	0.87
4	0.79	5.13	0.92	53.37	2.77	0.27	18.09	16.07	1.13	0.39
5	0.73	5.05	1.21	53.23	3.52	0.23	16.85	16.16	1.03	0.56
Cl. D 23683										
1 blue	0.65	4.86	1.68	54.7	4.08	0.34	15.43	14.46	0.33	1.37
3 red	0.56	5.21	1.17	52.35	5.7	0.32	16.51	16.7	0.52	1.1
Cl. D. 2368 Gercy										
8 blue	0.59	5.08	1.1	52.64	5.21	0.31	17.36	16.1	0.07	1.2
9 red	0.49	4.8	1.12	52.77	5.5	0.27	15.46	17.07	0.313	1.25
10 blue	0.6	4.82	1.75	56.77	3.6	0.34	14.97	13.94	0.36	1.24
C. D.123684										
7 red	0.49	4.78	2.18	56.73	4.32	0.19	15.41	12.76	0.05	1.26

TABLE 3 ROUEN CATHEDRAL, NORMANDY: 13TH TO 14TH-CENTURY STAINED GLASS ELECTRON MICROPROBE ANALYSES

Inventory/ sample no.	Na	Mg	Al	Si	K	Ca	Ti	Mn	Fe
Cluny 1									
1	3.68	8.41	1.69	51.61	13.16	14.02	0.22	1.12	0.5
2	2.28	6.32	1.6	53.67	10.7	15.93	0.1	0.8	0.56
3	1.05	4.28	1.27	57.86	15.71	13.44	0.19	0.53	0.53
4	1.55	5.23	1.49	54.13	15.89	15.07	0.19	1.03	0.71
5	0.36	4.38	2.64	49.46	18.46	18.98	0.15	1.37	0.53
6	0.99	1.47	1.37	54.85	16.83	14.23	0.17	0.53	0.8
7	2.38	6.93	0.87	54.8	15.16	11.05	0.11	1.37	0.86
8	3.19	7.59	1.37	50.64	13.7	14.76	0.14	1.33	0.21
9	2.2	6.53	0.99	56.53	16.03	10.53	0.16	0.74	0.56
10	2.5	7.42	0.95	55.84	14.2	11.82	0.07	1.1	0.5
Cluny 2									
1	2.25	7.18	0.86	56.38	15.78	12.8	0.06	0.98	0.4
2	2.13	7.19	0.84	56.02	15.23	12.75	0.09	1.13	0.38
3	0.26	4.25	2.46	47.24	20.75	18.42	0.19	1.33	0.58
4	0.34	4.54	2.31	47.57	20.57	17.77	0.17	1.22	0.44
5	2.25	5.85	1	57.98	12.83	13.43	0.09	0.89	0.49
6	1.83	5.95	1.34	52.76	14.01	16.27	0.23	0.75	0.46
7	2.89	7.7	0.76	58.45	12.1	13.47	0.06	1.1	0.41
8	2.21	7.25	0.52	53.61	17.73	10.3	0.04	1.29	0.51
9	2.12	6.36	1.42	54.25	11.03	18.3	0.08	0.98	0.63
10	1.68	4.89	1.05	50.68	15.56	16.97	0.14	0.94	0.43
11	2.39	6.86	0.84	54.39	15	12.4	0.05	1.3	0.5
12	2.97	8.24	0.67	57.98	11.4	13.6	0.13	0.95	0.31

TABLE 4 FRENCH 15TH-CENTURY STAINED GLASS ELECTRON MICROPROBE ANALYSES

Inv. no.	Origin	Date	Sample	Na	Mg	Al	Si	P	Cl	K	Ca	TI	Mn	Fe
1	Bourges (?)	C15	1	2.04	5.37	0.87	54.95	3.73	0.33	16.26	14.35	0.1	0.55	0.45
1	Bourges (?)	C15	2	2.16	5.45	0.95	54.52	3.86	0.28	16.38	14.32	0.14	0.54	0.47
1	Bourges (?)	C15	3 blue	1.56	4.38	1.57	50.88	3.65	0.07	11.71	23.91	0.1	0.96	1.06
2	Normandy	*c.*1500	4 green	1.47	4.24	1.54	50.51	3.29	0.05	12.31	25	0.12	0.88	1.94
2	Normandy	*c.*1500	5 blue/green	2.23	2.84	2.7	60.45	2.51	0.33	4.4	22.1	0.9	0.42	0.44
2	Normandy	*c.*1500	6 colourless	1.8	2.95	3.35	59.8	2.06	0.29	7.91	22.3	0.12	0.68	0.5
2	Normandy	*c.*1500	7 green	0.58	3.12	4.09	58	1.91	0.11	6.86	22.6	0.2	0.76	0.88
3	Provins	C15	4 white	2.65	6.66	0.97	57.72	3.53	0.28	12.27	14.12	0.12	0.73	0.35
3	Provins	C15	5 green	2.29	6.8	0.84	55.9	3.71	0.22	13.31	13.92	0.24	0.9	0.45
3	Provins	C15	6 red	0.62	5.11	2.33	55.86	3.83	0.2	15.89	14.84	0	1.42	0.35
3	Provins	C15	7 blue	3.13	6.79	0.91	57.76	3.42	0.37	10.63	14.13	0.1	0.76	0.49
4	Brittany	C15	1 greenish	5.25	7.26	1.09	52.26	4.08	0.2	9	13.56	0	1.91	0.81
4	Brittany	C15	2 blue	7.15	8.44	0.87	52.57	4.42	0.25	9.79	14.1	0	1.46	0.38
4	Brittany	C15	3 greenish	5.28	8.55	0.89	53.3	4.42	0.24	10.21	13.45	0	1.51	0.27
4	Brittany	C15	4 green	5.8	7.63	1.07	53.2	4.23	0.3	1.12	12.88	0	1.44	0.46
5	Sainte-Chap.	C15	1 blue	1.32	5.63	0.67	53.17	5.3	0.35	14.55	17.4	0	0.51	1.07
5	Sainte-Chap.	C15	2 green	1.37	5.15	0.82	52.81	4.65	0.42	14.65	15.32	0.02	0.56	0.68
5	Sainte-Chap.	C15	3 red	0.59	2.28	2.28	53.29	3.6	0.31	20.11	13.41	0.2	0.79	0.52
5	Sainte-Chap.	C15	4 white	3.16	7.28	1.34	58.78	3.24	0.33	10.52	13.33	0.03	0.73	0.24
5	Sainte-Chap.	C15	5 red	2.7	3.14	3.68	59.93	2.96	0.62	5.19	20.89	0	0.65	0.65
5	Sainte-Chap.	C15	6 white	2.99	7.22	0.92	52.56	3.7	0.48	16.79	11.85	0.09	1.55	0.46
5	Sainte-Chap.	C15	7 blue	2.96	8.27	0.84	51.96	3.39	0.47	16.09	12.16	0.09	1.18	1.13
5	Sainte-Chap.	C15	8 violet	3.48	4.47	3.48	55.03	1.56	0.22	16.53	14.62	0.08	1.46	0.7
5	Sainte-Chap.	C15	9 red	0.76	4.88	2.68	52.27	3.35	0.19	18.59	13.47	0.08	0.78	0.4
5	Sainte-Chap.	C15	10 green	2.25	6.92	0.82	54.09	2.48	0.35	9.85	12.52	0.03	0.43	0.37
5	Sainte-Chap.	C15	11 blue	1.17	5.74	1.85	53.28	3.95	0.46	15.82	14.73	0.23	0.75	0.58
	Rouen castle	C13	1	0.86	4.87	0.46	52.22	4.96	0.43	18.1	14.84	0	0.98	0.3
	Rouen castle	End C13	3	1.19	5.01	0.55	56.89	3.06	0.56	15.32	13.99	0.05	0.78	0.44
	Rouen castle	End C13	4	1.5	6.02	0.72	55.37	4.08	0.47	15.36	14.55	0.02	0.6	0.27
	Rouen castle	End C13	5	1.42	6.27	0.64	55.44	4.13	0.54	15.07	14.52	0.08	0.82	0.39
	Rouen castle	End C13	6	1.6	6.12	0.53	55.34	4.01	0.57	15.37	13.94	0.06	0.75	0.39
	Rouen castle	End C13	7	1.52	5.93	1.54	53.97	4.34	0.33	13.71	15.05	0.13	1.13	0.53
	Rouen castle	End C13	8	1.62	7.08	0.64	57.08	3.76	0.49	11.99	14.54	0.01	1.04	0.38
	Rouen castle	End C13	9	1.98	7.14	1.18	56.76	4.6	0.34	11.12	14.91	0.16	1.01	0.55
	Rouen castle	End C13	10	1.45	5.78	0.62	54.41	4.07	0.39	15.59	14.85	0.09	0.6	0.2
	Rouen castle	End C13	11	2.19	6.49	0.92	52.72	4.12	0.42	13.17	15.18	0	1.82	0.58

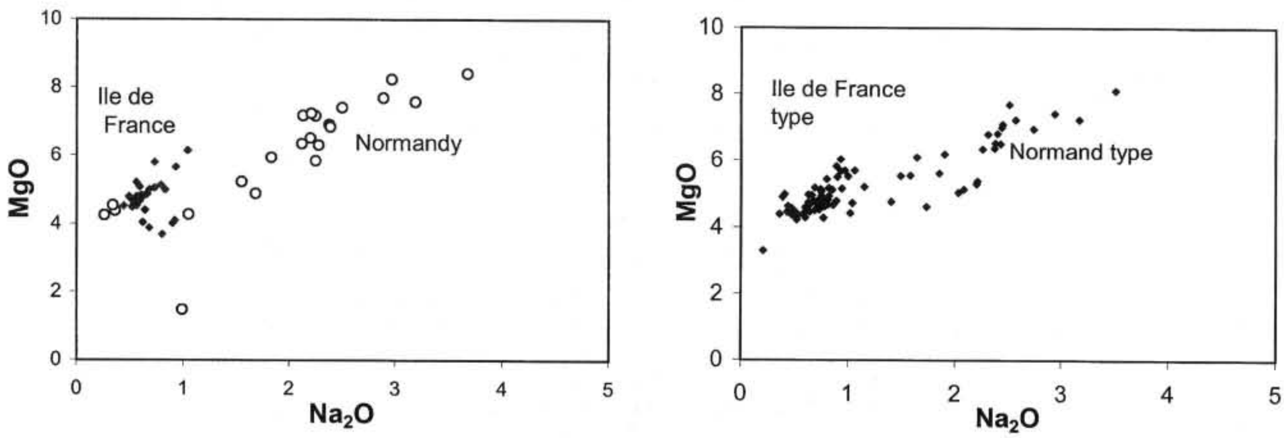

FIG. 2 Thirteenth-century French and Sainte-Chapelle stained glass samples (TABLES 2, 3). Left – France 13/14th century, right – Sainte Chapelle 13th century

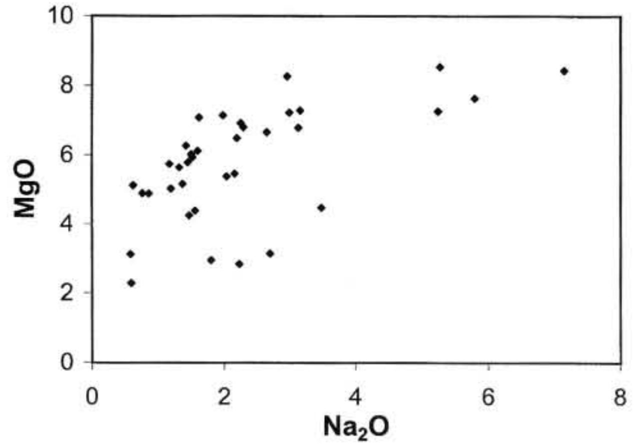

FIG. 3 French 15th-century stained glass samples from data in TABLE 4

STAINED WINDOW GLASS TRADE IN THE 15TH CENTURY

Looking at the later, 15th-century, French glass compositions, one sees that they have the same amounts of sodium and magnesium but fall less clearly into two groups. A higher amount of magnesium (around 6%) can probably be related to Normandy production while the other, lower in sodium, is from the Ile-de-France (TABLE 4, FIG. 3).

From the Museum collection of roundels (made on a single piece of glass) of the late 15th and early 16th century we can see evidence of extensive trade in flat glass. A Parisian glass painter could use any quality of glass. Compositions suggest that a large portion of the roundel materials, even those painted by a Flemish painter, come from Germany. Five of those analysed are probably from France or have an origin near the French region of traditional production.

In conclusion, three different medieval traditions of making glass in France can be identified. Two potassic-calcic glasses made in the north of France are not comparable with the sodic glass from the Middle East which was based on the use of barillia or salicorn plant ash or Antique glass. Both these French traditions – sodic and wood ash – are again different from those typical of Germany.

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THE STAINED GLASS WINDOWS OF THE SAINTE CHAPELLE IN PARIS: INVESTIGATIONS ON THE ORIGIN OF THE LOSS OF THE PAINTED WORK

M. Verità, C. Nicola and G. Sommariva

The deterioration of stained glass windows is a critical problem for the conservation of the European cultural heritage. Glass corrosion and the loss of paint work are the main causes of deterioration. The former is a well known and intensely studied problem, but only a few studies exist on the latter. *Grisaille* paste is an opaque black (or reddish-brown) material used for painting the main trace lines. Applied in a thin layer it was used to make the washed tones and shading on the glass pieces. The loss of the *grisaille* layer is a very common problem – it is an anomaly that some medieval windows have a perfectly preserved paint.

The curators of the Sainte Chapelle in Paris have established a relatively good state of preservation of the glass pieces, certainly better than that of other French stained glass windows of the same period, while the loss of the paint work is a serious problem. The chapel was built by Saint Louis (King Louis IX) in the middle of the 13th century to preserve the holy relics of the passion of Christ. It is a unique monument, and has the largest narrative cycle in the history of stained glass windows (Callias-Bey 2001). The chapel was described as the *Cappella Vitreata* during the Middle Ages because of its 750m^2 of stained windows in the upper part. They include more than 1100 figurative panels. Important restorations were performed during the 19th century, but almost two thirds of the panels are original ones. Dominant glass colours are blue, yellow and red. Several concentric lines attest that crown glass was used. A diameter up to 0.4m has been estimated.

The present investigation is part of a European project (VIDRIO) involving several European laboratories on the conservation of stained glass windows. The VIDRIO project is a multi-disciplinary research programme, including field surveys and laboratory studies of all the relevant environmental parameters influencing the weathering of glass and paint alteration. The research partners are experts in thermo-hygrometric (CNR-ISAC, Padua, Italy) and environmental parameters (MITAC, University of Antwerp, Belgium), particle deposition (LISA, University Paris XII, France), bioactivity (Generalis GmbH, Luckenwalde, Germany) and glass (LRMH, Paris, France; ISC Fraunhofer, Bronnbach, Germany; SSV, Venice, Italy).

The aim is to ascertain the nature of the glass and *grisaille* paint of the original panels of the Sainte Chapelle by means of scanning electron microscope and X-ray microanalysis, in order to understand the mechanisms of deterioration and loss of the painted work.

Grisaille, its nature and ancient technology

According to the medieval treatises of Theophilus (Hawthorne and Smith 1963) and Antonio da Pisa (Mecozzi 1991), *grisaille* paste was made from powders of a highly fusible glass (fusible at a temperature below that of the substrate) mixed in the right proportions with a pigment (copper or iron oxides), plus an organic binding agent such as water and egg white. In his treatise, Antonio da Pisa suggests the use of *paternostri* (yellow beads made of a lead silicate) as highly fusible glass. The mixed ingredients were applied with paint brushes. The firing of the glass pieces was carried out in a kiln at temperatures (and for a time) that did not allow the substrate to melt, around 650–700°C. Once the fire was extinguished, the kiln was closed and allowed to cool slowly to attain a good annealing. After firing, the *grisaille* paint is a porous material made of the pigment grains bonded to the glass piece to form a single object (Verità 1996). To prevent deterioration, the painted surfaces are usually placed on the interior of the building.

It is important to remember that not every *grisaille* is suited to every glass. The composition of the glass piece and the glassy phase of the *grisaille* must be such that their thermal expansions are adjusted to each other. After firing, the contraction that takes place upon cooling will be prevented if there are different thermal expansion co-efficients, and stresses will arise between the two materials. The occurrence of micro-cracks depends on the stress intensity. In practice the expansion co-efficient of the glass piece should be slightly greater and, therefore, the *grisaille* is compressed. Other critical parameters that can lead to poor adhesion of the *grisaille* and problems in conservation include the *grisaille* grain size (grains that are too large interrupt the continuity of the glassy film); the wrong ratio between the two components; the insufficient mixing of the powders and the binding agent; firing at a too low temperature; as well as previous cleaning and restoration with aggressive materials and techniques (Bettemburg 1991; Verità 1996).

Analysis, results and discussion

Sampling

The sampling was performed by a conservator of the Studio AVICE (Le Mans, France), where the stained glass window of lancet no 102 (exposed south) of the Sainte Chapelle was dismantled and restored. Of the twelve small fragments received for analysis, six had *grisaille* paint. One blue piece

TABLE 1 EPMA QUANTITATIVE COMPOSITION (WT% OF THE OXIDES) OF THE ORIGINAL (13TH CENTURY) GLASS PIECES

Sample		SiO_2	Al_2O_3	Na_2O	K_2O	CaO	MgO	SO_3	P_2O_5	Cl	TiO_2	Fe_2O_3	MnO	BaO	SnO_2	CuO	PbO	CoO	ZnO
SC1	colourless	51.7	1.60	1.75	14.3	17.2	5.85	0.16	4.90	0.50	0.26	0.65	0.84	0.25	-	0.04	-	-	-
SC7	colourless	53.6	1.57	0.95	17.0	15.2	5.80	0.09	3.58	0.50	0.20	0.41	0.80	0.22	-	-	-	-	0.05
SC10	colourless	54.8	1.70	0.69	18.5	12.7	5.15	0.10	3.85	0.53	0.18	0.51	1.08	0.14	-	-	0.05	-	-
SC11	colourless	54.6	1.57	0.80	18.5	12.7	5.25	0.22	3.80	0.45	0.19	0.45	1.05	0.24	-	0.06	-	-	0.10
SC3	pink	49.7	1.50	0.90	17.3	15.7	6.15	0.16	4.65	0.40	0.25	0.62	2.30	0.33	-	0.03	-	-	-
SC4	pink	50.2	1.63	0.90	17.0	15.7	6.30	0.10	4.35	0.48	0.20	0.54	2.30	0.30	-	-	-	-	-
SC9	pink	54.3	1.52	0.75	18.9	12.3	5.25	0.18	4.05	0.44	0.19	0.41	1.40	0.23	-	-	-	-	0.08
SC5	brown	50.0	1.80	2.90	14.4	14.4	7.40	0.22	4.75	0.38	0.20	0.88	2.20	0.25	0.12	0.05	-	-	0.04
SC2	blue	51.3	1.70	0.65	15.7	16.2	5.95	0.15	4.80	0.55	0.21	0.79	0.90	0.20	-	0.27	0.26	0.14	0.20
SC6	blue	53.7	1.70	2.00	13.5	15.0	5.90	0.14	4.85	0.60	0.23	0.72	0.80	0.16	-	0.16	0.29	0.06	0.14
SC12	blue	53.3	1.60	2.30	14.2	14.6	5.60	0.23	4.70	0.50	0.26	1.10	0.83	0.22	0.13	0.19	-	0.08	0.13
SC8	green	53.0	1.54	0.74	19.2	12.3	5.10	0.15	3.80	0.44	0.20	0.44	0.72	0.21	-	1.67	0.10	-	0.35
SC1r	red	51.7	1.60	1.90	14.0	16.8	5.70	0.18	4.70	0.45	0.26	0.74	0.84	0.22	0.07	0.75	-	-	0.06
	Mean	*52.5*	*1.62*	*1.33*	*16.3*	*14.7*	*5.80*	*0.16*	*4.37*	*0.48*	*0.22*	*0.64*	*1.24*	*0.23*	-	*0.36*	-	-	*0.13*
	Std. Dev.	*1.56*	*0.07*	*0.65*	*1.84*	*1.39*	*0.42*	*0.04*	*0.43*	*0.05*	*0.03*	*0.16*	*0.5*	*0.04*	-	*0.38*	-	-	*0.07*

TABLE 2 EPMA MEAN QUANTITATIVE COMPOSITION (WT% OF THE OXIDES) OF THE GRISAILLE (PIGMENT + GLASSY PHASE + DEPOSITS)

	Grisaille thickness (µm)	SiO_2	PbO	Fe_2O_3	Al_2O_3	Na_2O	K_2O	CaO	MgO	SO_3	P_2O_5	CuO	Cl
SC9	15	25.0	54.0	1.7	1.8	1.0	1.5	7.0	0.5	5.0	2.2	-	0.3
SC5	15	21.0	43.0	27.0	0.3	0.1	1.0	3.5	0.1	2.0	1.0	0.4	0.6
SC4	25	23.0	28.0	39.0	0.5	0.2	0.2	3.0	0.1	2.0	2.0	1.3	0.7
SC6	50	15.0	36.0	40.0	0.5	0.1	0.6	4.7	0.2	1.0	0.3	1.4	0.2
SC7	110	20.0	32.0	40.0	0.7	0.3	0.5	3.2	0.3	2.0	0.4	0.2	0.4
SC8	50	18.0	41.0	35.0	0.4	0.3	0.3	2.5	0.1	1.0	0.3	0.7	0.4
	Mean	*19.0*	*34.3*	*38.5*	*0.5*	*0.2*	*0.4*	*3.4*	*0.2*	*1.5*	*0.8*	*0.9*	*0.4*
	Std. Dev.	*2.5*	*4.3*	*1.8*	*0.1*	*0.1*	*0.2*	*0.7*	*0.1*	*0.5*	*0.6*	*0.5*	*0.1*

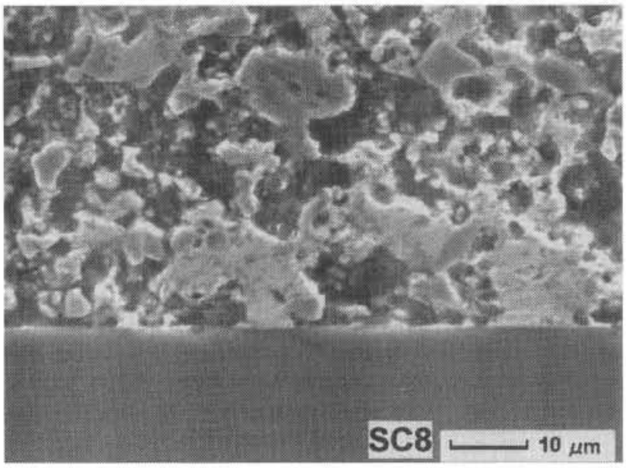

FIG. 1 SEM-SE micrograph of the polished cross-section of the grisaille of sample SC8

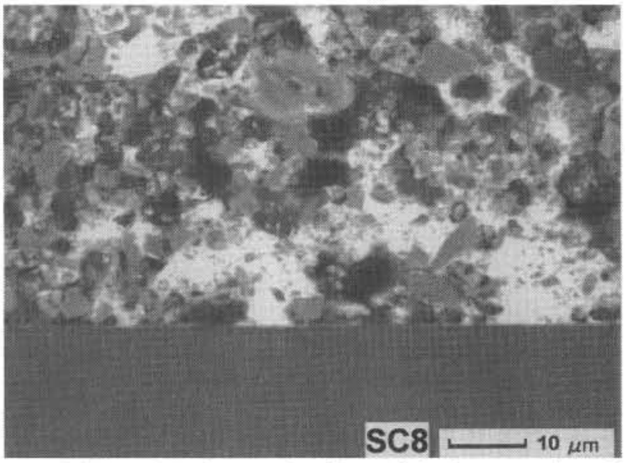

FIG. 2 SEM-BSE micrograph of the polished cross-section of the *grisaille* of sample SC8

was removed from the framework of leads and the weathering phenomena were investigated by optical microscope. The fragments were embedded in acrylic resin and prepared in polished cross-section to allow the glass/*grisaille* adhesion to be investigated by optical microscope, SEM and X-ray microanalysis (after carbon coating). An EPMA (Cameca SX50) was used both for the analyses of the glass and of the mean (glassy phase + pigment) *grisaille* composition (TABLES 1, 2). An EDS detector (Oxford Isis 300) associated with an electron microscope (Jeol 5900) was used for the analysis of the glassy phase of the *grisaille*, in order to have a better focusing of the electron beam. The quantification was improved by analysing reference lead silicate glasses under the same conditions, and determining correction factors to be applied to the analyses of the unknown samples. No X-ray diffraction analysis was possible because of the small size of the fragments.

Condition of the grisaille *layer*

In the SEM-SE (secondary electrons mode) micrograph of a cross-section of sample SC8 (FIG. 1), the heterogeneous, porous and granular morphology of the *grisaille* paint is evident. The thickness varied between 15 and 110µm. In the SEM-BSE (back-scattered electrons mode) the different phases are easily detectable (FIG. 2 – showing the same area of the micrograph as FIG. 1). A porous matrix (black areas) can be observed where particles (grey grains) are surrounded by a vitreous phase (white, because of its high atomic weight and the large back-scattering of the electrons).

In the six samples, the *grisaille*/glass interface is a straight line, indicating a modest interaction between the two materials. The *grisaille* layers are made (TABLE 2) of lead oxide, silica, iron oxide (the pigment) and a few other oxides. No ion diffusion between the lead silicate (Pb^{2+}) and the glass (K^+, Ca^{2+}) was detected, which confirms that the painted pieces were fired at a relatively low temperature and for a short time.

Micro-cracks were observed in the *grisaille* layer in all the samples, mainly parallel to the glass surface. In many cases, fractures reach the glass piece and propagate perpendicularly to the surface with the *grisaille*, with the underlying glass shelving off (FIG. 3).

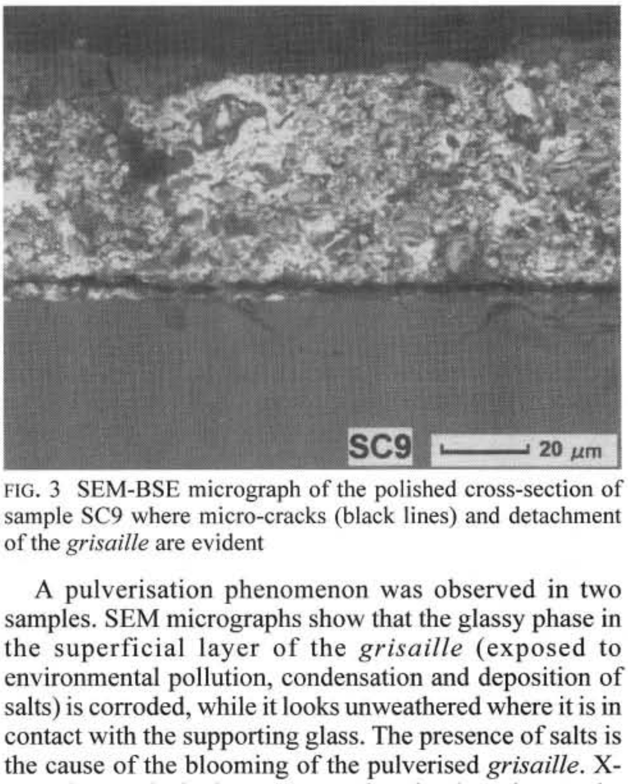

FIG. 3 SEM-BSE micrograph of the polished cross-section of sample SC9 where micro-cracks (black lines) and detachment of the *grisaille* are evident

A pulverisation phenomenon was observed in two samples. SEM micrographs show that the glassy phase in the superficial layer of the *grisaille* (exposed to environmental pollution, condensation and deposition of salts) is corroded, while it looks unweathered where it is in contact with the supporting glass. The presence of salts is the cause of the blooming of the pulverised *grisaille*. X-ray microanalysis demonstrates that the deposits consist mainly of Ca and S (probably calcium sulphate, gypsum), elements not belonging to the *grisaille* paste composition. Deposits of calcium sulphate were detected also in the *grisaille* cross-sections, diffused in the pores and in micro-cracks.

Corrosion of the glass substrate followed by the spalling of the paint work, which is very frequent in other medieval windows, was observed only in one sample (SC3) of the Sainte Chapelle (FIG. 4).

A series of chemical analyses, laboratory reproduction of the original glass and *grisaille,* and a series of tests followed the initial documentation in order to understand the origin of the micro-crack formation.

Glass composition

The quantitative chemical compositions of the glasses are reported in TABLE 1. The relatively homogeneous

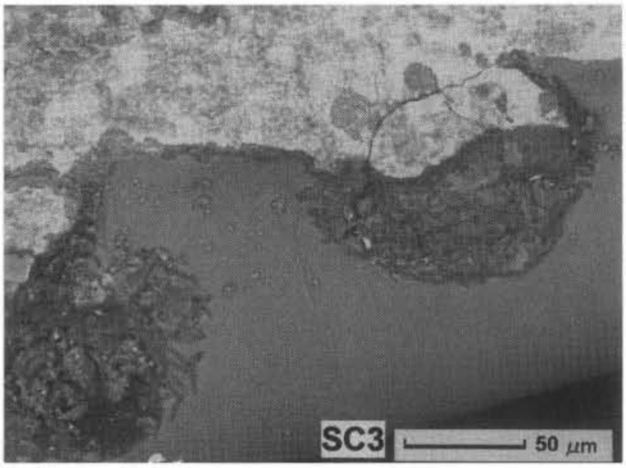

FIG. 4 SEM-BSE micrograph of the section of sample SC3 evidencing a corroded area of the glass underlying the *grisaille* layer

composition of the samples (of sample SC1, both the red and colourless layers were analysed), which attests to their common origin, is evident from the low standard deviation (Std. Dev.) of the mean values (Mean). Comparable K and Ca contents, relatively high Mg and P contents and traces of Ba are characteristic of this composition that can be classified as a potash-lime-silica glass. A content of silica of less than 54wt%, indicates a modest chemical durability of the glass which was made by melting continental plant ash and silica sand. Similar compositions were found in analyses of French glasses dated to the 11th–14th century (Barrera and Velde 1989). A significant and variable content of Na (0.7–2.3%) and traces of chlorine can be interpreted either as the result of ancient soda-lime glass recycling (natron glass) or as secondary components of ashes of continental plants growing on the sea coast.

Clear glass was decolourised with manganese dioxide to neutralise the iron content of the natural raw materials. Traces of copper seem to indicate a recycling of red glass. The pink colour was obtained by adding manganese (Mn^{3+}), the green by adding copper (Cu^{+}), and the blue by a mineral of cobalt also containing zinc, copper and lead. Red glass, one of the most important secrets of the north European glassmakers, was obtained by reducing a certain amount of metallic copper and creating thin layers of the red (flashed colour) in an uncoloured glass.

Grisaille *composition*

The mean quantitative composition of the six *grisaille* samples are shown in TABLE 2. These analyses were made by scanning the electron beam on the entire section of the *grisaille*, from the glass interface to the surface. The contribution of the glassy phase, of the pigment grains and of any deposit present in the pores (environmental deposits, residues of previous cleaning, etc) are therefore taken into account. The *grisaille* in sample SC9 is made of lead silicate without the pigment. As already discussed, the relevant and variable Ca and S content (as well as the presence of Cl) are attributed to the deposits of extraneous materials. The quantitative chemical composition of the glassy phase of the *grisaille* is difficult to determine because of its heterogeneity, which is due to a partial dissolution of the pigment during firing and to the small size of the glassy areas. Analyses were performed on a minimum of ten points for each section, choosing the larger areas of vitreous phase and avoiding the weathered layers. The compositions are shown in TABLE 3. A very high lead oxide content (more than 70%) and traces of alumina, lime, copper and potash are characteristic of the samples. It is interesting to observe that a very similar composition (PbO 70% and SiO_2 27%) was found by Wedepohl for the yellow-green glass of 13th/14th-century beakers found in Germany (Wedepohl 2000). This suggests that a possible source of the low melting glass of the *grisaille* was lead silicate vessels or beads, as suggested by Antonio da Pisa. Furthermore, the absence of alkalis demonstrates that pure lead oxide and silica were used, thus excluding the hypothesis that *grisailles* were made by the intentional addition of lead oxide to the melt used to make the glass pieces (Perez Y Jorba 1991).

Laboratory tests

To study thermal and mechanical properties, laboratory reproduction of the glass and of the *grisaille* followed the analyses. A glass with the mean composition reported in TABLE 1 (trace elements were excluded) was melted in a platinum crucible in an electrically heated furnace at 1350°C. After the complete melting of the batch, the glass was poured in water and remelted for a better homogenisation. Afterwards, the melt was poured into disks 2–3mm thick, annealed at 700°C and cooled to room temperature. The lead silicate (71% PbO; 24% SiO_2, 4% Fe_2O_3 and 1% CaO) was melted at 1000°C in a sillimanite crucible and processed as described for the glass (annealing temperature – 500°C).

A Netzsch 402E dilatometer was used to measure some of the thermal properties of the synthetic glasses, in accordance with standard ISO 7884-8 (1987). A linear expansion coefficient (α) of 113 x 10^{-7} °C^{-1} for the glass and 88 x 10^{-7} °C^{-1} for the lead silicate was measured. The glass transition temperature (Tg) was 615°C (glass) and 458°C and the dilatometric softening point (Sp) 674°C and 491 °C respectively.

A large difference of α (25 x 10^{-7} °C^{-1}) exists between the lead silicate and the glass. This means that, once fired together, significant stresses arise at the boundary of the two materials. To give an idea of the stress, in the ceramic technology to avoid crizzling and/or peeling of the glaze, the á difference between the glaze and the ceramic body should never exceed 5 °C^{-1}x 10^{-7}.

In order to measure the stress arising at the glass/lead silicate interface, samples made of superimposed synthetic glass and lead silicate platelets were fired at 650°C for 30 minutes. After annealing, the samples were prepared in polished cross-sections 6mm thick. Stresses were measured as optical retardation in polarised transmitted light in proximity to the glass/lead silicate boundary. The optical retardation was converted to stress according to the draft international standard ISO/DIS 4790. These measurements showed that the glass was under tensile stress and the lead silicate under compressive stress. The intensity varies between 100 and 200kg/cm^2, i.e. it is much larger than the tensile stress considered acceptable for commercial glass (less than 40kg/cm^2). These results demonstrate that a permanent stress exists at the glass/*grisaille* interface and

TABLE 3 EDS QUANTITATIVE COMPOSITION (WT% OF THE OXIDES) OF THE GLASSY PHASE OF THE *GRISAILLE*

sample	SiO_2	PbO	Fe_2O_3	Al_2O_3	Na_2O	K_2O	CaO	MgO	P_2O_5	CuO	ZnO
SC9	13.0	75.0	1.2	1.5	1.2	1.1	4.0	-	3.0	-	-
SC5	12.0	76.0	4.0	0.5	0.5	0.4	4.5	0.1	2.0	-	-
SC4	25.0	70.0	2.0	0.3	0.3	0.2	1.3	0.1	0.4	0.3	0.1
SC6	20.0	75.0	3.0	0.2	0.1	0.4	0.5	0.1	-	0.5	0.2
SC7	20.0	77.0	1.7	0.4	0.1	0.2	0.4	-	-	0.2	-
SC8	22.0	73.0	2.2	0.8	0.2	0.4	0.5	0.4	-	0.5	-
Mean	*22.0*	*73.5*	*2.2*	*0.4*	*0.2*	*0.3*	*0.7*	*0.2*	*0.4*	*0.4*	*0.2*
Std. Dev.	*2.0*	*2.5*	*0.4*	*0.2*	*0.1*	*0.1*	*0.3*	*0.1*	-	*0.1*	-

can explain the formation of micro-cracks in the *grisaille* and in the underlying glass observed in the original samples of the Sainte Chapelle.

Due to its fragile structure, an important role in weathering of the paint work is played by atmospheric parameters (Munier *et al.* 2002). It can be expected that thermal stability is the most critical parameter; any thermal shock will increase the stress and accelerate the propagation of the micro-cracks and the spalling of the *grisaille*. The crystallisation of salts inside the micro-cracks will have a similar effect as well.

In order to test the effect of the environment, samples made of a glass piece painted with a *grisaille* layer reproducing the original compositions were exposed at the Sainte Chapelle in different positions: inside the chapel, in the interspace between an original and a protective window, and outside, sheltered and unsheltered from the rain. Samples will be collected after 4, 8 and 12 months of exposition. The tests are in progress and the results will be the subject of a future paper.

CONCLUSIONS

In conclusion, the main cause of the loss of the painted layer on the Sainte Chapelle samples was found to be the propagation of micro-cracks in the *grisaille* and in the underlying glass. The *grisaille* layer is structurally fragile because the *grisaille*/glass fit was not taken into account. The low-melting glass used to prepare the *grisaille* paste was probably simply obtained by pulverization of lead silicate vessels or objects. It has a much lower thermal expansion co-efficient compared to the glass piece, so that significant, irreversible stress arises at the boundary of the two materials upon firing together. As a consequence, micro-cracks can grow at any time. It is evident that the formation of cracks reduce the stress, but it is a matter of discussion if they are sufficient to stabilize the *grisaille*. Furthermore, environmental parameters such as variations of temperature and the deposition of salts can influence the durability of the paint work.

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COMPOSITION OF THIRTEENTH TO SEVENTEENTH-CENTURY GLASS FROM NON-FIGURATIVE WINDOWS IN SECULAR BUILDINGS EXCAVATED IN BELGIUM

Olivier Schalm, Hilde Wouters and Koen Janssens

Introduction

Archaeological excavations in historic city centres – mostly in basements and the cesspits of dwellings – have resulted not only in an extensive number of vessel glass objects of different types, but also in a large amount of flat glass: plain window glass fragments, mirror glass and stained glass fragments with painted decorations. Plain window glass is usually the most frequently encountered type of flat glass in excavations. Although historic window glass had a high utilitarian value and played an important role in the appearance of the façades of buildings, up to now it has been investigated to a far lesser extent than extant stained glass windows and luxury glass vessels made in Venice or *façon de Venise*.

The manner in which the chemical composition of vessel glass depends on the vessel shape and on the period and region of fabrication is already well documented. Due to a lack of published compositions, such relations can not be studied in detail for window glass. However, this information might explain possible variations in the deterioration of stained glass windows that have survived the ravages of time. This article presents the first results of a quantification campaign of 446 Belgian and three German, 14 to 17th-century window glass fragments. Figure 1 provides an overview of the origin of the Belgian fragments. The article deals with the relation between the period of fabrication and the chemical composition of window glass originating from a small geographical region. The use of sea salt and lime as raw material for the production of glass is also discussed.

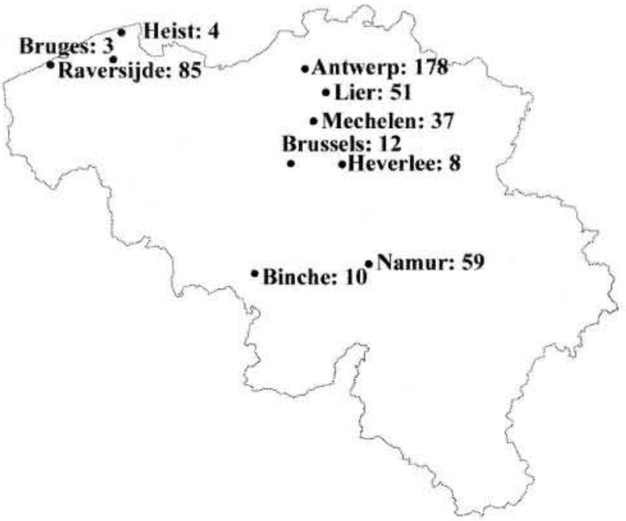

FIG. 1 Map of Belgium and the cities from which glass has been analysed. Archaeological plain window glass was collected from Heist, Brugge, Raversijde, Antwerp, Mechelen and Namur. The excavated glass from Binche originated from a stained-glass window. Samples from windows *in situ* were collected in Lier, Heverlee, and Brussels. The number of analysed fragments is indicated

Historical background

Since window panes cut from cylinder or crown glass were too small to fill the window frames, several panes were assembled into larger entities by means of a network of H-shaped lead strips (cames). In stained glass windows, this network contributes to the design of the picture. In secular buildings, windows with a geometrical network of lead were often used. Several common types of lead patterns are shown in Figure 2. Archaeological window glass usually has a high degree of fragmentation and the shape of the former panes can only be identified for a limited number of fragments. For example in the 15th-century fishing town of Raversijde, Belgium, some excavated panes had a rectangular or circular (i.e., the so-called 'bull's eye') lozenge shape.

From the 15th century, citizens could afford (non-figurative) window glass in their houses. First, only the upper parts of the window frames were filled, but it evolved into a complete filling. Excavations demonstrated that window glass was not restricted to the richest communities and citizens in prosperous cities. For example, in Raversijde excavated window glass fragments were associated not only with the former chapel but also with several private houses. Most of the studied window glass had a light green hue. Intentionally coloured glass was only rarely encountered in secular buildings. A few fragments excavated in Raversijde and in Antwerp indicate that the borders of windows in secular buildings were sometimes decorated with glass paint.

Experimental

It was expected that the composition of the fragments originating from a single excavation site would not be uniform because several visual parameters such as colour, thickness, deterioration and surface texture changed from fragment to fragment. Therefore, the fragments were

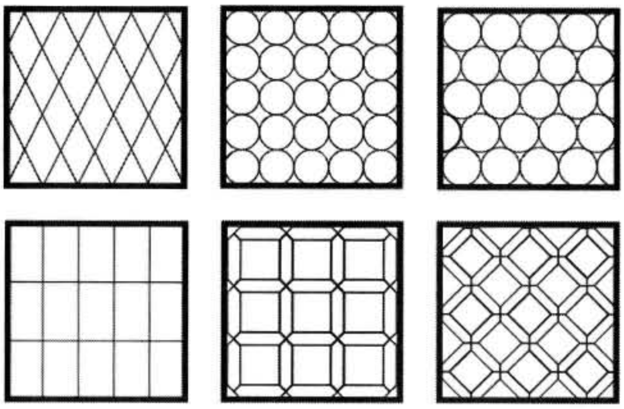

FIG. 2 Common lead patterns for non-figurative windows. The patterns in the top row are typical of the 15th century, those in the bottom row of the 16th century

classified on the basis of their visual differences into approximately homogeneous groups. Only one sample was collected from each group in order to avoid the sampling of two fragments originating from the same pane. The samples were dated by their archaeological context. Fragments were sampled from different sites in one city and from different cities in Belgium. The dataset contains a large number of plain window glass fragments, excavated stained glass fragments, and fragments originating from still extant windows. Most of the glass originates from secular buildings, but the dataset includes a small amount of glass from churches, chapels or monasteries. The medieval glass in the dataset is somewhat under-represented because it was much harder to find than 16th to 17th-century glass. Except for a couple of blue and red flashed glass fragments, all samples were made in naturally coloured glass with a light green hue. The dataset contains three fragments of 16th to 17th-century mirror glass excavated in Antwerp. Although mirror glass can be identified by the perfect transparency of the glass, its black crust on one side of the glass and engraved decorations on the borders of the other side, it is often confused with window glass. The black crust is the remainder of the metallic coating and is usually rich in tin and mercury.

Several glass samples were embedded in the same block of resin. The orientation of the samples in the resin was such that the cross-section, perpendicular to the original glass surface, could be studied. The surface of the resin was ground flat with corundum papers and polished with fine diamond pastes (down to a final diameter of 1 µm for the diamond powder). A carbon coating was applied to the polished surface. The samples were analysed by means of a Jeol 6300 electron microprobe system equipped with a digital, thin-window energy dispersive Si(Li) X-ray detector of Princeton Gamma Tech (PGT). This instrument is able to collect X-ray spectra of small areas of non-conducting material containing light elements (Na, Mg, Al, etc.). It is an outstanding technique for silicate glass analyses.

For every sample, four X-ray spectra were collected at a voltage of 20kV, a beam current of 2nA, 100 s acquisition time and a magnification of 500. A quantification algorithm based on thin film sensitivity co-efficients was used to calculate the composition of the window glass (Schalm 2000; Schalm and Janssens 2003). A data matrix is obtained in which each row consists of the average composition of a sample and each column the oxide constituent of the glass. Hierarchical clustering was performed on the data matrix by means of the software package SPSS. The clustering is based on the non-normalized concentrations of Na_2O, MgO, SiO_2, K_2O and CaO using Euclidian distance. The data matrix was divided into seven clusters.

RESULTS

In the literature (Henderson 1988; Wedepohl 1997), a distinction is often made between lead glass (SiO_2-K_2O-CaO-PbO), soda glass (Na_2O-SiO_2-CaO), mixed-alkali glass (Na_2O-SiO_2-K_2O-CaO), potash or forest glass (SiO_2-K_2O-CaO) and high-lime/low-alkali (HLLA) glass (SiO_2-K_2O-CaO). The group of potash glass and HLLA glass is sometimes denoted as calco-potassic glass. However, the relation between these names and the chemical composition is not always explicitly stated by the authors. To facilitate the discussion provided below, such a relation is proposed in FIGURE 3. The flow chart in the figure agrees with published classifications.

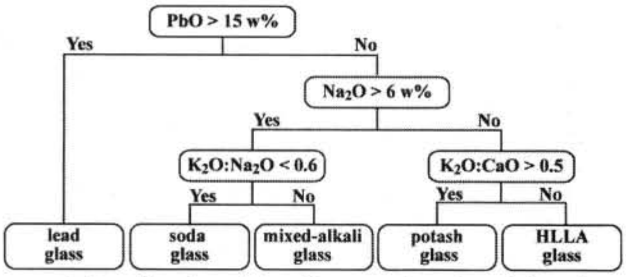

FIG. 3 Classification of glass fragments based on their major composition

The glass types are usually associated with different glassmaking recipes. Therefore, soda glass, potash glass and HLLA glass are sometimes described as soda-lime glass, wood ash glass and wood ash lime glass respectively. Due to a large compositional variation within every type, a clear distinction between these types is not always straightforward. For example, glass fragments can contain a small amount of PbO, sometimes up to 7%, but this is not sufficient to classify them as lead glass. Lead glass contains usually between 30 and 60wt% PbO. Therefore, hierarchical clustering was employed to classify the individual samples while the flow chart in FIGURE 3 was used to classify the average compositions of the clusters into different glass types (Barrera and Velde 1989; Gratuze 1994; Müller *et al.* 1994)

The most variable oxides present in glass in concentrations higher than 1%, are SiO_2 and the oxides originating from the fluxing agents: Na_2O, K_2O, MgO and CaO. Only these oxides are used in the hierarchical clustering. The average composition of the seven identified groups is given in TABLE 1. All the window glass from secular buildings that have been analysed belong to the group of calco-potassic glass, while the three fragments of mirror glass are soda glass. One window glass fragment contained 2.03wt% PbO, but this was not sufficient to classify it as lead glass.

TABLE I AVERAGE COMPOSITION OF THE DIFFERENT CLASSES AS IDENTIFIED IN THE DATA SET OF 441 SAMPLES BY MEANS OF HIERARCHICAL CLUSTERING. LISTED UNCERTAINTIES REFER TO THE 1S STANDARD DEVIATION ON THE AVERAGE CONCENTRATION VALUES EXPRESSED IN WEIGHT PRECENTAGE. THE SYMBOLS REFER TO THOSE USED IN FIGS 4 AND 5

	C13–14th window glass		C15–17th window glass				Mirror glass
	Potash	HLLA	Potash			HLLA	Soda
	(1) ●	(33) △	(1) □	(4) ▲	(24) ■	(383) ◇	(3) ○
Na_2O	0	0.6 ± 0.4	3.5	0.9 ± 0.3	1.8 ± 0.7	2 ± 1.5	12.1 ± 0.7
MgO	3.5	4.2 ± 0.4	0.1	5 ± 2	6 ± 1	3.4 ± 0.8	2.8 ± 0.5
Al_2O_3	1.7	3.1 ± 0.6	0.6	2 ± 1	2.1 ± 0.6	4 ± 1	2.2 ± 0.2
SiO_2	49	47 ± 1.5	67	62 ± 2	56 ± 2	59 ± 4	67 ± 1
P_2O_5	0.4	2.2. ± 0.8	0.1	1.8 ± 0.7	2.7 ± 0.9	2.3 ± 0.7	0.3 ± 0.1
SO_3	0.2	0.3 ± 0.1	0.4	0.2 ± 0.2	0.2 ± 0.1	0.2 ± 0.2	0.1 ± 0.1
Cl	0	0.1 ± 0.1	0.2	0.3 ± 0.2	0.3 ± 0.1	0.3 ± 0.2	0.9 ± 0.1
K_2O	26	13 ± 2	19	14 ± 2	11 ± 2	6 ± 3	4.2 ± 0.7
CaO	18	27 ± 2.5	9	12.2 ± 0.9	17 ± 1	22 ± 3	9 ± 1
MnO	0.8	1.1 ± 0.2	0.01	1 ± 1	1.2 ± 0.8	0.8 ± 0.4	0.4 ± 0.1
Fe_2O_3	0.3	0.7 ± 0.2	0.1	0.5 ± 0.1	0.7 ± 0.2	1.0 ± 0.3	0.6 ± 0.2
BaO	0.2	0.9 ± 0.2	0.1	0.3 ± 0.3	0.4 ± 0.2	0.5 ± 0.2	0.1 ± 0.1
PbO	–	–	–	–	–	0.1 ± 0.1	-

The analysed mirror glass has a typical *façon de Venise* composition, a Venetian imitation produced in north-western Europe during the 16th–17th century. It contains somewhat more K_2O than genuine Venetian glass. This indicates that mirrors were produced in the Low Countries.

The calco-potassic window glass is subdivided into a group of 13th to 14th-century glass and a group of 15th to 17th-century glass. No compositional evolution could be detected in the group of 15th to 17th-century window glass. The dataset suggests a sudden change in chemical composition during the 14th to 15th century. For both periods, window glass could be further subdivided into a small group of potash glass and a larger group of HLLA glass. The 15th to 17th-century period is dominated by a large group of HLLA glass with a wide variation in its average composition but it could not be subdivided further by means of hierarchical clustering. The potash glass of that period consists of several clusters. The presence of bright green lead glass and soda glass panes are sometimes reported in stained glass windows (Rauret *et al.* 1985; Orlando *et al.* 1996; Kuisma-Kursula and Räisänen 1999) but these types of glass were not found in the dataset of secular window glass.

Most of what is known about medieval stained glass manufacturing technology originates from the 12th-century manuscript *On Diverse Arts* by Theophilus (Hawthorne and Smith 1963). According to him, glass was made with one part of washed sand and two parts of beech wood ash (*ibid.* book II, chapter IV). The low amount of SiO_2 in the 13th to 14th-century window glass (<50wt%) and the large quantities of oxides that have been introduced by the fluxing agent (K_2O + CaO = 40wt%) might suggest that this glass was indeed made by means of a recipe resembling that of Theophilus. The P_2O_5 concentration of about 3wt% suggests the usage of unpurified wood ash. However, the presence of potash glass (K_2O:CaO ratio of 1.4) and HLLA glass (K_2O:CaO ratio of 0.46) points to the existence of different recipes in that period.

A sudden change in the chemical composition is observed in the dataset. From the 15th–17th century onwards higher amounts of SiO_2 (> 50 wt%) are noticed, indicating that a recipe with relatively more sand and less fluxing agents has been employed. The composition of the fluxing agent differs as well – it contains more Na_2O and less K_2O. For the HLLA glass, the K_2O:CaO ratio changed from about 1:2 to about 1:4. The presence of P_2O_5 suggests that unpurified wood ash is still employed as a raw material. However, the chemical composition of the 15th to 17th-century HLLA glass can only be obtained when the wood ash in the medieval recipe is replaced by an ash rich in calcium or by a mixture of fluxing agents, for example wood ash with lime. The sudden change in composition appears to be caused by a change in glassmaking technology.

Medieval window glass contains a somewhat lower concentration of Na_2O than 15th to 17th-century glass, although higher amounts of wood ash – the major source of alkali – have been employed for its production. This means that an additional sodium source was employed for the fabrication of 15th to 17th-century glass. A correlation between soda and chlorine, which is shown in FIGURE 4, was only found for the group of 15th to 17th-century glass. The soda concentration varies between 0 and 5wt%, while chlorine varies between 0 and 0.7wt%. For all calco-potassic samples, the content of Na_2O was always smaller than 6wt%. As the amount of Na_2O increases, the number of calco-potassic samples decreases.

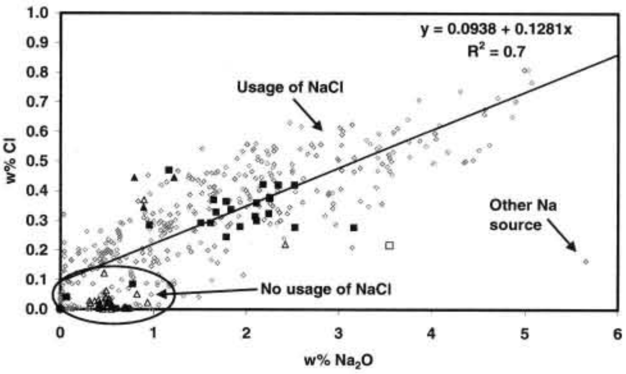

FIG. 4: The linear relation between Na_2O and Cl for the 15th to 17th-century HLLA glass. Most of the medieval glasses do not follow this relation. The symbols are related to the compositional groups of TABLE I

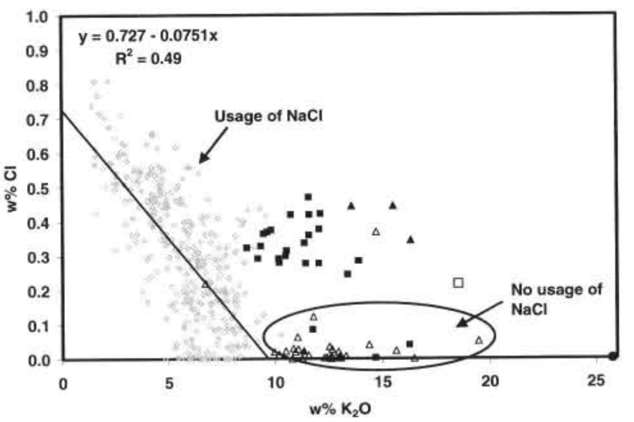

FIG. 5 The amount of Cl as a function of K_2O for the calco-potassic glass. For the 15th to 17th-century HLLA glass (383 samples), a relation between these constituents is noticed. The symbols are related to the composition in TABLE I

Most probably, sea salt was employed as the sodium source. During glass fusion, this ingredient transforms into Na_2O while most of the chlorine evaporates. Only in one sample the high Na_2O content appears to be unrelated to the chlorine content. An admixture of soda-glass cullet to the batch might explain this exception. The usage of sea salt indicates that not only relative amounts of the glassmaking recipe has been changed in the 14th–15th century, but also new raw materials were introduced into this recipe.

No relation between Na_2O and other oxides such as K_2O and CaO is expected when a mixture of sea salt and wood ash is used as a fluxing agent, because wood ash is poor in sodium (Misra *et al.* 1993; Stern and Gerber 2004) and sea salt is poor in potassium and calcium (Brown *et al.* 1991, 30). Indeed, for the 15th to 17th-century HLLA glass, no relation was found between Na_2O and CaO – the concentration of CaO remained constant around 22wt% with an increasing concentration of Na_2O. However, the amounts of Na_2O and K_2O appear to be related – glass with somewhat higher amounts of Na_2O (and higher amounts of Cl) contains less K_2O (FIG. 5). This would suggest that the relative amounts of ingredients rich in sodium and rich in potassium were not chosen independently.

The analyses indicated that mirror glass was produced in north-western Europe with a *façon de Venise* composition. All window glass samples in the dataset were of the calco-potassic type. No lead glass or soda glass panes were found in this group, although they are sometimes reported in stained glass windows. Most of the window glass consists of HLLA glass. The potash composition does not occur often in the group of window glass. The dataset could be divided in two periods: 1) the period before the 15th century and 2) the 15th to 17th-century period. Window glass from the older period is characterized by a low SiO_2 content (< 50wt%), a high amount of oxides that are related to the fluxing agent, and a low concentration of Na_2O. Glass from the second period is characterized by higher amounts of Na_2O and SiO_2 but a lower amount of K_2O. The compositions suggest that the glass making recipe suddenly changed around the 14th–15th century, not only in the relative amounts of the raw materials but also in the usage of new ingredients such as sea salt.

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A POST-MEDIEVAL GLAZIER'S WORKSHOP IN CHESTER AND ITS ANTECEDENTS

IAN ARCHIBALD

INTRODUCTION

This paper reports some preliminary results from an unexpected find of glass craft debris during building work in 1995. Although no certain *in situ* structures relating to glass production were located in the assessment trenches, the nature of the finds, and documents of the 16th to 17th century, identify the site as a glaziers' workshop. This evidence illuminates the craft of glazing from both a technological and social perspective. It also suggests close relationships between glazing, other glass processes and ceramic technology, and an extended craft tradition with apparent origins in a post-Roman ecclesiastical environment. It is possible to give only a brief introduction to the archaeological context here. A more complete report is in preparation (Archibald forthcoming).

Handbridge is a suburb of Chester in north-west England. The site lies exactly on the line of Watling street as it runs south from the crossing of the Dee at the Roman fort. This area was occupied by a cemetery of the fort and the Roman aspects of the site have been examined previously by Newstead (1948). Until the 20th century, Handbridge was an industrial area with rope making, copperas production and a range of activities associated with the water mill on the Dee including potting, paper making and the tobacco industry (FIG. 1)

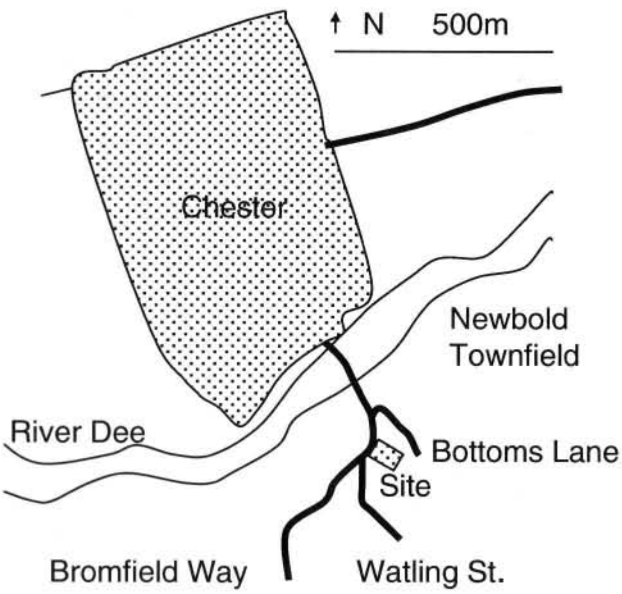

FIG. 1 The site located on a map derived from Speed's early 17th-century map of Chester

Assessment of the site through limited excavation has revealed a long sequence of deposits: cowsheds dating from both the 18th and 19th century, which seal a Civil War destruction deposit (1643–45), itself sealing an industrial hearth of 17th-century date, which ultimately overlies a sequence of late Roman/early medieval structures. These last, because of their orientation, associated burials and imported pottery, are assumed to be ecclesiastical in nature.

GLAZIER'S WORKSHOP

Glassworking debris is found in all deposits from the Roman period onwards, and in all cases is associated with pottery manufacturing, suggesting a tradition dating from the close of the Roman period and continuing until the early 18th century, when it was substituted by agricultural activity.

The buried soil layer, which seals the Roman and early medieval deposits and is sealed by later 18th-century activity, is rich in fragments of window glass of a great variety of qualities, thicknesses and colour (FIG. 2). They are clearly detritus from craft activity rather than from a building. There is a high percentage of fragments with the fire-rounded edges typical of the cylinder process. Many fragments show multiple cutting lines. Some fragments clearly result from trimming larger pieces. Some pieces are distorted by heat and have tool marks. They cover a wide range of dates, from thick crown glass, perhaps from the 13th century; to glass formed by a cylinder process utilising forest glass; to blue flashed glass from the late 15th to early 16th century; to high quality fire-polished and diamond-cut glass probably originating in Haughton Green in the early 17th century (pers. comm. Ruth Hurst Vose). One heat-distorted fragment is in a blue/amber dichroic material, shows tool marks, and was found along with molten droplets in a similar dichroic material. Lead cames of an early medieval form were found and a few droplets of melted lead. A fragment of 10th to 11th-century Chester ware apparently used as a palette for a ferrous paint, was also found in a disturbed context as was another Chester ware fragment showing signs of vitrification.

The heat-affected fragments suggest that local glass technology extended beyond cutting glass and fitting in windows. Melted glass fragments in a range of different colours (green, cobalt blue, colourless, amber and opaque white) and of a variety of qualities and degrees of corrosion were found. That these are the result of a deliberate craft

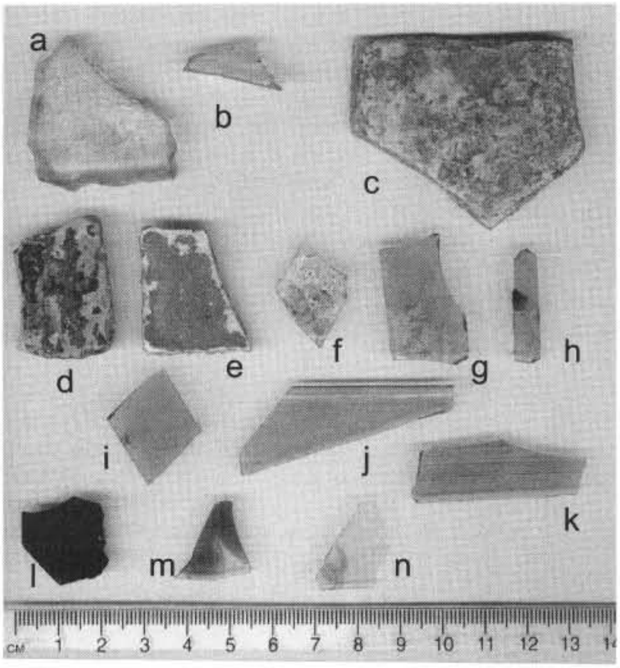

FIG. 2 Window glass from the Handbridge site: a–b Roman, c medieval crown glass; d–g medieval cylinder glass, h blue flashed glass; i–k Haughton Green glass with diamond cut marks; l purple grozed fragment; m–n silver stained sherds

process, rather than a domestic fire, is indicated firstly by the presence of opaque droplets, and secondly because of tool marks on some of the pieces. Glass blowing is certainly a possibility. An iron object, possibly a *procello*, and crucible tongs would support this hypothesis, but the only moile appears to be of Roman glass. Some of the droplets may also be residual from the earlier late/post-Roman industrial phase; perhaps the opaque glass was part of the bead making activity.

Possible glassmaking evidence was also found. This consists of a small number of crucible fragments, and some fragments of highly vitrified sandstone furnace lining. Electron microprobe analysis of the glassy surface of one of the crucible fragments reveals a glass composition typical of 17th-century English glass – soda-lime-silica with soda derived from plant ash. A fragment of a goblet bowl in a fine brownish/colourless fabric, found in close proximity to the crucible fragment, has a similar composition (FIG. 3).

Vessel glass fragments were also found, perhaps brought to the site as cullet. Vessels represented include a 13th-century urinal, an opaque white lid of possible 14th-century date, 16th-century beakers, and 17th-century *façon de Venise* goblets. The *façon de Venise* fragments might possibly be local production related to the crucible fragments. Several small fragments of convex mirror glass with finely grozed edges were recovered. These were of the type made by filling a blown sphere with molten lead before breaking into small mirror pieces. Although these small mirror fragments were still reflective where the lead backing was still in place, the glass was so bubbly and contaminated with inclusions that they cannot have functioned well as a mirror and must be considered wasters.

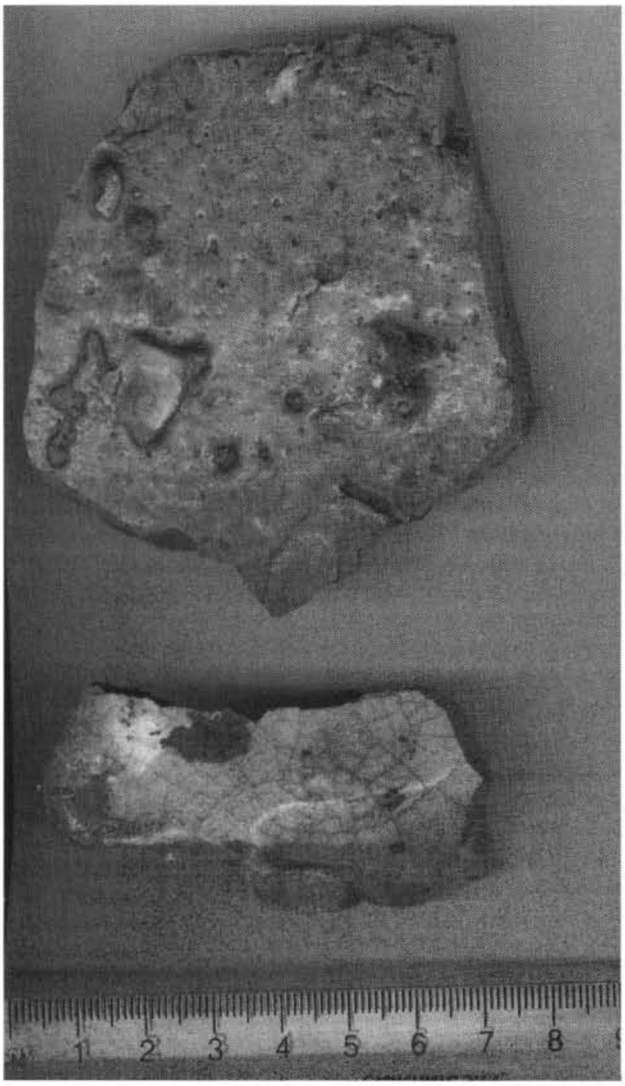

FIG. 3 Fragments of 17th-century crucible and furnace lining

A sealed context dated to the Dark Age period (5th–10th century) and containing industrial waste also produced some small, colourless, slightly opalescent and bubbly, glass bead wasters. These had been wound on a mandrel, but in all cases the perforation had sealed up. Some of the beads were joined in pairs, indicating either that they had been intended to be segmented, or that they were fabricated by having more than one bead on the mandrel at a time. Three beads were found in context and a further 50 were found residually in later contexts. A tube of bubbly cobalt blue glass with opaque white inclusions, and sealed at one end, might be left over from drawing beads; an example of a drawn bead in a similar fabric was found residually in a later context along with a heat-distorted opaque blue and white bead and other beads of ancient origin (FIG. 4).

In addition to the beads, this industrial context contained further evidence for glassworking, in the form of small 'twists' of heat-deformed glass. One of these was analysed using an electron microprobe and proved to be a soda-lime-silica glass, with low levels of magnesium and potassium oxides, coloured by iron and manganese. Close to the industrial deposit a sherd of a possible E ware bowl was found, partially vitrified, with yellowish glass adhering to

FIG. 4 Bead working debris from the late-Roman industrial deposit

the broken edges. This would date the glassmaking and the industrial deposit to the 6th–7th century, consistent with the dating of demolition of the supposed ecclesiatical structure. Fragments of Roman window glass and vessel glass were also found in a rubble sill construction, which sealed the industrial deposit, and in all later deposits. A moile in a typically Roman blue/green glass was also found in the topsoil.

Ceramic production

Products, for which wasters have been recovered, include Roman oxidised ware, medieval clear-glazed white ware, Midland purple, Midland yellow, tin glaze, black-glazed ware, slipware, stoneware and an unidentifiable white-glazed ware. The industrial hearth area dating to the 17th century is most probably the degraded remains of a pottery kiln rather than a glass furnace.

The Dalby family

The archaeological evidence for a glazier's workshop has been confirmed through documentary research. In the 16th and 17th century the records of the Chester Glaziers' company indicate that the company contained only four glaziers. Only one of these families, the Dalbys, can be confidently associated with Handbridge. This association is also documented for the entire period in question through wills, deeds and churchwardens' accounts. A record of 1650 (Sheaf 1951, 59, 9515), relating to crown property in Chester formerly belonging to the fraternity of St Anne, records the property on which the current site is situated.

> A tenement in the liberties of Chester of 2 rooms and 1 newly built, bounded on south by Mr. Hurlton's tenement and by Ald. Sproson's, on north, with 2 loundes of land, about 2 acres by ye bottoms in the Townfield, bounded on West by Bromefeilde lane, in tenure of Moses Dalbie £1 2s 4d.

This property appears, from other crown land records, to have been in the possession of the Dalby family since at least 1550. The 'loundes' referred to lie in the township of Claverton outside the city liberties.

An inventory of Edward Dalby III (CCALS WS1612 – author's transcription) provides corroboration of involvement in potting.

> Item all the glasse in the shoppe £5 13s 10d
> Item more shillfes boards and lead in the shoppe 6s......
> Item more a grate and basket and harthe for a killin one former one coumbe a troughe to kneade in and a swim troughe 57s 6d
> Item more 42 foote of boards and an olde wheel and a forme 2s 8d

This was not the only, or indeed main, residence of the Dalby family; a 17th-century will (CCALS WS1680) indicates that they were also in possession of a messuage in Barrow, a village 6km east of Chester, and various other properties within and without the liberties of Chester.

The documentary research has shown that the Dalby family were influential glaziers in Chester. The records of the Chester Painters, Glaziers, Embroiderers and Stationers company, the churchwardens' accounts and registers of Chester Cathedral and the parish churches of St Peter's, St Mary's, Holy Trinity and St Bridget's, and the database of Cheshire wills (Burne 1958; Simpson 1909; Earwaker 1898; Farrall 1914; Sheaf (various), CCLAS Guild Records T/1, 2) enable a rich picture of the activities of the Dalbys to be recovered over the period from 1533 until *c.* 1727. A family tree of the male family members surviving to adulthood, drawn from information contained in the aforementioned resources, is shown in FIGURE 5.

Throughout the period, the Dalby family were prominent in the Painters and Glaziers company, sharing the post of steward with prominent herald painters such as Thomas Chaloner and the four generations of the Randle Holmes whose careers parallel in many ways those of the Dalbys. Richard Dalby I and Edward Dalby V were, for example, churchwardens at St Mary's, as were several Randle Holmes. Thomas Dalby (II) appears as witness for several charters involving Chester's civic elite, and was clearly involved in local government in the early 17th century. Edward Dalby (III) ran what appears to have been by the standards of the time, a substantial business, with two of his sons as apprentices, as well as at least two other apprentices. Many of the other glaziers in Chester were apprenticed to Edward in their early careers. His will indicates a substantial collection of brass and pewter as well as paintings. Edward and his brother Richard acted in the Shepherds' Play which was the Painters and Glaziers responsibility within the cycle of Chester Mystery Plays. They appeared in several performances in the 1570s, including the final staging, in 1577, when the Shepherds' Play was performed for Henry, Lord Derby, and Ferdinando, Lord Strange. As two of the Shepherds they performed on stilts! (Bridges 1906). The text of the play

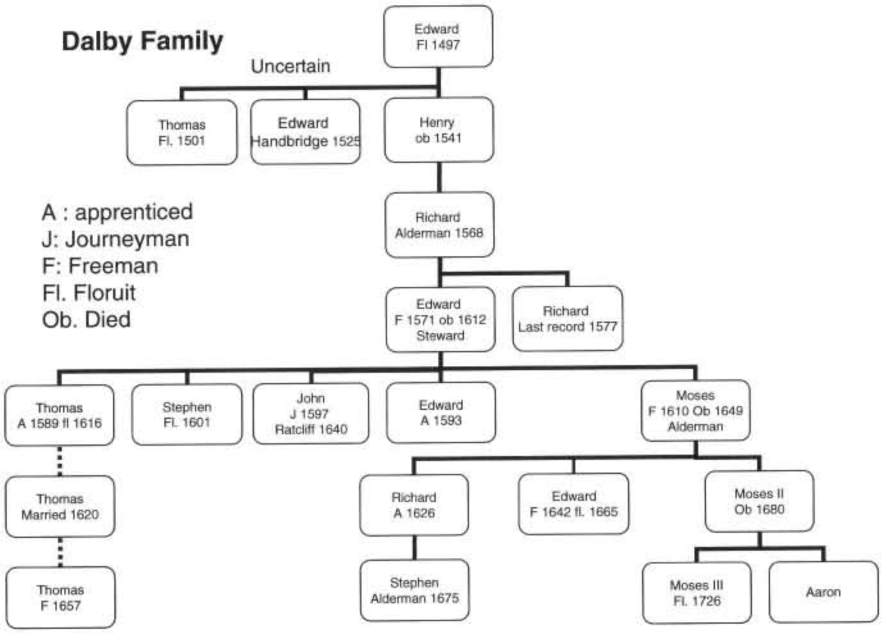

FIG. 5 The Dalby family of glaziers

(Mills 1992) even includes a passing reference to the glaziers' craft – the First Shepherd in attempting to construe the Herald Angel's Gloria, says:

> Nay it was 'glorus glarus' with a 'glo'
> And a lot of 'celsis' too.
> And as ever I have rest from woe,
> He said something about 'glass.

Moses Dalby (III) appears in the electoral records for 1727 in Claverton, along with five of Chester's most important landowners, although the extent of his own freeholding is unclear.

The various churchwardens' accounts provide details of the work carried out by the Dalbys. Sometimes this provides a quite poignant picture of the difficult times in which they lived. In 1533, the churchwardens' accounts of Holy Trinity record payment to Henry Dalby for 'glazing steple windows 5s 4d', while in a different context in 1574, the same accounts note 'Paid Edward Dobye 10/- for defacing the images in the windows'. Edward was Henry's grandson. Sometimes the projects undertaken were quite ambitious. In 1638/39, St Peter's church records

> Item paid to Mosses Dolbie for glazeing the windowes and for mending and clenseing the ould windowes and making the sun dyall £10-0-0

The Dalby clientele included prominent local house owners as well as ecclesiastical establishments.

John Dalby, journeyman to the Chester guild in 1597 (CCLAS Guild record T/1; Mahler 2003), appears as a glassmaker in Ratcliffe in 1635–40. Was he working in a Mansell licensed glasshouse in order to continue his trade during the monopoly, a period when the Chester glaziers were apparently importing glass from Haughton in Manchester?

So far it has not been possible to provide direct documentary evidence for any Dalby acting as a glazier earlier than 1533 (or later than 1664 when Moses Dalby undertook his largest recorded contract, £30 to reglaze parts of the cathedral, thereafter potting and farming became the prime activities). The Dalby family, however, can be traced back further; in Handbridge to at least 1501, when one Thomas was identified as constable for 'Honbrigge' (Sheaf 1915, 23, 2771) and maybe to 1497, when Edward Dalby was involved in a law case involving the lost girdle of Lady Dutton. Earlier still, John de Dalby was mayor of Chester 1366–68 and Sheriff 1355–56, and Alexander de Dalby was Dean of St John's and was an administrator in the service of the Black Prince, rising to become Constable of Bordeaux by 1368. William de Dalby was involved in a disputed bequest to the Carmelites, involving many of Chester's governing merchant class, in 1327 (Bennett 1935). Given the status of the family in the 14th century, it is unlikely that they were directly involved in glazing. There are, however, connections to the later family. John de Dalby was involved in the importation of bark and is recorded as paying prisage. The bark mill was in Handbridge. He was also involved in a dispute over the removal of large amounts of timber (£40 pounds worth – maybe several hundred trees) from the land of Maud Swinnerton in Barrow. This indicates an involvement with Barrow which is reflected in the later Dalby properties, and it also shows an appetite for timber which might be consistent with fuel supply for a glass manufactory. Maybe the bark also fell into this category? The fact that the later – glazier – Dalbys were socially prominent reflects the earlier position.

Overall, however, the documentary evidence suggests a mercantile rather than a craft role for the earlier Dalbys. None of the pre 16th-century records of glazing in Chester identify a Dalby involvement in glazing. The archaeological evidence from the site, however, clearly suggests that the glassworking tradition extends much earlier than the 16th century. This is something that requires further work. The Dalby name suggests that they were incomers to Chester (perhaps from Yorkshire or Lincolnshire) during the period of glassworking on the site. That they acquired the glassworking skills, entry to the craft guild and the workshop property suggests perhaps marriage into an earlier glazing family.

Conclusions

The Handbridge site raises several issues relating to the glazier's craft. The activity was of long duration on the site. There were connections with related technologies such as glass working, possibly glassmaking, and ceramics. The glaziers were part of a wider commercial network in the rest of England and participated in a social network which included important herald painters. The relationship with earlier Chester glaziers whose work on sites in Chester, Wales and Westminster has been noted (Ridgway 1947; 1948; 1962) remains to be established, but it seems that there was a continuous vitreous technological tradition on the site for over a millennium.

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THE PAINTED TABLETS FROM THE COLLECTION OF THE NATIONAL MUSEUM OF SLOVENIA – THE PROBLEM OF PROVENANCE

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Stained glass windows constitute a particular problem in Slovenia. Very few have been preserved because most were destroyed by earthquakes (a devastating earthquake in 1511 completely destroyed Loka Castle which was famous for its stained glass windows), the Turkish incursions, fires, wars, etc. Among the preserved ones, three are in the glass collection of the National Museum of Slovenia (FIGS 1–3). These shields are of additional interest, because they bear witness to family relations and as such also to trade relations between the Slovene provinces and several south German towns. Another interesting aspect is their secular motifs. Only two other stained glass windows, which show coats of arms have been preserved in Slovenia, but they belong to an earlier period (14th century). They are the coats of arms of the Counts of Celje in the filial church of St Lenart in Drevenik above Kostrivnica. Historically, the painted tablets were usually the central pieces of stained glass windows. They were surrounded by blown glass panes (clear, yellowish, or greenish) and the lead frames of the shields revealed visible joints with the blown glass – that is grooves into which the other parts of the stained glass windows were mounted. The tablets are found in the stained glass windows of family chapels and in residential houses (Fischer 1991, 1462), but some also embellished sideboards. In the 16th century they were often donated as gifts and this explains why secular motifs start to appear, and among them coats of arms. The tablets were often serially made – first the decorative parts were produced and then the coats of arms and inscriptions were added in accordance with the commissioner's wishes.

The three painted tablets in the glass collection of the National Museum of Slovenia have different histories. All three were acquired at a similar time but not together. J. Anton Graf donated the first in 1832. The provenance of the second plate is not known, but it came to the museum at the same time, but, obviously, not by the same donator. Franz Kniffiz von Steinhofen donated the third in 1836. The three shields feature the coats of arms of two closely related merchant families. This suggests that in spite of the different styles all three may have originated simultaneously.

Two of the three painted tablets are marked with inscriptions and dates. The text on the first tablet reads 'Barbara Altin/sein hausfraw/1544' (FIG. 1) and on the second 'Katherina Ligsaltzin/Barbara Altin Marx Thenns Hausfrauen/1546' (FIG. 2). The first tablet features the coat of arms of the Alt and Ligsaltz families in the centre, the second one that of the Alt family. The third tablet is completely different from the other two. The figure and

FIG. 1 Painted tablet with the inscription 'Barbara Altin/sein hausfraw/1544'. Diam. 198mm. Narodni muzej Slovenije (N 2071). Photo © Narodni muzej Slovenije

the coat of arms indicate that it belonged to Marx Thenn. It is not dated. Its coat of arms however suggests that in spite of the totally different style it was made at approximately the same time as the two dated tablets (FIG. 3). The first tablet was obviously made in memory of Thenn's first wife, while the second one is somewhat enigmatic, but it is most likely that it was made when Thenn married his second wife (Katarina Ligsaltz) and in memory of his first wife, Barbara Alt. The first tablet was undoubtedly part of a bigger set, as it is obvious from the inscription 'sein hausfraw'. An interesting aspect of the shield is also that its inscription does not reveal to whom it refers. This can only be determined based on the inscription on the second shield and it is further proof that the shields were made in the same workshop, though not at the same time.

It is quite possible that the shields were produced in a workshop as a kind of serial product. They are definitely not real stained glass windows, composed of multi-coloured small pieces of glass and set in a lead frame joining the individual parts into a whole. In the Museum's first and second painted tablets, major elements of the design's whole (e.g. both helmets, the halves of the quarters, the

FIG. 2 Painted tablet with the inscription 'Katherina Ligsaltzin/ Barbara Altin Marx Thenns Hausfrauen/1546'. Diam 200mm. Narodni muzej Slovenije (N 2146). Photo © Narodni muzej Slovenije

FIG. 3 Painted tablet with Marx Thenn's coat-of-arms. Diam 197mm. Narodni muzej Slovenije (N 2147). Photo © Narodni muzej Slovenije

plumes, etc) are composed regardless of the colours involved, and the larger coloured fields and details were painted. Essentially, this means that randomly chosen pieces of clear glass were painted to imitate a stained glass window, instead of composing pieces of coloured glass in accordance with the coloured fields of the motif itself. In particular in the quarters the borders between two different colours are in some areas painted (imitating a lead frame). Enamel paints were used in the process. The restoration of the first and second shields showed that the pieces of glass were grozed from a larger piece, and not cut off with a diamond.

The stained glass windows of the first and second shields were therefore made combining two techniques – that of stained glass and that of painted glass.

The first two shields can be attributed to the same painter. This is suggested by the details (the figure of the bearded man, the helmet, and the ornaments in the decorative fields). The third shield is quite different, but the ornaments in the decorative fields are executed in the same style as in the first two. An essential difference is the absence of a lead frame, which means that it was not part of a stained glass window, but a glass painting.

The third shield was reassembled in 1963 but has not yet been professionally restored. The other two shields were restored in 1998. Their restoration revealed that a part of the original inscription on the tablet dated 1546 was replaced during restoration in the mid 20th century. This means that the inscription is (no longer) the original one.

In the available written sources there is no evidence of a specialised workshop for stained glass windows in the Slovene provinces. Records, however, mention a range of glassmakers in the towns. But it is not clear whether any of the Ljubljana glassmakers (the sources mention several) was capable of producing stained glass windows. Preserved bills mainly refer to the supply of windows made of blown panes and to broken and replaced window panes. Stained glass windows were usually made in collaboration between glassmakers and painters. To date we know of only one artisan who was a glassmaker and a painter and who was active in Škofja Loka around 1527.

Furthermore, there are no data indicating whether one of the three glassworks in Ljubljana (the first founded before 1526, owned by Andreas Dolenik & Zoan Francesco Catanio; the second founded *c.* 1534, owned by Veit Khisl & Hans Weilhamer; the third founded *c.* 1570, owned by Adam Moscon) had a painter in their employment (Kos and Žvanut 1994, 42). Some of the products of the Khisl glassworks are painted or gilded (gold leaf ornament, stylised motifs painted with enamel paints), but this is certainly the work of a skilful glassmaker, not a painter. In the 16th century, quite a number of painters were active in Slovenia, but archive sources and preserved works show that they were mainly engaged in wall paintings – frescos. Panel paintings were mostly imported.

According to the information in the Acquisitions book, the first two tablets had been used for the sign of a glassmaker's workshop situated in a house next to an inn called Zum Wilden Mann on the Mestni trg (City square) in Ljubljana. It is possible that its owner was Kristoph Prunner, the leaseholder of the Khisl's glassworks.

The Thenn family were merchants in Salzburg. The Alt brothers were involved in trade with Carniola, especially with Veit Khisl. It is possible that they had brought the tablets with them from Salzburg. Other famous production centres of stained glass windows were Augsburg and Nürnberg. However, we cannot exclude the possibility that the tablets were made in Ljubljana. Augustin Hirschvogel, a glass-painter, painter, and engraver from Nürnberg, worked in Ljubljana from 1536 to 1543 (Korošec 1978, 53–4). His father, Veit Hirschvogel, was an important glass painter. We have not found any evidence yet that Augustin Hirschvogel had pupils in Ljubljana. There are also references to Georg Glockenton (a wood carver and painter from Nürnberg), who may have worked in Ljubljana. He is well known for his numerous painted coats of arms, but no written source has been found yet which would confirm that he worked in Ljubljana.

A chemical analysis was made of a fragment of the clear glass to determine the chemical structure of the tablets. Compared with the Ljubljana glasses, which are classified into three groups (Šmit *et al.* 2002, 346–7), it was established that these shields differ considerably and that they do not belong to any of the three groups. The chemical analysis thus revealed that the shields were not produced by any of the three Ljubljana glassworks. Considering, however, that glassmakers often bought ready-made pieces of glass to produce stained glass windows, this is not sufficient proof that the objects were imported.

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THE CONSERVATION OF TWO SEVENTEENTH-CENTURY ENAMELLED STAINED GLASS WINDOWS BY JAN DE CAUMONT IN THE ABBEY 'T PARK IN LEUVEN, BELGIUM (FLANDERS)

JOOST M.A. CAEN

In January 1993, the 'Friends of the Norbertine Abbey 't Park' were able to purchase two stained-glass windows at Sotheby's, New York (Caviness and Cothren 1989, 268–9). The two windows (COLOUR PLATES 108A, 109A), each originally consisting of three panels, were part of a series of 41 much larger windows that had been fitted in the clerestory of the abbey between 1636 and 1644. All the windows were sold by the monks in 1828, forced as they were to sell off much of their property in order to be able to re-establish their monastic life after the tribulations of the French Revolution and occupation. The windows were subsequently sold on, and eventually became dispersed in private and public collections in England and the US in the course of the 19th and 20th century.

In 1937, an important fragment was given back to the abbey and, in 1971, three complete windows were returned and placed in the clerestory.

HISTORY

According to the accounts of the cloister, all the windows were produced by the glass painter Jan de Caumont at the request of Abbot Jan Maes. Jan de Caumont was born in Doullens in Picardy, France, around 1580. He became a citizen of the City of Leuven in 1607, probably through his marriage with Anna Boels. He started working in the glass workshop of his wife's uncle, Simon Boels, a well known glass painter in Leuven. Around 1626, he took over Boels's workshop and became the city's official glass painter. He was particularly productive between 1635 and 1645, producing windows not only for the Abbey 't Park, but also for other churches in Leuven and elsewhere, including Mechelen. Jan de Caumont died in 1659. Production in the workshop was however continued by members of his family until the beginning of the 18th century (Swyngedouw and Steppe 1979).

The windows depict scenes from the life of Norbertus, founder of the order. Every scene is accompanied by a descriptive text in Latin. Jan de Caumont based most of his windows on prints by Theodoor Galle of drawings by Maarten Pepijn. These appeared as illustrations in a book by Johannes Chrysostomes vander Sterre, entitled *Vita Sancti Norberti*, which was printed in Antwerp in 1622.

Each window was composed of two central panels depicting a scene from the life of Saint Norbertus. Two panels on either side featured a saint or a blessed one, and one panel above each of these scenes had embellishments and a coat of arms, with the one below having the text.

The two windows purchased in 1993 both consist of three panels. The two upper panels show a scene from the life of Saint Norbertus, and the third has a text in Latin. One of the windows depicts the *Adoration of Saint Norbertus after his Death* (COLOUR PLATE 108), the other features the *The Transportation of the Remains of Saint Norbertus from Magdebourg to Prague in 1627* (COLOUR PLATE 109).

TECHNIQUE

These six panels, and indeed the other windows as well, are exquisite examples of the elaborate glass-painting techniques used by glass painters in the Low Countries in the late 16th and early 17th century. According to the style of the era, glass painters should 'paint on the glass' rather than 'paint with glass' (COLOUR PLATE 110).

Jan de Caumont employed all the glass-painting techniques that were available at the time. He used *grisaille* paint on both sides of the glass, silver stain of various tints on the exterior side, blue and purple vitreous enamel, opaque red paint (opaque sanguine) on the interior, and translucent flesh tone (translucent sanguine) on the exterior. Tints of green were obtained by applying blue enamel to the interior side and silver stain to the exterior side. Most of the glass is highly transparent and slightly greenish in colour, but besides this clear glass he also used pot-metal glass and red flashed glass.

The technique of applying enamel to stained glass windows had its origins in the first half of the 16th century in the Southern Low Countries (Van der Snickt *et al.* 2003, 29). It allowed the glass painter to apply colour to larger pieces of white glass, unimpeded by the lines of the lead cames. As well as *grisaille* paint (the earliest type of glass paint), silver stain had been used since the early 14th century, while sanguine (the flesh tone red) is found on stained glass dating back to the second half of the 15th century. The style evolved increasingly towards more transparent paintings with a rectangular lead came pattern, especially towards the end of the 16th century,

There was, most likely, a connection between the use of enamels in Flemish stained glass windows and the fact that many Italian (Venetian) glass blowers were working in Antwerp at that time, as they were familiar with the techniques of enamelling on vessel glass.

In the archives and literature, we find little information about the use of enamels in 16th-century stained glass. The first author to write extensively about these techniques is

Antonio Neri in his book *L'Arte Vetraria* (Neri 1612). Neri arrived in Antwerp in 1609, and probably came into contact with Johannes Isaac Hollandus or Anselmus de Boot, either of whom might have informed him about various enamelling techniques. Obviously the use of enamels was already quite widespread, as we find blue enamel in much of the stained glass production from the Low Countries dating from after 1550, especially in roundels and unipartite panels. Neri's work was of great importance, as his text would become the source for many subsequent books and recipes.

The first half of the 17th century was a very important period in the history of stained glass production in the Low Countries. Unfortunately, this period has not been closely studied. Clearly, though, it was an era during which elaborate techniques culminated in magnificent glass paintings. At the same time, however, these paintings may be regarded as an expression of the decadence that already heralded the decline of the craft of glass painting on the European continent.

Conservation

The conservation of the two windows (six panels combined into two frames) started with a very close examination and documentation of the objects.

It was quite obvious that there were several broken glass pieces and gaps, as well as many repair leads. The leading was of a relatively recent date as the cames had a modern profile. At many places, the cames were broken, and the joints were badly soldered. Furthermore, the lead was in bad condition and very brittle. Subsequent research revealed that several glass pieces had been affected by corrosion (especially near the lead cames due to the 'cold bridge' the lead was causing) (COLOUR PLATE 111), and that the condition of the enamels was quite poor, as is often the case in such windows.

The results of the preliminary examination were discussed with Monuments and Sites administrators, representatives of the Royal Commission on Monuments and Sites and the owners of the abbey (the Norbertine Order). All of them quickly agreed that the poor repairs of the 19th and 20th century had to be removed in order to regain the legibility of these magnificent works of stained glass art. The actual condition of the windows was also a real danger and in need of further conservation, as many broken glass pieces were ready to fall out, and some leads were no longer giving enough support.

It was decided that the lead cames should be dismantled. The pieces of glass were carefully cleaned with a mixture of water and ethanol (50/50). Superficial spots of paint, that might have been the result of, for example, the painting of the room where the panels were kept, were removed with acetone. Putty was removed with a scalpel, although a thin layer was left on the glass in order to avoid damage to the glass surface.

After all the broken glass pieces had been cleaned, they were bonded with an epoxy resin (Ciba Geigy – Araldite 2020). No pieces were back-plated as this technique causes a dangerous microclimate for the glass and its conservation products. Large gaps (normally ones of more than 10 by 10mm) were filled with newly constructed glass. These glass pieces were made with glass and glass paints using traditional stained glass techniques and the intention was to re-establish an 'integrated legibility' at approximately 2m distance. When you examine the windows from a closer distance, it is clear that these pieces are reconstructions. Furthermore all these infills were signed with the conservator's monogram. At one place this monogram is accompanied with the conservator's full name and the date of the conservation. The reconstruction of these gaps was quite easy as all of them could be made according to the surrounding design. Small gaps were filled with untinted epoxy resin.

The next step was the re-leading of each panel with lead cames of the same section as the 'original'. These original dimensions could be determined on the basis of corrosion traces at the edges of the glass pieces.

When the windows were purchased in the US, the three panels of each window were leaded and soldered together to form one panel. It was now decided to separate the three panels of each window to return them to their original form, and to construct two new steel frames to exhibit the three conserved panels of each in the clerestory of the abbey. Although the clerestory is the original place of this glazing, the windows were not placed at their exact original spots. They will probably be returned to their correct position when the clerestory building is restored in the near future.

The panels have not been cemented again as they were all strong enough with the new lead and the new copper profiles around them. There was no need to make the panels wind and water tight as they were not exposed to the exterior climate because there was a protective outer glazing.

After the windows had been re-leaded, all the bondings and small gap fillings were retouched (COLOUR PLATES 108B, 109B) with light-proof pigments and an acrylic resin (Rohm and Haas – Paraloïd B72) dissolved in di-acetone alcohol as a binder.

The corrosion of the glass has not been treated, as normally the corrosion products are 'protecting' the healthy glass against further corrosion, as long as the glass is kept in a stable climate. The actual setting of the windows with protective glazing and interior air ventilation guarantees this stability. Nor have the deteriorated enamels been consolidated as their condition is not so bad that an irreversible consolidation treatment was needed.

The conservation of these panels certainly aroused my interest in the evolution of glass-painting techniques in the 16th and 17th century. Since then, we have, in collaboration with natural scientists at the Academy of Fine Arts in Vienna and at the University of Antwerp, conducted some intensive research on *grisaille* paints, opaque and translucent sanguine paint, silver stain and enamel. Much work remains to be done, in archival and historical research as well as in analysing glass samples and glass paints. Although late 16th and 17th-century stained glass is not particularly 'popular' among scientists, I, for one, sincerely hope that more research will follow and that international collaboration in this field will be intensified.

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GAIN WITHOUT LOSS? STAINED GLASS RESTORATION IN 2003

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Among the last words that normally would come to mind when thinking of restoration is the term 'loss'. After all, conservators are the protectors of the cultural heritage, not their destroyers, and the restoration of stained glass should be no exception to this rule. Like all the other conservation specialisms, its methods aim to be non-interventive. But life is not as straightforward as that, and the reality is often very different from the clear-cut theory, when, under pressure from a client's demand or the common convention, historic windows are turned into 'contemporary' glass. Without intending to, in these cases we lose more than we aim to gain, and while the result may be aesthetically pleasing, ethically it can be a disaster.

So what does constitute loss in conservation? There are several levels at which loss may occur, the easiest to define being the material loss, or is it? The corrosion crust contains original material, not least in the ever elusive gel-layer. Can we therefore carry out cleaning, however gentle, without the risk of removing original or historically important material? Secondly, there is the authenticity of the window, which is under threat when restoration is due. Loss of authenticity can easily be covered up, and has in the past occurred more often than most people assume. And last but not least, there is the history of the window, the scars of which one might or might not wish to remove, a decision which is often extremely difficult to make.

How easy by comparison does the life of the 19th-century restorer appear to us today. After centuries of neglect, there was a growing demand to restore the crumbling windows, but the restoration undertaken seldom complied with the strict meaning of the word, which after all is to bring back a lost image based on the knowledge of what had been there originally. For the 19th-century restorers, it was more important to restore the role the window had to play as part of a whole. Paramount was the revival of an impression rather than a faithful reconstruction.

Canterbury Cathedral is a prime example of this 19th-century desire to resurrect the lost splendour of ancient buildings, and to put a few things 'right' along the way. This attitude was, of course, not confined to stained glass. In 1832, the fabric lost one of the few remaining parts of the Norman cathedral, the north tower of the west front, which was replaced with a copy of the south tower. The surviving 12th-century stained glass was re-arranged in the same spirit, affecting single panels and entire windows alike. Panels such as the one depicting the story of Adam the Forester, which looked fragmented in a watercolour of 1841, had changed considerably in an illustration showing its condition in 1897. Following the latest restoration by Samuel Caldwell Junior in 1920, this panel now gives an impression of medieval authenticity which is thoroughly misleading.

Entire windows 're-grew' at the same time. In 1861, the three westernmost windows on the north side of the Trinity Chapel were almost bare of any stained glass. By the 1890s, much stained glass had returned to the windows, not out of some mysterious storing places, as Samuel Caldwell had claimed in the case of the figure of Thomas Becket, but assembled from a mix of medieval and modern glass. Today, the window supposedly containing the medieval figure of Canterbury's famous Saint, is 'complete' again, and Thomas Becket can be found depicted in many publications as an original early 13th-century panel, which in fact it is not.

Caldwell Junior and his predecessors at Canterbury were children of their time, and there is no point in accusing them of wrongdoing. Fritz Geiges in Freiburg, for example, or Eduard Hosch in Lausanne did the same within this prevailing 'Zeitgeist'. Hosch and his predecessors turned the fragmented rose window of Lausanne Cathedral into something very pleasing to the eye. But at the same time this rose is now at least in parts misleading, a fate that only a few other windows in this category escaped. The Dean's Eye at Lincoln comes to mind here as one of the exceptions, and a comparison between the two rose windows raises the question whether the price paid for the 19th-century restoration was not too high. Is the loss of authenticity sustained in Lausanne justified by the gain in terms of aesthetics and the possibility to 'read' and interpret, or often misinterpret, the windows?

Be that as it may, the bold approach of the 19th century has sensitized us to the danger of reconstructions, and today we aim for a restoration which is based on facts rather than on conjecture. But is not even this restricted approach already going too far? To answer this question, it is necessary to start with the most basic level of restoration, the vandalized church window. Here we are faced with windows which until the fateful event had been fully intact, but now lie in ruins. If the window was medieval, there would be no doubt that all fragments would be glued together again and that the glass would be returned, bearing the scars but still integral.

However – there is no point in pretending otherwise – there is a lamentable difference in the perception of loss between medieval and more modern glass. The story is different with 19th or 20th-century windows. With 19th-century glass reversing the effects of vandalism is, after all, merely a formality covered by an insurance claim, and the client is expecting replacement like with like. So restorers produce faithful copies of the damaged pieces, duly signed and dated, and the window looks like new on its return – which in fact it is. A window restored in this way is indeed an early 21st-century window of contemporary stained glass based on a 19th-century design. Aesthetically a gain, there is no doubt, but does it make sense to go that far? Does this gain justify the loss of original material? To date, there are many answers to this seemingly straightforward question.

This ambiguity continues on the next level with a restoration technique which is less interventive but by no means less problematic. It is a technique called back-plating, which first and foremost provides the conservator with the means to support a badly shattered glass by fitting clear glass to the back of a re-assembled piece. But a back-plate has more to offer, it provides also the means to re-introduce lost paint lines, since the repainting and firing of an original piece is not advisable for many good reasons. By painting the pigments onto a separate plate and placing it at the back of the original the lost areas do indeed come back, which is a fully reversible process if the outcome were found disagreeable. The problem here is, how far can and should one go in this reconstruction.

The 16th-century East Window in the Hoby Chapel at All Saints, Bisham, suffers extensively from enamel loss, a common phenomenon as the enamels have a different expansion rate to the base glass, resulting in their shelving off leaving areas of reduced legibility behind. When we removed the glass for conservation in 2002, one of the provisos made by the Council for the Care of Churches (CCC) was that the re-introduction of lost enamels should be kept to a reasonable limit. Of course, this term can be stretched as far as one dares to go, and we have probably gone farther than the CCC would have wanted us to. We have tried to define thresholds, by asking case by case whether the result justifies the intervention. It is now for others to judge whether we have done the window justice (COLOUR PLATES 112, 113), but there is no doubt in my mind that fellow conservators would have drawn different lines. I, for my part, hope that the result is regarded as a gain; but we must be aware that what we see now is not the true face of the window, but what the conservators made of it in the 21st century – contemporary glass, if you like.

Back-plating can be even more problematic when the restorer gets the reconstruction wrong. In 1999, my studio restored the Great East Window at Gloucester Cathedral, the main thrust of the work being *in situ* cleaning and consolidation. One of the few panels we had to remove from the stonework for more interventive conservation had, as it turned out, been re-leaded in the 1970s. On analysing the panel, we realized that the surviving background foliage had been back-plated by the restorer with a design only remotely resembling the original, despite the fact that, on close inspection, the tracelines of the original design could still be detected. This enabled us to 'correct' the design based on facts, so this time gain without loss – or are we playing charade, fooling the spectator into believing that what can now be seen is the original work of art?

Again, the answer will probably be as multi-faceted as there are spectators, but to make matters even more difficult what about restorations without direct evidence of what had been in the place now void of any depiction? Is this justifiable under certain circumstances, or should it be avoided at all cost? Can a work of art function in a mutilated state? The tracery of the early 17th-century van Linge window at Lydiard Tregoze, Wiltshire, was left until 1999 with one of its four angel heads missing. The surviving heads had one intriguing fact in common which led us to hazard a reconstruction. Instead of looking straight back at the spectator, they all look to the left of the centre axis, exactly to the point where the monument of the donor of this window is positioned. The fourth angel must have done the same, so we gave him his head back, and unless this angel was the one who was blinking, we should have got it right. The tracery is complete again, but not authentic. Loss?

But Lydiard Tregoze is an exception to the rule. Normally, we would not allow such far-reaching reconstructions to happen, not only because of missing information, but also in respect of the history of a window, the third aspect I mentioned at the beginning of my paper. Several panels in the Great East Window of Gloucester Cathedral, on their restoration in around 1865, had been provided with similar 'blobby' faces as the one at Lydiard Tregoze. Why Willement, who was in charge of the restoration, had done so, is impossible to tell. As we have seen previously, the norm was quite different in the 19th century. As a result, these faces stand out quite clearly, and calls to do something about them are often heard. We were intrigued to see what the outcome would be if we were to heed the calls, and we produced a front-plate copied from a head further up the window (COLOUR PLATES 114, 115). With the new head, the figure undoubtedly came to life again, but indeed transformed so much that in the end I regretted having helped to visualize what this window could be if we were to turn parts of it into a late 20th-century window. In the end, we resisted the calls to put in reversible front-plates, so as to preserve these parts as an *in situ* document of the restoration history of this window.

As a final example of the dilemma, an extreme intervention should be listed here, which stained glass conservation cannot do without if it is to fulfil its duties. It means carrying coal to Newcastle if I were to explain the reasons why we have to introduce appropriate preservation measures to prevent windows deteriorating further. This protection, which is commonly subsumed in the term 'isothermal glazing', has one ethical problem. By introducing a separate protective layer, a severe intervention in the original setting takes place, fully reversible, but still severe from a certain point of view. We move the historic glass slightly inwards, away from the original framework to create space for the protective components to go in its place. This is something I personally can live with, but others already regard as loss in respect of the ethics, not the material.

However, there is indeed on occasions material loss involved, when the masonry has to be cut back to make room for a new sub-frame. Quite rightly, the question here is whether the loss in historic material, namely the stone, justifies the gain without which the other historic material, the glass, would not stand a chance of surviving much longer. But even if we do not go that far, and apply a method by which the historic glass is held in bespoke bronze frames which in turn are tagged onto the mullions, we are being accused of perforating our churches. This so-called 'damage', together with the above-mentioned separation of historic material, is regarded as unacceptable loss, and therefore fought hard against by many architects in the UK. I appreciate that some perceive the results of protection as a loss, but I find it acceptable compared with the gain, the more so as the process is fully reversible.

Gain without Loss? I think that all the examples have shown that there is always a degree of loss involved, regardless of the degree of intervention. One fact can be learned in conservation more than anywhere else – it is impossible to achieve an improvement in one aspect without adversely affecting another. However, what constitutes loss is very much determined by our very personal attitude towards the object, its age and its monetary value. Hence, this is a dilemma which cannot be ultimately resolved and always will be looked upon differently according to the prevailing Zeitgeist.

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CONSERVING COLLECTIONS

A FRENCH FEAST: THE CORNING THEATRE IN CONTEXT

Stephen P. Koob and Jutta Annette Page

In 2002, the Corning Museum of Glass acquired an extraordinary lamp-worked scene from France (CMoG Acc. No. 2002.3.22) at auction in Paris (Messieurs Rieunier & Bailly-Pommery 2002, 55, lot 104). The object is unique in that it is the only one known with moveable figures. The stage-set appearance of the object (colour plate 116), complete with proscenium, elevated stage platform, apron, and 'players' prompted it to be termed a 'theatre', a term already preferred by Barrelet for such works (Barrelet 1960, 301, fig. 8).

The scene is believed to depict the *Wedding at Cana*, as told in the Gospel of John (2.1–12). It relates the story of a wedding celebration in Galilee. The host runs out of wine, which signals a premature and potentially embarrassing end to the wedding celebration. At the urging of his mother Mary, Jesus saves the day by turning the water in six large jugs, intended for the Jewish purification rites, into wine – and good wine at that.

Probably the most famous representation of this subject matter is Veronese's (Paolo Caliari) huge painting in the Louvre, of about 1562–63 and commissioned for the convent of S. Giorgio Maggiore at Venice, where it was kept until 1799. Its complex figural arrangements, spatial layering, and veiled meanings are, of course, a far cry from an object whose intended purpose was never more than to amuse the beholder.

The figural scene is presented on a single plane rather than the multi-level arrangements of the complex narratives found in the traditional lamp-worked shrines with religious themes that are attributed to 18th-century glassmaking centres in France, and especially to Nevers.

Figure identification

Nine of the figures in the theatre are seated around a long dining table. The New Testament account allows the figures to be loosely identified. In the foreground to the left is the prominent figure of Jesus wearing a long tunic. He is bare-footed (the only figure in the group with lamp-worked feet), and raising his right hand in blessing. Seated to his right is a matron in a traditional blue headscarf and also draped in a long-flowing tunic, probably his mother Mary. Across from them, facing the audience, are a bearded male and a lady wearing a diadem, both dressed in elegant 18th-century costume. They are accompanied, on their right, by a young couple. The other male figures of the wedding party are wearing oriental-style costumes, setting them apart as exotic visitors from the East.

On a balcony above the dining floor is a Nativity scene, which appears to be original to the tableaux. The figures, Mary and Joseph, the Christ child, an ox and a mule are made of a clay-like material, probably *peau de mie*, a mixture of flour, water, and animal glue that was commonly used in Provence for crèche figures at this time.

History and comparative chronology

The wedding party is set in a grotto, a feature popular in 18th-century royal gardens. Shells and shell grottoes were a 'veritable passion' among the wealthy and fashionable, reflecting on both nature and the identification with classical art and ancient Rome (Jackson 2001, 8–10). The ancient tradition of the grotto was intimately connected with the art of mechanisms and automatons, hence especially suitable surroundings for a mechanical theatre set.

A few other lamp-worked scenes with building interiors exist. A true theatre representation is a tableau of similar size to the Corning object in the Musée de Cluny by the lamp worker Jacques Raux (d. 1777) that is dated to the first half of the 18th century (Barrelet 1960, 300). It depicts a stage with actors from the *Commedia del Arte* and its label identifies Raux as 'Émailleur to the King', residing in the Rue St Martin (Weigert 1971, 33). In this tableau, the figures are entirely modelled in glass and stand in a formal dining room of a French chateau with a view into a formal garden in the background. The chandeliers, glass tableware, and small dogs are very similar to those in the Corning theatre. An unusual Nativity scene in the Musée des Arts Décoratifs (Barrelet 1960, 295) is set in an interior with balconies framed by scroll balustrades.

The closest parallel, however, is a small tableau of nearly square format, dated 1740 (Barrelet 1960, 301, fig. 8). It was formerly in the Collection Artus and is now in the

Musée des Arts Décoratifs (acc. No. 4761; 420 x 310mm). The scene is set in a garden grotto with sculptural glass figurines in niches. Its primary figures are 50–60mm high and all are entirely modelled of glass (Volka 1995, 72–3; Barrelet 1960, 301). The treatment of the grotto, the putti holding garlands, and the chandelier are nearly identical to those in the Corning theatre. It reportedly represented an interior view of the grotto at Versailles. In the centre, a gentleman and a lady (supposedly King Louis XV and Madame de Pompadour) are seated at a table playing cards. A servant carrying a candlestick just enters the room, which is lit above by a glass chandelier.

All of the tableaux mentioned above are immobile dioramas. The Corning Theatre is a rare survivor of animated lamp-worked scenes made in the mid-18th century, which were created for public (and private) amusement. According to Colette Save, visitors to the market at Saint-Germain could give a shopkeeper a few pennies and he would activate his automaton made with lamp-worked figures. One of these, still in existence, is a scene under a glass dome containing a lady with a spinning wheel, her suitor and a parakeet sitting on a perch (Save 1969, 54).

Construction and materials

The theatre is large, and measures 0.715m long, 0.565m high, and 0.586m deep. Its grotto decoration is made with real snails, shells and other organic matter that is combined with details made of various types of glass (COLOUR PLATE 116). The architectural structure consists of an arched colonnade supported by twisted glass columns made of purple and colourless glass rods. The walls of the loggia and the proscenium are paneled with mirrors. The remaining surfaces are richly embellished with coloured paper encrusted with sparkling crushed glass, snail shells, and beads that are arranged to form colourful bands and rosettes. A profusion of lamp-worked fruit, flowers, and several polished rock crystal pendants add to the festive effect (COLOUR PLATE 117).

Three lamp-worked chandeliers set with candles hang from the vaulted ceiling. They are constructed of two central wires encased with colourless glass. Each one has glass spokes radiating from the lower centre out towards the eight candles. The candles are made of opaque white glass with red flames and opalescent glass beads decorate the top of the chandelier (COLOUR PLATE 117). The chandeliers in all of the existing French lamp-worked interior scenes appear to be of the same type: a chandelier densely hung with beaded chains and pendants of rock crystal or glass and topped by a royal crown (Klappenbach 2001, 62). A lavish example of this kind of chandelier is in the Royal Collection at Hampton Court, in the King's audience chamber, which dates to 1700 (Klappenbach 2001, 62, fig. 57).

Six pieces of cut and polished rock crystal were used in the theatre (COLOUR PLATE 117). Two round ones are suspended at the top of the double columns, and two drop-shaped examples with a smaller one above are hanging between two garlands in the right and left alcove. A white wooden balustrade separates the dining scene from the formal garden. The balusters are not entirely round, their backs having been cut to a 90° angle, possibly by cutting one round baluster vertically into four pieces. Numerous mirrors and pieces of mirrored glass have been applied. These are all flat and probably backed with silver or lead. The central fountain with swans in the foreground is reflected in a mirror and flanked by flower urns and dolphins on pedestals. The blue and white flower vases echo the pattern of the painted wooden jugs in the Corning theatre, probably representing blue and white faïence such as the celebrated *bleu de Nevers*.

The box has a dove-tailed construction. The lower section of the box is hollow, and contains the wires and wooden slats that are attached to the figures above the floor. The wires and slats extend across to the right side of the box, where they protrude out the bottom side (COLOUR PLATE 118). An operator or story teller could move the figures, while relating the story and the dinner conversation. The fountain scene is recessed into the hollow base cavity, and is framed using animal glue and paper. The base was also once dove tailed, but only one dove tail is still in place, the others having been destroyed through insect damage or during the replacement of the bottom panel (*see* Conservation, below). Four holes underneath the base, on the left and right, front and back, once accommodated peg feet.

Several layers of paper cover the exterior, which appear to date to different periods. The innermost paper is possibly newsprint, or printed paper of different types. The exterior may have been re-papered at the same time the bottom panel was replaced. The upper layer of newspaper has a date of 1814, which can be considered the restoration *post quem* date.

The construction materials include numerous types of glass, from bits of ribbon glass to chips of ground glass. Red and yellow glass chips were predominantly used as a filler between decorative elements. Other smaller glass decorations include multi-faceted transparent coloured glass gems with foil backing in blue, green, colourless, yellow, and purple. The rococo chairs on which the figures are seated, are also fitted with finely trailed glass mesh imitating caning. The lamp-worked chair backing was applied to the cardboard frame of these chairs. The flooring under the table is a painted paper with a stylized floral design.

Other materials of note are the clothing, mostly of silk, which is decorated with metal-wrapped threads and metal appliqué. The spear held by the guard in the background, is made of bamboo with an inserted spear tip made of zinc or tin. Shells are used throughout and were identified as common Northern yellow periwinkles (*Littorina obtusata*), Atlantic yellow cowrie (*Cypraea spurca acicularis*), Atlantic gray cowrie (*Cypraea cinerea*), common Atlantic margin shells (*Marginella apicina*) and top shells (*Monodaonta lineata*). Crushed shell is apparent as surface covering.

Numerous wooden elements appear as well. Thin layered wood sheet attached to the bases of the columns give a woven appearance with a veneer-like construction. Caning or reeds are also used to outline the architectural elements, especially the bases of the columns.

Cardboard was used as a supporting mechanism throughout, as a backing, or to bring a decoration forward, or to connect between architectural elements (such as the garlands).

The table and the floor are also made of thick layers of cardboard. The table has two layers that are glued on top of each other, supported by two smaller diamond-shaped tables with legs that are connected by cardboard covered with paper, and the whole is draped with a (now tattered) silk tablecloth with a striped pattern.

The table is set with miniature lamp-worked wine glasses, three of which are lined with coloured fabric resembling liquid, presumably wine. Other glass vessels are an opaque yellow glass pitcher, corked colourless flasks, and an opaque white-lidded jar with trailed decoration. Two wooden bottles that are painted black stand in for wine bottles, and two wooden candlesticks with white candles light the table. There is a metal cup and several metal knives (a total of nine are remaining). No forks are in evidence. The meal laid out on the table is represented mostly by shells, crushed glass, as well as dried peas and beans.

Movement of figures

On the right exterior wall of the box are a set of wooden levers and wire pulls terminating in glass bead knobs with a pattern of moulded raspberry prunts (COLOUR PLATE 118, top). The pulls are connected by a system of wires underneath the stage floor (COLOUR PLATE 118, bottom) to the figures above, operating their heads. The levers are slats of wood that work on a pivot close to the centre of the box and allow the hands of the figures to move up or down or for the figures to lean forwards or backwards. One of the levers appears never to have been properly connected and one wire was either never connected or the connection is now entirely lost, as is the case with the figure of a guard posted on the left stage.

The movement of the figures has always been rather limited to turning the heads from right to left, as well as a vertical motion of the right arms of several characters. Each figure is composed of an armature made of iron wire, covered in copper, to which the white glass for the body parts is attached and modelled.

Conservation

When the theatre arrived in Corning, its front was covered by a glass pane set into a gessoed wooden frame. Even with very careful packing and shipping, numerous loose pieces were observed on the inside, including detached shells, lamp-worked fragments, metal dinner plates and one small glass bottle. Most of these had fallen to the floor and were mixed with other bits of dirt and debris. One of the putti, from the upper left hand side had fallen into the lap of one of the dinner guests.

The glass cover pane, along with the gessoed frame, did not appear to be original, as the glass was modern (float glass), and the frame did not fit the theatre box exactly. Moreover, the frame had been attached with modern iron staples. The exterior of the box showed remnants of a tattered red brocade covering, which was sampled and identified as a synthetically dyed satin damask (M.W. Ballard pers. comm.), probably dating to the mid 19th century and possibly attached at the same time as the glass frame. Both the gessoed frame and all the tattered silk have been subsequently removed, as they were not consistent with the original construction.

At some time, possibly before the 19th-century 'restoration', or perhaps as reason for the restoration, there was a serious bug infestation of powderpost beetles, which did considerable damage to the bottom and lower sides of the wooden box. Currently, there is no evidence of active contamination. A board covering the lever and pull system on the bottom is made of modern pine, distinctly different in cut, colour and appearance from the rest of the box. It was added, again probably at this same time, to stabilize the box and to protect it from further damage.

A number of losses in extremely delicate and fragile areas were also noted. The rococo chairs on which the figures are seated, for instance, are fitted with finely trailed glass mesh imitating caning. Much of this glass mesh is broken or lost. Numerous shells are missing or broken, along the edges and notably, behind and to the sides of the rock crystal pendants. Any movement of the theatre causes these pendants to sway, and they must have damaged adjacent areas. Some pieces are completely missing and must have been lost before or during the previous restorations. Such is the case with one of the four putti, three of the four swans' heads, one of the glass jugs that was once carried by the dog, and parts of the flower garlands.

After the red silk covering had been removed, the exterior of the box was vacuumed to remove dust and debris, and old packing tape applied along both edges of the case was sprayed with deionized water and removed. A thick piece of cardboard was taken off the bottom of the case, and the bottom board was removed to examine and clean around the mechanism of wires and pulls (COLOUR PLATE 118, bottom). All of the levers and wire pulls were in remarkably good condition, and simply required vacuuming. The only damage was to the ends of some of the wooden slats or levers, which had suffered from insect damage.

The frame and cover glass were removed, and all the loose fragments on the floor and the table were carefully collected and put aside. The interior was then carefully cleaned using a soft brush, including the fabric of the tablecloth and the clothes of the dinner guests, which were similarly dusted. All the glass elements, figures and mirrors were then carefully cleaned using a solution of deionized water, 5% ethanol and a drop of non-ionic detergent, applied by brush. Any residues were removed by rinsing with a brush dampened with deionized water. The collected fragments were sorted through, and numerous shells were re-attached using an acrylic adhesive, Acryloid B-72. Lamp-worked pieces, including the glass jars, a putto, a feather, the flowers and the candlesticks were re-attached using a thickened (partially cured) epoxy adhesive (Hxtal NYL-1). These were wired or taped in place until the adhesive had set.

The three missing swans' heads were cast and replaced using Hxtal epoxy resin, tinted with titanium dioxide pigment, after using the one remaining original as a model. They now look more appropriate to the scene, having lost their previously distracting appearance as headless birds. The pine cover was put back on the bottom, primarily to stabilize the theatre, and was re-attached with the same screws that had been used previously.

A digital (DVD) video was made of all the figures moving, individually, and in groups, so that a record was available for future use, either in lectures or to accompany the theatre on display.

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INVESTIGATION OF THE CORROSION OF SEVENTEENTH-CENTURY *FAÇON DE VENISE* GLASS USING ADVANCED SURFACE ANALYSIS TECHNIQUES

Sarah Fearn, David S. McPhail and Victoria Oakley

Introduction

It has been well documented over many years that certain types of glassware displayed within the glass collection at the Victoria and Albert Museum in London are susceptible to deterioration over time. Venetian and *façon de Venise* glassware of the 17th and 18th century is particularly prone to corrode and the instability of glass from this period has been found to be due to the purification of the raw materials such as plant ashes which were used to produce the well known clear *cristallo* glass (Neri 1612). This purification of the raw materials depleted the glass of the essential network-former calcium oxide (CaO), and increased the wt% of sodium and potassium oxides. The resulting corrosion of these vulnerable glasses goes through various well known stages; initially the glass artefact may appear foggy and dull, under humid conditions droplets of moisture appear on the surface as the alkali salts deliquesce – a condition referred to as 'weeping' (Oakley 2001) – and as the deterioration progresses a series of fine micro-cracks start to appear and the glass has become crizzled. The phenomenon of crizzling has been reported in detail in a number of publications (Brill 1975; Ryan *et al.* 1993; Oakley *et al.* 1992).

In order to safely store and display these vulnerable objects so that their deterioration is not enhanced in any way, and hopefully, if possible retarded, it is important to have a thorough understanding of the effects of the museum environment on these glasses. Currently museum glass collections are kept at relative humidities of *c.* 39–42%RH. One reason for this is that at relative humidities below 42% potassium is not leached out, and remains *in situ* (Bimson and Organ 1968). However, this research only focused on the leaching of potassium, and did not investigate the leaching of other hygroscopic species such as sodium.

More extensive studies by Brill, based at the Corning Museum of Glass, New York, suggested that lower humidity values could be just as problematic as the glass surfaces become dehydrated. Brill suggested therefore that a range of 40–60% relative humidity was a safe range for storing glass objects and that the humidity level needs to remain stable. This work was carried out at relatively high temperatures in order to have detectable deterioration. Ageing glass at elevated temperatures is not, however, an accurate representation of the long-term corrosion that occurs under the ambient conditions of a museum. Ideally, ageing experiments would be carried out in environments that are comparable to the museum. However, as briefly mentioned above, it has not been previously possible to age the replica glasses at room temperature as the deterioration occurring would require very long ageing times for a compositional change that could be accurately detected.

In recent years, however, the capabilities of many advanced surface analytical techniques have been dramatically improved so that it is now routinely possible to measure changes that are occurring on a nanometer scale. One technique in particular, which has already been successfully applied to measuring compositional changes in aged glass, is secondary ion mass spectrometry (SIMS) (Ryan 1996; Wicks 2001; Ryan *et al.* 1996). In SIMS, an energetic beam sputters away the sample surface in a controlled fashion such that it is possible to follow the distribution depth of elements through a material, creating a depth profile. With relation to the corrosion of glass, therefore, it is possible to detect very small changes in composition at the surface of the glass in relation to the bulk material and the leaching alkali ions can be monitored easily as a function of depth. The energy of the beam used to sputter away the sample surface determines the best possible depth resolution of the analysis. Simply, the lower the beam energy the better the depth resolution, enabling smaller features and compositional changes to be revealed.

Advances in SIMS instrumentation over the past few years, have now made it possible to carry out depth profiling routinely using sub keV beam energies, giving nm depth resolution. This means that glass corrosion can now be performed at room temperature, over reasonable time periods, and accurate depth concentration profiles of the leaching alkali ions can be obtained. Other techniques such as optical interferometry and focused ion beam microscopy have also been employed to study the surface of the aged glasses.

By applying a series of advanced surface analytical techniques to the problem of the deterioration of museum glass it is hoped that a more accurate picture of room temperature corrosion will be determined. This will hopefully enable museum curators and conservators to be able to select suitable environmental conditions for the safe storage of vulnerable glass objects.

The work presented here marks the very beginning of this research, and the first data that has been collected using these techniques.

Replica glass

As it is not possible to carry out ageing and destructive analyses on original museum artefacts, it is necessary to

TABLE 1 SHOWS THE TARGET COMPOSITION FOR THE REPLICA GLASS, THE 'IDEAL GLASS', COMPARED TO THE COMPOSITION OF THE FABRICATED REPLICA GLASS, THE 'ACTUAL GLASS'. FIGURES ARE WT% OF OXIDE

Oxide	SiO_2	Na_2O	CaO	MgO	K_2O	Al_2O_3	Fe_2O_3	MnO	Total
Ideal glass	70.60	20.25	2.61	1.07	3.68	1.10	0.31	0.37	100%
Actual glass	72.67	17.66	2.74	0.74	3.25	1.21	0.24	0.36	99%

produce analogue glass. EPMA analysis was carried out on a small fragment of glass from a seriously corroded *façon de Venise* glass, which had been de-accessioned from the glass collection of the V&A museum. The composition obtained is shown in TABLE 1, the 'ideal glass'. It can be seen that the artefact contained a high quantity of soda (Na_2O), a small amount of potash (K_2O) and a small amount of the stabilising lime (CaO).

Normally when analogue glass has been made in the past for ageing experiments only small quantities, typically 100–300g, have been produced. This glass is then cast into small pellets, polished to give a flat surface and then placed in the required ageing/corroding conditions. However, fabricating the replica material in this fashion introduces two problems. Firstly, composition variations may occur between samples as more glass is required for more experiments, secondly polishing the glass creates a surface which is not comparable to that of a glass object that would have been produced by a glass blower.

In order to overcome these two problems and to try to create an analogue material that corresponds to a real object as much as possible a large batch of replica glass – 25kg – was melted and then samples were blown by a glass blower. In order to be able to carry out the ageing and surface analyses nine large flat plates, which required no polishing, were produced. The composition of each plate was then measured using EPMA. No significant variation in composition was observed over the set of plates and the average composition is shown in TABLE 1, the 'actual glass'. Along with the flat plates, some objects were also produced, in order to observe where glass deterioration may commence on an object as opposed to a flat surface.

SURFACE ANALYSES OF AGED GLASS

Once the replica material had been produced, pieces from the plates were cut and placed in an environmental chamber set to a known humidity and at room temperature. The humidities chosen for the ageing experiments were 39, 43 and 55%RH. The glass samples were then left for a period of time to age. The ageing times used in these first experiments were quite short, being only 21, 45, and 69 hours.

In order to assess the start of the glass corrosion/deterioration of the surface, the root mean square roughness (RMS) of the glass surface was measured using an optical interferometer – the Zygo New-View. This technique is a non-contact, non-destructive procedure and is performed in ambient conditions and can also produce 3-D images of the glass surface. A magnification of 100 is used to scan the surface, analysing an area of 72μm by 54μm. A series of eight random regions were measured and the average RMS was then calculated. The RMS values for each of the aged samples has been plotted as a function of ageing time (FIG. 1). It can be clearly seen that as both the ageing time and humidity increase the surface roughness of the glass dramatically increases. This was also visible from the images of the surface that showed, again with increasing humidity and ageing time, an increased density of what appeared to be crystals on the glass surface. This was quite surprising, as the glass still appeared to be clear to the eye and exhibited no signs of becoming dull, or cloudy.

After measuring the surface roughness, the surface of the aged glass samples was further analysed using the focused ion beam microscope (FIB). This technique is comparable to analysing the surface with an SEM, but instead of using a beam of electrons to image the surface, a beam of ions emitted from a gallium (Ga) liquid metal ion source is used to probe the surface. The beam source is also very small and focused to a size of *c.* 5nm. In order to image the glass surface charge compensation is required as glass is an insulator. In SEMs this problem is overcome by gold coating the sample surface, but in the FIB microscope it is not necessary to coat the sample surface as charge compensation is carried out by an electron flood gun.

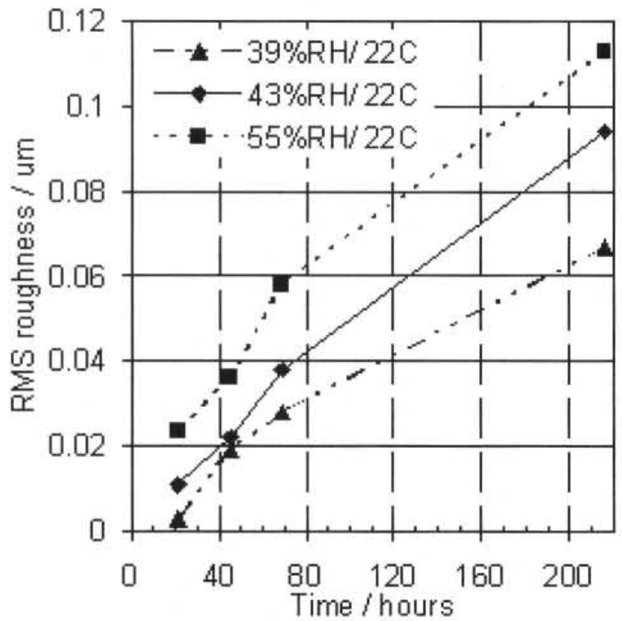

FIG. 1 The surface roughness of the replica glass samples aged at the same temperature and humidity, but for increasing ageing time

The FIB microscope is, however, a destructive technique as the Ga ion erodes away the sample surface as it images, although this phenomenon can be put to good use. By milling away material in a controlled manner to produce a crater, the crater walls are in fact cross-sections of sample and can then be imaged by the beam. With the FIB

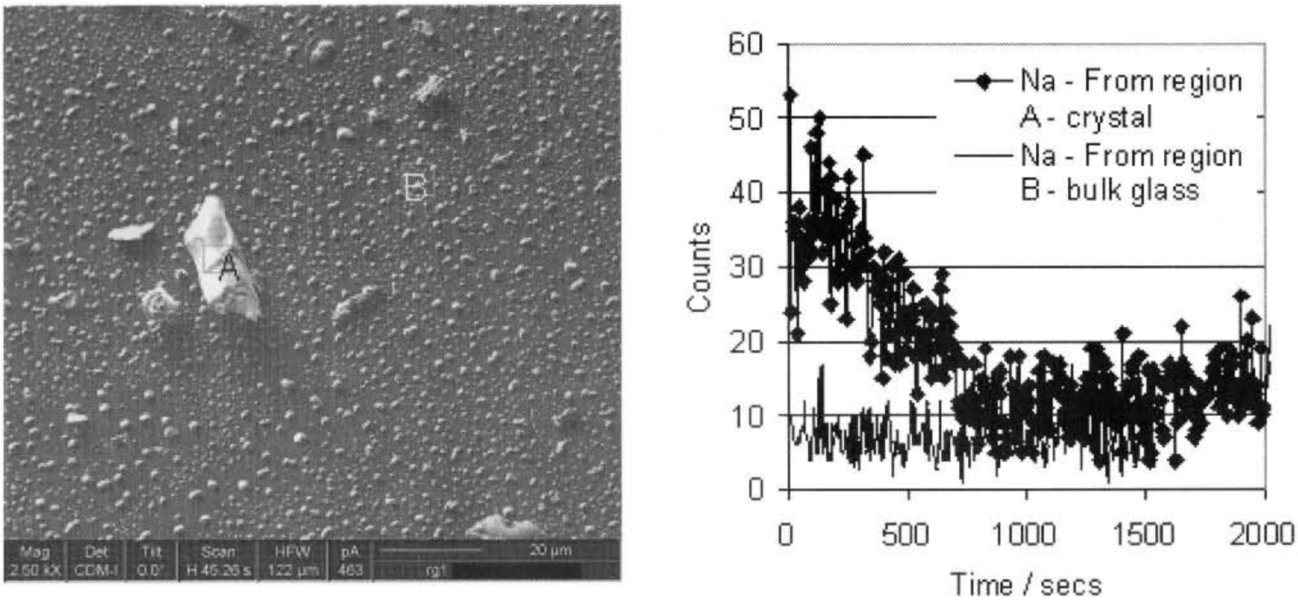

FIG. 2 Left: a FIB image of the glass surface aged at 55%RH for 45 hours. The image shows the presence of both large and small crystal structures. Right: a Na SIMS profile obtained from the large crystal, region A, and the glass region B

microscope it is therefore possible to image below the surface of the sample, as well as the surface, making it a very versatile technique. For the purposes of the work presented here, only the surface has been imaged.

A FIB image of a glass surface aged at 55%RH for 45 hours is shown in FIGURE 2, left. It can be seen that there are clearly corrosion products on the surface of the glass and crystals of various sizes. From the image alone it is not possible to say what the corrosion products are. With the FIB miscroscope, however, it is also possible to carry out secondary ion mass spectrometry (SIMS), and as the ion beam is very focused it is possible to perform this analysis in very small areas. SIMS was, therefore, carried out on the large crystal and the bulk glass – regions marked A and B respectively on FIGURE 2, left. A crater of 5µm^2 was sputtered. FIGURE 2, right, shows the results of this SIMS depth profiling for Na. It can be seen that from region A, the large crystal, a large amount of Na is present whereas the quantity of Na from region B remains constant. This result does seem to indicate that even at these short ageing times at room temperature, Na is clearly leaching out and forming some sort of corrosion product on the surface of the glass.

To measure the extent and depth to which the Na cations had leached out from the glass, and to quantify the corrosion/deterioration in some way low energy SIMS depth profiling was carried out. As mentioned earlier, the beam energies that can now be usefully used in SIMS depth profiling have been dramatically reduced in recent years leading to a massive improvement in depth resolution enabling very small changes in composition to be measured on a nanometer scale. In this case the beam used to depth profile the aged samples was a nitrogen beam (N_2) at 1.25keV.

FIGURE 3, left, shows the Na cation depth profile for the glass aged at 55%RH at room temperature for ageing times of 21, 45, and 69 hours. All three profiles display similar shapes. At the start of the profiles the Na signals, which are high due to precipitation of Na on the surface, drop to a minimum point compared with bulk concentrations of 11.92at% (17.66wt%). This minimum becomes lower as the ageing time increases. After reaching a minimum point the signals then gradually increase until the bulk of the glass has been reached, indicated by the flat stable signal. This first region, from the surface until the signal becomes stable, represents the depleted region where the Na cations have been leached. The depth to which this depleted/leached region extends is used as a measure of how corroded/deteriorated the glass has become. If there had been no corrosion/deterioration of the glass, the Na signals would have been stable and flat from the very beginning of the analysis, assuming no effects on the analysis are introduced by the SIMS ion beam. Although the ageing of these samples has been performed at room temperature and for relatively short periods of times, it has been possible to measure the depletion of the Na in the near surface due to the high depth resolution of the SIMS technique.

The depletion depths were therefore measured from the low energy SIMS depth profiles and plotted as a function of time (FIG. 3, right). From the gradients of these plots it is possible to make an estimation of the corrosion rate. However, it must be stressed that for a more accurate measurement many more data points would be required and a more extensive range of ageing times measured. However, from FIGURE 3, right, it has been estimated that at 39%RH and 55%RH the corrosion rates are 0.92mm/year and 1.44mm/year respectively. By extrapolation from the leaching rates obtained from the same glass composition aged at elevated temperatures, Ryan obtained a Na leach rate of *c.* 1.5mm/year at 40%RH. Although these early results appear to correlate well with the work of Ryan, it is predicted that the initial depletion of Na will decrease with the square root of time, until a steady state is reached (Grambow and Muller 2001).

From these very early SIMS results it appears that Na cations are still leaching out of the replica glass at

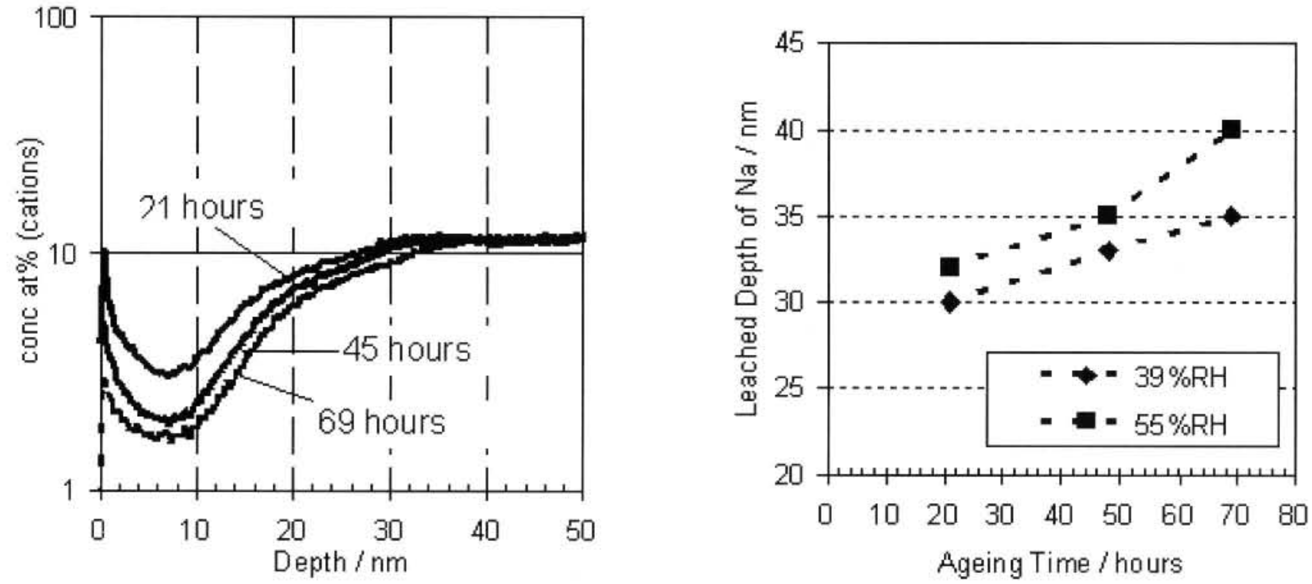

FIG. 3 Left: a SIMS depth profile of the Na ions from the glass samples aged at 55%RH and room temperature. Right: the plot of the Na leached depth as a function of ageing time for two samples aged at 39 and 55%RH

humidities that have been suggested as safe for storage of museum glass objects.

CONCLUSION

By applying a range of advanced surface analytical techniques it has been possible to measure and resolve the deterioration of a replica glass aged at known humidities for relatively short periods of time and most importantly at room temperature. This provides us with a very powerful new protocol for assessing the kinetics of the corrosion process as well as the mechanism.

Initially the change in surface roughness of the aged surface was measured using an optical interferometer. This clearly showed the progressive build up of corrosion products on the glass surface as humidity and ageing time increased. Measuring the surface roughness of a glass object at regular intervals could prove a useful technique to museum conservators wanting a safe non-destructive method of monitoring the glass deterioration. Washing these deposits off and analysing the washings is another way of assessing the amount of alkali that has diffused out of the glass. This would be complimentary to SIMS depth profiling.

Further analysis of the aged surfaces by FIB miscroscopy enabled the different types of crystals that were forming on the surface to be viewed, and also analysed. It was shown that the larger crystals contained a higher quantity of Na compared to the underlying bulk glass.

Finally low energy SIMS was shown to give quantitative depth profiles of the Na cation in the top 100nm of the sample. The SIMS was able to resolve the small compositional changes that had occurred between the different ageing times for the different humidities, and an estimate of corrosion rates was made.

By combining these three very powerful surface analytical techniques it can be seen that room temperature ageing can now be carried out and accurately quantified. Hopefully further work that will be carried out will enable a clearer and more accurate picture of the ageing process of vulnerable glasses at room temperature.

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DETERIORATING NINETEENTH AND TWENTIETH-CENTURY BRITISH GLASS IN THE NATIONAL MUSEUMS OF SCOTLAND

Katherine Eremin, Belén Cobo del Arco, Laurianne Robinet and Lorraine Gibson

Introduction

The National Museums of Scotland collections include about 2000 19th to 20th-century British glass artefacts. An initial conservation survey in 1996 identified 153 artefacts as actively deteriorating (Cobo del Arco 1999). Examination of additional artefacts is ongoing and 212, *c.* 20% of those surveyed to date, are deteriorating. The visible signs of deterioration were alkaline deposits or weeping (170 artefacts), crizzling (32 artefacts) and flaking (10 artefacts). An analytical investigation of the glass composition, corrosion products and environment was undertaken to ascertain the causes of corrosion and prevent further deterioration.

Environmental analysis

The unstable glass was originally stored at Leith Customs House (LCH) and displayed at the Royal Museum of Scotland (RMS). Most was subsequently moved to the new Granton store. The LCH store has an average relative humidity (RH) of 20–40% in winter, 50–65% in summer, whilst the RMS gallery has an average RH of 30–35% in winter, 60–65% in summer. Attempts to control the RH in these locations were unsuccessful. These environmental fluctuations are unsuitable for unstable glass as they lead to cyclical deliquescence and crystallization of salts, with highly alkaline droplets accelerating network dissolution. The new store achieves 40±5%RH, as recommended for unstable glass.

In LCH and the RMS the wooden cupboards or cabinets are known to be unsuitable for lead or leaded copper alloys due to out-gassing of organic pollutants. The levels of organic acids and aldehydes at the three sites were monitored using passive samplers (Gibson *et al.* 1997; Gibson and Brokerhof 2001). The values are given in Table 1. The LCH and RMS cases had high levels of organic acids and aldehydes, dominated by acetic acid. The surrounding rooms/galleries have lower levels indicating the pollutants are internally generated from the case materials, mainly wood and wood-products for the organic acids, and glues and resins (including the resin in medium density fibreboard, MDF) for the formaldehyde. The new Granton store has low organic acid levels and very low formaldehyde levels, with similar values inside and outside the glass and metal cupboards.

Glass compositions

Compositional instability in glass results from high levels of alkali, either sodium or potassium, and low calcium levels (Werner 1958; Brill 1975; Schmidt 1992; Ryan *et al.* 1996). However, there are few published analyses for 19th to early 20th-century British glass and none for Scottish glass.

Samples were taken from 23 artefacts, selected mainly by their suitability for sampling. It was not possible to obtain samples from each visually distinct group of artefacts. Samples included flakes from existing broken edges, the flange on press-moulded glass and the pontil mark on blown glass, and drilled samples from existing

Table 1 Carbonyl pollutant concentrations in case, gallery and storage areas. LCH: Leith Custom House; RMS: Royal Museum of Scotland

Site	Acetic acid $mg\ m^{-3}$	Formic acid $mg\ m^{-3}$	Formaldehyde $mg\ m^{-3}$
LCH cases 1998	–	–	858 ± 39
LCH room 1998	–	–	118 ± 12
LCH cases Sep 2002	1193 ±19	366 ±18	280 ± 10
LCH room Sep 2002	614 ±41	220 ±11	113 ± 12
RMS cases Sep 2002	1829 ±21	520 ±18	34 ± 23
RMS gallery Sep 2002	481 ±18	100 ±34	< 12
RMS cases Nov 2002	2019 ±85	443 ±14	133 ± 12
RMS gallery Nov 2002	246 ±38	73 ±16	< 12
Granton cases Sep 2002	329 ±41	82 ±18	< 12
Granton area Sep 2002	248 ±18	168 ±7	< 12
Granton cases Nov 2002	204 ±39	62 ±16	< 12
Granton area Nov 2002	345 ±38	83 ±15	16 ± 14

broken edges or chips. A mini bench drill with a 3mm diameter diamond core was used, with water supplied by pipette. Broken edges were drilled 2mm deep. Samples were mounted and polished (finishing with 0.25mm diamond paste) for electron microprobe (EMP) analysis. A Cameca Camebax Microbeam-1985 with the Cameca ZAF correction procedure was used, with a rastered beam of 8–10ìm, at 20kV and 9nA. Mineral standards were used for calibration and glass standards analysed with the unknowns.

Most artefacts had no suitable sampling areas and were hence analysed non-destructively, mainly by non-destructive X-ray fluorescence (XRF). The system used cannot detect elements below potassium due to air between the sample and detector. Small artefacts were analysed non-destructively using a controlled pressure scanning electron microscope with energy dispersive microanalysis (CP-SEM-EDX) to identify the light elements and determine surface compositions. The compositional data is summarized in TABLE 2 – duplicate samples are referred to as A, B or C and altered rims or banding identified.

Stable glass

Seven stable glass artefacts were analysed for comparison with the unstable artefacts. The analyses identified three different stable compositions: potash-lead glass with 34–36% lead oxide (PbO) and 8–11% potash, potash-lime glass with 13.6% potash, 11% lime and soda-lime glass with 13–14% soda, 6.5% lime, 2% potash and 3% lead oxide.

Unstable glass

Analysis of the unstable glass showed most were soda-lime glass, with soda, potash-lead and potash-lime glass also represented. Their instability results from high levels of alkali and low levels of lime, as found by Brill (1975), Schmidt (1992) and Ryan *et al.* (1996).

Clear press-moulded glass

Most artefacts were soda-lime glass, with only one potash-lead glass dish. The latter is severely crizzled on the inside. Non-destructive CP-SEM-EDX of the external surface suggested 5% potash, <1% soda, <0.5% lime and 22% lead oxide (PbO). EMP analysis of a sample revealed the internal composition was 15% potash, 0.5% soda, 0.1% lime and 20% lead oxide.

All soda-lime glass artefacts had crystalline deposits and/or frost-like fingerprints. Analysis indicated at least three distinct compositional groups. The main compositional group included commemorative plates dated to 1887 and 1888 and items produced by the English manufacturer George Davidson. EPM analyses of five artefacts indicated 19–20% soda, 5–7% lime with <0.5% potash. A second compositional group was distinguished by minor barium and detectable strontium, with two artefacts having 17–18% soda, 3–4% barium oxide (BaO) and 3% lime by EPM. The third distinct compositional group contained a Scottish jug with lower soda and lime (16% and 2% respectively) and higher potash (2.5%).

Coloured press-mould glass

Several press-moulded artefacts consisted of coloured glass, including purple marble glass with white and purple banding, jet glass, opaque white glass and translucent blue glass. Prior to conservation, the purple marble glass artefacts had long fibres and flecks of salts, the jet glass had a network of needle-like deposits and the white glass had scattered salts.

The purple marble glass was soda-lime glass, coloured with manganese, with around 20% soda and 3% alumina and lime. The opaque white glass could not be sampled but non-destructive analysis indicated a surface with 5–7% soda, 1–2% potash, 1% lead oxide and <0.5% lime, suggesting considerable loss of alkalis from an original soda or mixed alkali glass.

Two press-moulded jet glass artefacts, presumed to be Scottish (Murray 1982), and a light blue translucent press-moulded bottle moulded with Glasgow Eye Infirmary could not be sampled but non-destructive XRF indicated low lime and no potash, suggesting soda-lime glass.

Clear blown and cut glass

The clear drinking vessels could not be sampled but had no detectable potassium by XRF and sodium-rich corrosion products, suggesting soda-lime glass. Corrosion varied, with frost-like fingerprints, clouding of the surface and fibrous deposits. Calcium levels differed, indicating a number of compositional groups, and some artefacts (including an 1887 Jubilee tankard) contained lead. Three custard bowls with etched decoration and slight deterioration formed a distinct compositional group of potash or mixed alkali glass, with moderate barium and lead, low calcium and detectable strontium.

EPM analysis showed one wine glass (with amber-coloured silver staining on the surface) was potash-lime glass with 13% potash and 8% lime. This had surface dulling and frost-like fingerprints, suggesting slight instability. Three other artefacts with minor deterioration also appeared to be potash-lime glass by non-destructive analysis. However, sodium salts in the corrosion products from one showed this must be a mixed alkali glass, and the others may be similar. Non-destructive analysis showed one cut-glass whisky glass was potash-lead glass.

The most deteriorated artefacts were two decanters with crizzling, surface flaking and pitting and a jug with incipient crizzling. All three appeared compositionally identical by non-destructive analysis. Both decanters were sampled and were soda glass with 14–15% soda, 4% potash, 5–7% lead oxide and <1% lime. Pieces from the rim of one decanter were used to investigate deterioration (see below).

A cross-section through the rim showed extreme alkali depletion across a 40mm zone (FIG. 1, COLOUR PLATE 119). The decanter is thought to date from the late 19th to early 20th century, indicating an average alteration rate of 0.4ìm per year. This silica-rich gel-layer is hydrated, resulting in low analytical totals by EPM. Analysis by ion microprobe with secondary ion mass spectrometry (a Cameca ims-4f) indicates a water content of 6–8% in the altered layer. The upper layer of glass is separating from the interior along an uneven fracture 5–25ìm below the alteration front, with fine cracks perpendicular to the surface. The altered zone occurs at both surfaces and penetrates deeper into the glass around cracks. Moser (1961) described flaking and the development of orthogonal cracks as characteristic of moisture-related

TABLE 2 COMPOSITIONS OF SELECTED 19TH TO 20TH-CENTURY BRITISH GLASS ARTEFACTS

The compositions are averages of electron microprobe analyses on polished samples with the exception of * which are average surface compositions from controlled pressure scanning electron microprobe analysis of the artefact. ** HMEN 209.307 also has 0.4% UO_2, 0.1% TiO_2; *** Unreg decanter; rim also has 6–8% H_2O.

Sample	Area	SiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K2O	Cl	SO_3	PbO	As_2O_3	Sb_2O_3	BaO	P_2O_5	Total
Stable																	
Clear blown or cut																	
A.1905.260		55.37	0.12	0.09	0.04	0.01	0.05	1.53	7.99	0.23	0.07	33.78	0.01	0.15	–	0.03	99.49
HMEN 209.359		53.21	0.36	0.07	0.04	0.02	0.02	0.40	11.15	0.05	0.08	33.79	0.09	0.19	–	0.01	99.47
HMEN 209.347		55.37	0.16	0.05	0.02	0.02	0.05	0.17	8.86	0.08	0.09	34.39	0.01	0.17	–	0.03	99.49
HMEN 75		54.04	0.64	0.09	0.09	0.04	0.07	0.16	8.93	0.09	0.10	35.25	0.01	0.15	0.05	0.01	99.74
Perth chandelier		52.71	0.23	0.13	0.07	0.03	0.06	0.14	8.87	0.08	0.10	36.25	0.03	0.15	–	0.04	98.88
HMEN 209.490	A	73.37	0.24	0.06	0.15	0.10	6.58	12.66	1.69	0.14	0.13	2.81	0.24	0.40	–	0.12	98.70
	B	74.52	0.23	0.04	0.12	0.08	6.42	13.98	1.76	0.14	0.12	2.90	0.23	0.43	0.02	0.13	101.13
HMEN 209.594		71.15	0.41	0.08	0.05	0.23	11.21	0.80	13.55	0.10	0.27	0.10	0.44	0.29	0.03	0.24	98.94
Slightly deteriorated																	
Clear blown and cut																	
HMEN 47		77.33	0.17	0.05	0.05	0.16	7.91	0.11	12.68	0.01	0.17	0.02	0.33	0.29	–	0.26	99.54
Deteriorated																	
Purple marble press-mould																	
HMEN 209.469	white	67.65	3.46	0.20	0.16	0.11	3.62	20.84	0.60	0.30	0.10	0.07	0.66	0.01	0.09	0.09	97.95
	purple	62.35	2.70	1.10	3.85	0.17	3.19	22.07	0.36	0.22	0.10	0.94	0.59	–	0.53	0.10	98.27
HMEN 209.539	white	65.87	3.21	0.15	0.08	0.11	3.50	20.13	0.33	0.25	0.10	0.00	0.53	–	0.05	0.07	94.37
	purple	61.42	2.68	1.00	4.33	0.18	2.48	21.04	0.47	0.19	0.10	1.15	0.61	–	0.52	0.07	96.24
Clear etched																	
HMEN 243	A	72.84	0.43	0.11	0.12	0.09	3.24	17.88	0.14	0.24	0.17	0.00	0.36	0.05	3.34	0.07	99.08
	B	73.56	0.44	0.08	0.12	0.11	3.25	17.56	0.16	0.24	0.19	0.04	0.35	0.03	3.42	0.06	99.58
	C	72.77	0.31	0.08	0.16	0.08	3.14	18.07	0.14	0.23	0.20	0.00	–	–	3.32	0.06	98.54
HMEN 209.63		71.42	0.19	0.08	0.15	0.06	3.26	16.97	0.06	0.22	0.10	0.56	0.88	–	4.27	0.06	98.27
Clear press-mould ?English																	
Unreg 5		70.18	0.15	0.05	0.09	0.12	6.12	19.47	0.11	0.20	0.07	0.00	0.56	0.04	0.03	0.10	97.27
HMEN 209.401		72.16	0.14	0.05	0.09	0.10	6.30	18.70	0.16	0.12	0.07	0.00	0.40	0.00	0.01	0.16	98.46
HMEN 209.429	A	73.24	0.17	0.05	0.08	0.09	5.59	18.61	0.12	0.23	0.06	0.02	0.53	0.03	0.03	0.11	98.96
	B	73.63	0.15	0.05	0.07	0.08	5.59	19.19	0.15	0.21	0.06	0.05	0.52	0.02	0.03	0.10	99.90
	C	72.37	0.15	0.06	0.07	0.09	5.60	19.03	0.14	0.23	0.07	0.03	0.50	0.03	0.03	0.09	98.49
HMEN 98		71.66	0.14	0.05	0.08	0.07	6.24	19.52	0.07	0.17	0.10	0.02	0.51	0.04	0.12	–	98.79
HMEN 190		71.77	0.13	0.04	0.09	0.07	6.70	20.14	0.21	0.15	0.11	0.03	0.57	0.05	0.02	0.08	100.16
HMEN 209.507		74.46	0.27	0.08	0.10	0.08	4.33	19.59	0.04	0.09	0.10	0.12	0.00	0.11	–	0.05	99.41
Clear press-mould ?Scottish																	
HMEN 100		77.09	0.29	0.05	0.18	0.07	1.80	16.09	2.46	0.29	0.07	0.02	0.20	0.06	–	0.05	98.72
Vasart/Momart																	
HMEN 209.462		73.77	1.38	0.15	0.18	0.09	3.07	17.15	0.40	0.08	0.07	0.01	0.19	0.27	0.05	–	96.86
HMEN 215.45		75.75	0.62	0.05	0.15	0.03	2.94	16.82	0.06	0.11	0.05	0.00	0.22	0.27	–	0.05	97.12
*Apple-green blown?***																	
HMEN 209.307	A	62.58	0.26	0.06	0.04	0.02	0.05	0.32	2.83	0.21	–	25.80	–	0.03	–	–	92.20
	B	59.09	0.24	0.09	0.03	0.02	0.03	2.61	11.64	0.19	–	24.27	–	0.12	–	–	98.34
	C	58.62	0.26	0.06	0.01	0.02	–	2.63	12.05	0.20	0.09	24.36	–	0.13	–	0.01	98.44
Clear press-mould																	
HMEN 209.358		60.30	0.31	0.04	0.04	0.02	0.11	0.54	14.78	0.34	0.11	20.22	0.01	0.12	0.04	0.10	97.08
*White agate press-mould**																	
5–7% Na_2O with 1–2% K_2O, 1% PbO and <0.5% CaO and SnO_2																	
Very deteriorated																	
Clear blown																	
Unreg 3		73.09	0.30	0.10	0.13	0.03	0.48	13.75	4.44	0.19	0.29	4.78	0.21	0.08	0.00	0.05	97.92
Unreg 4		72.19	0.33	0.06	0.09	0.03	0.61	14.09	4.48	0.19	0.29	6.57	0.27	0.09	–	0.05	99.32
Unreg decanter	A: interior	72.05	0.39	0.07	0.10	0.04	0.60	14.46	4.79	0.18	0.27	6.52	–	–	–	0.04	99.50
	A: rim***	74.38	0.32	0.09	0.09	0.06	0.63	6.00	3.92	0.20	0.29	6.73	0.28	0.06	–	0.03	93.07
	B: interior	71.61	0.54	0.09	0.12	0.02	0.60	15.11	4.80	0.17	0.27	6.46	0.28	0.05	–	0.04	100.18
	B: rim***	76.91	0.37	0.09	0.19	0.03	0.64	1.67	2.21	0.17	0.28	7.40	0.21	0.00	–	0.05	90.22

surface deterioration of soda-lime glasses. Brill (1975) observed similar alteration fronts and separation layers and estimated a hydration/depletion rate of 0.3ìm per year.

Green blown glass

The green wine glasses consisted of two main compositional groups, potash-lead glass and soda-lime glass. The latter could not be sampled; non-destructive analysis indicated calcium without potassium or lead and the corrosion products were dominated by sodium salts. The potash-lead glass included apple green uranium-coloured glass, dark green iron and copper-coloured glass

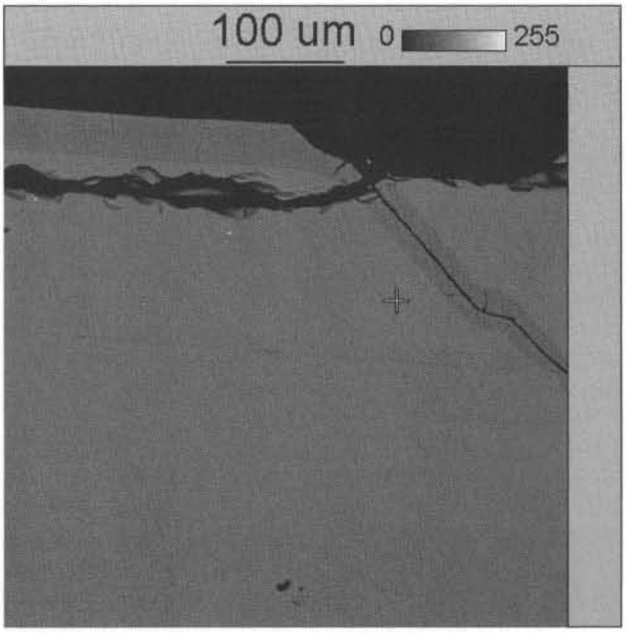

FIG. 1 Cross-section through the decanter rim showing the altered zone at the surface and the separation of this from the interior glass. Note the fine cracks perpendicular to the surface and the larger fracture running into the interior with depletion along both sides of this

and moss green iron-coloured glass, all with dendritic crystals. All the soda-lime glass was apple green from uranium and crizzled, with sparse deposits of fine branching dendrites or long thin crystals. No dendritic crystals could be sampled. EMP analysis showed the uranium potash-lead glass had 24–25% lead oxide with 11–12% potash, 2.6% soda and <0.1% lime. The surface was hydrated with greatly reduced alkali levels (TABLE 1).

Monart/Vasart Glass

Monart/Vasart glass was made at Moncrieff's North British Glassworks in Perth, Scotland, from 1922–1961, at Ysart Brothers Glass in Perth from 1946–1956 and at Vasart Glass Limited in Perth from 1956–1964. All Monart/Vasart glass was deteriorated, most had a thick layer of salts and several were crizzling. Glass from this manufacture is known to be unstable. These artefacts are extremely varied, often multi-coloured, and will be the subject of a separate study. Two samples were available for initial EMP analysis, indicating 17–18% soda with 3% lime and <0.5% potash.

CORROSION PRODUCTS

Corrosion products were sampled from 106 artefacts during conservation and divided into two batches, one for ion chromatography (IC), the other for Raman spectroscopy and scanning electron microscopy (see Robinet *et al.* 2004 for analytical details). The samples were heterogeneous mixtures of round, needle-like and flat-angular crystals a few microns to a few hundred of microns in size, and droplets. Previous glass deterioration studies identified a variety of corrosion products, normally carbonates, sulphates and chlorides (Tichane 1966; Moser 1961; Schreiner 1987; Sirois 1999; Römich 1999) and more rarely formate (Nockert and Wadsten 1978; Schimdt 1992). Identification of the specific phases is required to understand the causes and mechanisms of corrosion and determine the optimum environmental conditions for storage or display.

IC showed the main cation was sodium, with lower concentrations of calcium, potassium and magnesium and occasional ammonium. The main anion was formate, with variable amounts of chloride, sulphate and nitrate. Acetate was present only at very small amounts or was below the detection limit. Most samples had a high ionic difference with excess sodium ions, suggesting anions that cannot be detected by IC, such as hydroxides and bicarbonates.

Raman microscopy showed sodium formate was the dominant phase, mainly as small round crystals or larger flat angular crystals of sodium formate anhydrate II (the common room temperature phase). Some fine needle-like crystals of sodium formate anhydrate I' were also present. This is an unstable intermediate normally requiring temperatures of 250°C for formation (Heyns and Range 1991) and its presence here is unexplained. Many samples had small droplets of liquid formate, which cannot be fully identified but were probably potassium formate.

Minor sodium sulphate occurred as fine crystals growing on large sodium formate crystals, possibly from reaction with sulphurous gases. Occasionally, an unknown formate containing sodium and calcium and magnesium formate dihydrate were found, the former as fine needles around small sodium formate II crystals suggesting alteration of primary sodium formate. Sodium acetate and sodium nitrate may have been present as minor phases but were not unambiguously identified.

The Raman and IC data showed fairly close agreement and confirmed the dominance of sodium formate. This has previously been identified on glass exposed to organic gases, particularly formaldehyde (Nockert and Wadsten 1978; Schmidt 1992). The salts formed on individual NMS artefacts varied widely. Artefacts with similar (sometimes identical) compositions had different amounts, phases and/or mixtures of salts. Schmidt (1992) attributed efflorescence variations to local differences in formaldehyde concentration.

The corrosion products were dominated by formate, whilst the pollutants were dominated by acetic acid. Although acetic acid and metal acetates react with carbon dioxide to form carbonates, none were detected. The absence of alkali acetates hence requires further investigation. The formates can be attributed to the effects of formaldehyde and formic acid. A purely ionic phase would not be detected by Raman, so could account for the observed ionic difference in the IC analysis.

SIMULATION EXPERIMENTS

Small pieces of glass cut from the rim of an unregistered decanter (see TABLE 1) were placed in corrosive environments to investigate the effect of organic pollutants. The altered surface was not removed prior to degradation. Dessicators were set up with mixtures of *c.* 100ppm or

5ppm formaldehyde and/or 150ppm or 5ppm acetic or formic acid at 40%RH and 100%RH.

After five months, all samples at high humidity were surrounded by condensation and salts were visible on some samples at low humidity. The cut surface was the most deteriorated, presumably as this had the highest alkali levels. No droplets or crystals were observed at low humidity and low acetic acid, formic acid or formaldehyde. The crystals and droplets were sampled and analysed by Raman and SEM. Full results are given in Robinet *et al.* (2004).

A similar assemblage to the original corrosion products developed at 100%RH, 150ppm formic acid, with flat needle-like crystals of sodium formate anhydrate II and droplets of formate. Interestingly, sodium acetate developed on samples with 5ppm and 150ppm acetic acid at 100%RH and with 150ppm acetic acid at 40%RH.

Although the organic gas levels used were several times higher than those in the museum, the results confirm that organic gases enhance corrosion of unstable glass, with greatest corrosion at high humidity and high organic gas concentrations. The variety of phases formed indicates a complex corrosion mechanism and path. Tichane (1966) showed that heated soda-lime glass developed an alkali film, which reacted with acidic gases (even at very low concentrations) to form crystallites of the corresponding salts. A similar reaction of the alkali silicate film with organic acids may be involved in forming these formates and acetates. However, it may be a more complex sequence via intermediate carbonates (Schreiner 1987; Römich 1999). Surface deterioration mechanisms normally depend on water (Moser 1961), so it is interesting that some corrosion occurred at low RH. Further investigation with a wider range of conditions and compositions is ongoing.

Dissolution and precipitation of salts

The approved RH for the storage of unstable glass is often defined by the stability of sodium or potassium carbonate (Tichane 1966; Brill 1975). The dominance of sodium formate and lack of carbonates shows that the deliquescence point of the alkali formates is more significant for the NMS unstable glass. Peng and Chan (2001) showed that sodium formate deliquesces at 50.5–52.1%RH. During our original 1996 survey the salts appeared to deliquesce at 50–55%RH at room temperature.

The deliquescence points of some crystals from the corrosion samples and of commercially available potassium and sodium formate were determined directly in an environmental SEM. The crystals were transferred to an aluminium stub and held at 19°C at different water pressures (RH).

The anhydrous sodium formate began to deliquesce at 50%RH, showed extensive liquid at 52.5%RH and was fully liquid at 55%RH. When the RH was reduced, crystallisation began at 47.5% and was completed at 45%. This slight RH difference may be a kinetic effect. In contrast, a crystal of commercial potassium formate was fully liquid at around 16–17%RH.

It had been hoped that the ESEM could identify the composition of the droplets in the corrosion. At 30%RH, droplets and crystals were observed. At 20%RH, the droplets crystallized to fine needles. This would be consistent with potassium formate but it was not possible to analyse individual droplets.

Conservation

All the deteriorating artefacts were identified and photographed prior to conservation. All 212 artefacts were cleaned with swabs of de-ionised water and dried with precision wipes. The inside of decanters and bottles were rinsed with IMS after cleaning to ensure thorough drying.

The artefacts were re-examined after cleaning under a binocular microscope, with special attention paid to any possible signs of crizzling. Most showed no visible signs of deterioration but ten were cloudy, thirty four were crizzled (mostly incipient) and three were slightly pink but not crizzled. The cleaned artefacts were placed in the new environmentally controlled store at Granton.

Conclusions

A significant percentage of the NMS 19th to 20th-century British glass is compositionally unstable. High levels of acetic and formic acids and formaldehyde in the former stores and galleries, combined with fluctuating relative humidity, resulted in significant deterioration. The main corrosion product is sodium formate, which deliquesces at 50–55%RH. Droplets within the corrosion products are probably potassium formate, which has a much lower deliquescence point. Pieces of 19th-century glass exposed to high levels of formic acid and acetic acid at high RH rapidly developed sodium formate and sodium acetate crystals respectively. The lack of acetate in the original corrosion products is not understood. The project demonstrates the importance of storing and/or displaying compositionally unstable glass in a controlled environment with no sources of organic pollutants. Further work is required to fully understand the effects of organic gases on compositionally unstable glass.

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FAKES, IMITATIONS AND REUSE

IDENTIFICATION OF FALSE GEMS ON OBJECTS FROM THE MIDDLE AGES

Isabelle Biron and Anne Françoise Cannella

Introduction

The present work is based on a doctorate dedicated to a 14th-century manuscript (*c.* 1390) called *Le Trésorier de Philosophie naturelle des pierres précieuses* of the famous chronicler from Liège, Jean d'Outremeuse (Cannella 2001). The work is composed of four books: the first three books are lapidaries which deal with medical and magical properties of precious, curious and fabulous stones; the fourth book is a collection of technical recipes dedicated to the imitation of precious stones.

The study of this old manuscript has allowed us to take an interest in a quite original field – the imitating of precious stones using coloured glass (Biron and Cannella 2002). No other material was more suitable to artificially reproduce true gems. This practice is attested to throughout the centuries in technical, alchemical and historical texts as well as in the artefacts. The presence of false gems, sometimes simultaneously with genuine precious stones, is particularly obvious in objects from medieval goldsmiths, in jewellery, crosses, reliquaries and book covers for example. The use of glass gems served two main purposes. The most obvious is of an economic nature – glass gems were less expensive. Another reason is related to the symbolic value of precious stones and to their arrangement in the medieval religious goldsmith's art. When true gems were missing, glass imitating the same colour and the same form could perfectly complete a composition. Moreover, for medieval people, this brilliant and luminous material, manufactured by their own hands, represented a special attraction.

Until recently, coloured glass gems have not received the attention they deserved, either from art historians, historians of techniques, gemmologists or laboratory physicists and chemists. We do not yet know what types of glasses were really used because very few analyses have been performed to date on glass *cabochons*. The aim of our study is to undertake systematic ion beam analyses of medieval objects to check if specific recipes for making glass gems were applied.

Description of the objects

We chose 17 objects from French collections at the Louvre (OA and MRR) and the Musée National du Moyen Âge et des Thermes de Cluny (CL), thought to be covered by glass *cabochons*, and for which close dates are available from the manuscript (the *Trésorier)*. All are the works of medieval goldsmiths.

The objects fell into three groups. The first comprised three gilded, enamelled copper objects from the 13th century, originating from Limoges, France – a *ciborium* (inv no. MRR98) (colour plate 120), a Christ (OA11935), and a book cover (OA6173) – and a gilded silver piece – a *phylactère* from Constance, Germany (OA8100). The second comprised eleven gilded silver objects from the first half of the 14th century. These were a cross reliquary originating from the centre of France (CL14793) (colour plate 121), and ten pieces from the Colmar treasure, East France – two rings (CL20660 and 20663) and eight elements (CL20681). Finally, two gilded bronze pontifical rings dating from the second half of the 15th century and originating from Italy (inv no. CL9063 and CL9192) were selected.

Two additional pieces from Limoges – a Christ (CL944) and a cross reliquary (CL998) – already studied in the laboratory for analyses of the turquoise inlays (Gazzola 1996; Reiche 2000), have also been included in this work for comment and comparisons on their glass compositions.

Experimental set up for non-destructive glass surface ion beam analysis

The glass surface was analysed using the PIXE and PIGME (particle induced X and gamma ray emission respectively) methods applied directly to the objects with the AGLAE accelerator in our laboratory. A 2.8MeV proton beam, produced by a duoplasmatron source, is extracted through a 0.1µm silicon nitride (Si_3N_4) exit window.

Three detectors were used simultaneously. To obtain complete and precise analyses for both light and heavy elements, the X-ray spectra are recorded by two Si(Li) Kevex detectors, located at 45° with respect to the beam direction:

• from 0.3 to 10 keV (Na to Fe) with the small detector (10mm^2, resolution 140eV at 5.9keV, 0.25µm thick boron nitride window, 0.4µm C film, helium flux),

• from 5 to 40 keV (Fe to U) with the large detector (50mm^2, resolution 180eV at 5.9keV, 6µm Be window, 49µm Al filter).

An Ortec HPGe detector, at 45° with respect to the beam in a front geometry (resolution 2keV at 1.33MeV) was used to detect gamma rays. This set up allowed the identification of sodium using the 439keV gamma ray emission resulting from the nuclear reaction $^{23}Na(p,p_1\gamma)^{23}Na$. Other nuclear reactions were also used for the detection of different light elements like boron and fluorine.

The beam size is approximately 100µm on the target. The beam current is in the range 0.5–1nA. These parameters yield acquisition times between 300 and 600s. The X-ray spectra are processed with the GUPIX software and the calibration was done with reference samples.

Glass gem recipes from the *Trésorier*

Three basic recipes are mentioned in the manuscript to make glass gems. Most of them produce particularly brilliant glasses.

Rock crystal, which is quartz, was the favourite material. During the medieval period it was considered as a precious stone. This material was appreciated by glassmakers for its high silica content and for its low impurity level, especially iron. It gives a greater clarity and limpidity and a better quality to the false gems. Quartz blocks were heated until white hot, then thrown into cold water, before being crushed and finally reduced to powder. After that, a flux agent was added to obtain an easily fusible mixture (sodium carbonate, potassium carbonate or mixed alkalines). At most two of the gems analysed in this study could have been made from rock crystal.

Lead glass was another ideal source for coloured glass and the imitation of precious stones. Its use is attested to in many old treatises. The *Trésorier* mentions the addition of a lead lime to a crystal or to a glass. The addition of lead to a silicate produces a highly fusible glass (740–760°C) with an exceptional brilliance and which is easy to cut and polish. Only one of the gems analysed in this study has been made using lead silicate.

The addition of alkaline salts to silica is mentioned in the *Trésorier*. Either a sodium-rich salt (*alume catino, salsola soda* and *kali soda*), or a potassium-rich salt (tartar), or a mixture of both sources was used. The *Trésorier* is one of the first to propose tartar – which is calcinated lees of wine (K_2CO_3) – as a flux agent. A 16th-century treatise on enamelling recommends the addition of tartar to produce a more brilliant glass (de Vigenère 1615). Only two gems made using potash silicates were identified. Most of our analyses identify sodium silicates, which are not especially brilliant glasses, as the material employed.

Results and discussion

For a total number of 124 analyses of *cabochons*, 69 are true precious stones and 55 are made from glass. All the Limoges pieces are covered with glass gems (Colour plate 120), except the book cover OA6173 decorated with precious stones (and one modern glass addition). When glass and true stones are simultaneously decorating one object, glass *cabochons* do not exceed half the total number of gems used – the *phylactère* (OA8100), cross reliquary (CL14793) (Colour plate 121), cross (CL998) and Christ (CL944). The analytical results from the glasses are presented in Table 1.

Translucent and coloured glasses

Most ancient false gems are made with translucent and coloured glasses – of a total number of 41 glass analyses, only eleven opaque turquoise and two colourless glasses were identified. The opacifiers are tin oxide compounds. The most extensively used colour is blue (8 gems), followed by yellow (5), green (5), amber (3), red-brown (3) and yellow green (2). Pure rock crystal seems to be the favourite material to make colourless gems – out of all the analyses eleven are true crystals and only two are glasses.

The colorants mentioned in the *Trésorier* are not specific for glass gems but are common for all types of glass production during the medieval period: cobalt or copper for the blues (only cobalt was observed here); copper for the greens; manganese, iron, or copper for the red-brown

Table 1 Glass analytical results: some examples of the different kinds of glass gem compositions in weight oxide %

	Types of glass	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	MnO	FeO	CoO	NiO	CuO	ZnO	SnO_2	Sb_2O_3	PbO	As_2O_3
Ciborium MRR98																					
yellow	Soda-lime silicate vegetal Na	17.33	1.98	3.92	62.06	0.38	0.16	0.39	2.17	6.11	0.36	1.20	3.46	0.00	0.00	0.05	0.01	0.01	0.03	0.07	0.003
dark green	Soda-lime silicate mineral Na	12.05	0.57	2.80	69.38	0.04	0.55	1.03	0.94	7.74	0.07	0.43	0.81	0.01	0.00	2.27	0.02	0.29	0.02	0.78	0.005
dark green	Potash-lime silicate (forest)	0.62	3.93	1.30	56.07	2.37	0.27	0.46	16.79	12.96	0.19	0.73	0.49	0.01	0.00	2.79	0.42	0.21	0.00	0.11	0.005
Cross CL14793																					
colourless (cross)	Soda-lime silicate?	12.57	0.44	0.51	72.55	0.00	0.44	0.08	0.08	12.39	0.03	0.01	0.08	0.00	0.00	0.00	0.00	0.00	0.06	0.13	0.295
Phylactery OA8100																					
colourless	Potash-lime silicate?	0.41	0.17	0.56	69.67	0.05	0.37	0.11	16.28	10.66	0.08	0.23	0.12	0.00	0.00	0.00	0.00	0.00	0.57	0.05	0.374
yellow	Lead silicate glass	0.09	0.26	0.65	35.44	0.00	0.00	0.00	1.65	0.87	0.12	0.01	0.08	0.01	0.00	0.12	0.01	0.14	0.01	59.77	0.000
Book cover OA6173																					
opaque grey-blue	Modern lead silicate	15.30	0.45	0.07	46.83	0.00	0.54	0.38	1.44	1.27	0.00	0.00	0.06	0.00	0.00	0.04	0.02	0.00	0.05	30.88	1.598
Colmar treasure CL20681																					
green	Modern lead glass	0.22	2.81	0.01	9.84	1.06	0.00	1.21	0.28	3.19	0.08	0.00	0.06	0.00	0.01	1.55	0.12	0.00	0.04	77.24	0.652
Pontifical ring CL9063																					
colourless (Boron present)	Modern potash silicate	2.90	1.46	0.08	72.54	0.00	0.09	0.34	16.30	3.34	0.02	0.00	0.06	0.00	0.00	0.01	0.00	0.01	0.01	0.07	2.599

(only manganese was observed in our experiments); and iron (with the contribution of sulphur), iron and manganese, or orpiment (arsenic sulphide) for the ambers, yellows and green-yellows (orpiment was not identified in this work). The turquoise colour (11 gems) and lead alone as a yellow colorant (1 gem) are not mentioned in the *Trésorier,* though lead is involved in a yellow glass gem recipe added to a crystal with orpiment.

Moreover, the correspondence between the colorant and the main components necessary to made glass does not strictly follow the recipes. In the manuscript, copper is supposed to be added to a crystal with the addition of lead, but in the analyses, green inlays are sodium or potassium silicates with no use of crystal and lead. In the recipes, iron and manganese are supposed to be added to sand and a potassium source (beech wood), but in this study, yellow gems are sodium silicates.

Modern glasses: replacement

By nature, gems could be easily replaced. The replacement gems could be more ancient or more recent than the objects. Five modern replacements are identified through their glass compositions – one colourless potash-lime silicate (CL9063), one opaque grey lead sodium silicate (OA6173) and three green lead glasses (OA8100, CL20681). Their compositions present all the typical properties of glass from the end of the 18th to 19th century with high arsenic, high lead contents (except for CL9063), no aluminium, and little or no titanium or manganese (Biron *et al.* 1996; 2001; Bailly *et al.* 2001; Bronk and Röhrs 2002; Röhrs and Stege 2004; Röhrs 2004). Moreover, boron is detected in the potash glass and the opaque glass is opacified by small crystals of lead arsenate indicating a modern fabrication (Rooksby 1952; Turner and Rooksby 1959).

The other false gems are made with glass compositions in good agreement with the period concerned. There are, however, two exceptions. These are two colourless silicates which are difficult to identify and to date because of their unusual analyses. One 13th-century piece from Germany (OA8100) is of potash while another from the early 14th century from the centre of France (CL14793) (COLOUR PLATE 121) is of soda. These compositions could be from the 19th century because of their high arsenic content (0.3%). They could also be more ancient and made from rock crystal because of the very low levels of aluminium (<0.56%), titanium (<0.08%) and iron (<0.12%). According to Kunicki-Goldfinger (pers. comm), arsenic was introduced into the technology of colourless glass in Europe in the 17th century. In particular, the potash silicate gem composition fits well with a group of colourless glass vessels, melted in the second half of the 17th and in the 18th century coming mainly from central Europe (see for example Kunicki-Goldfinger *et al.* this volume). The only mention of arsenic by Jean d'Outremeuse concerns the coloration of yellow glass gems (orpiment and lead added to crystal).

Ancient glass compositions

The great majority of our gem analyses are soda-lime-silicate glasses with different colours (36 out of a total number of 41), including all the 13th-century Limoges pieces (COLOUR PLATE 120). Limoges enamels have already shown two chronological types of glass composition, the first using mineral sodium sources (12th to early 13th century) and the second using vegetal sodium sources (early 13th to 14th century) (Biron *et al.* 1996). The transitional period can contain both types. The same types of glass compositions were used for the enamels and for the glass *cabochons*. At that time, no specific recipes for glass gems were employed, even if sodium glass is presented in the *Trésorier*.

The 13th-century *ciborium* from Limoges (MRR98) (COLOUR PLATE 120) contains two green potash-lime-silicates. The potassium sources come from wood ashes, with high levels of calcium, potassium, magnesium and phosphorus. These glasses, also called 'forest glasses', appear during the Middle Ages in France. The use of potassium glasses for the Limoges enamels was very exceptional (Biron *et al.* 1996). Again, our results suggest that Limoges enamellers (or goldsmiths?) did not follow specific recipes to produce more brilliant glasses for their glass gems. They simply employed the available materials.

Only one yellow lead silicate glass has been found on the 13th-century *phylactère* from Germany with 59.8% lead oxide. Very rare medieval high-lead glasses are known. Wedepohl *et al.* (1997) published very similar compositions for green and yellow beads and glass vessels from 13th–14th-century Germany and central Europe. A lead oxide content of 67% has already been found in a French *plique* yellow enamel, dated *c.* 1300 (Biron 1999). Still, recipes from the manuscript recommend the addition of lead to a crystal with copper for a green glass, or to a glass with orpiment for a yellow glass. However no crystal and no orpiment were used in our pieces.

Relations between shape, colour and metal support

Most of the ancient glass *cabochons* have round forms with circular or ovoid bases (COLOUR PLATES 122, 123). Twenty-eight have circular bases with only two being flat, nine have rectangular bases with only two being cut, and four have square bases with one being cut. Apparently, there is no relation between the shape and the colour of the *cabochons*, nor between the colour and the basic glass composition.

Moreover, no relation can be established between the metal support and the nature of the gems – pieces are covered either totally by glass gems (copper, bronze), or precious stones (copper, bronze), or both (copper and silver).

CONCLUSIONS

A rather extensive use of false glass gems is observed in this study of the work of medieval goldsmiths – they represent not less than 44% of the total number of gems analysed. Like the majority of the true precious stones decorating our objects, glass gems are mainly translucent and coloured. The symbolic value of precious stones is therefore maintained.

Modern replacements were present in only 10% of our glass analyses. The other glass compositions fit well with the date of the pieces (including two uncertain cases).

Eighty-eight per cent of our ancient glass analyses are soda-lime-silicates, 5% are potash-lime-silicates – including mainly the Limoges work – and 2% are lead silicates. Despite some differences, all these glasses are mentioned in the *Trésorier.* We would expect, however, more *cabochons* made from the very brilliant materials, like lead-glass or rock crystal or potassium silicates. Because Limoges gems and enamels have similar glass compositions, we will now focus our attention on goldsmith's works of art beside Limoges, to check if such recipes were followed.

This research programme is still in progress on French collections and will be extended in the near future to Belgian collections.

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THE BONUS EVENTUS PLAQUE: CHANGING MATERIALS, CHANGING PERCEPTIONS

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Introduction

The extent to which our understanding of the material and technology of an artefact can affect the way that we see it is not always appreciated. The subject of the present paper, the *Bonus Eventus* plaque, has undergone a number of radical re-evaluations of its material during its history, and each of these has led to some re-evaluation of its position in the scheme of things. Here we show how modern materials analysis once again leads us to question our established view.

The plaque (colour plate 124) is of opaque blue glass with yellowish-white flecks. It shows in relief a youth facing to the right with short curlyish hair, portrayed in three-quarter view from the back and ending below the buttocks. He wears a cloak flung over his shoulders and falling down in folds by the sides. In his right hand he holds up a *patera* and in his left ears of corn that are held down towards the end of the plaque. On either side of his head is inscribed BONO EVENTVI.

Bonus Eventus (Good Success) presided over agriculture, giving success and good yields for the farmer. The earliest known reference to him is by Varro (*De Re Rustica* I, 1, 6) and his image is known from one other relief, as statues, on gems and on coins. On the first Roman coin of 62 BC he appears standing and naked with a *patera* in his right hand and ears of corn (and sometimes poppies) in his left both held down low. This same figure appears on later Roman coins of the end of the 2nd and the 3rd century AD. On other occasions he is wearing a cornucopia. On some gems of the 1st and 2nd century AD he is standing in profile and wears a cloak flung over his shoulders and holds in one hand a shoot of a vine (or a basket of fruits) and in the other hand ears of corn. The statues in the round comprise one head with curly hair to the shoulders and a youthful figure standing near an altar with a short tunic, and a cloak reaching over his shoulders. He holds in his left hand ears of corn and in his right fruit. A probable statuette of the god, a youthful figure in frontal view, but without an inscription naming him, was found in the grounds of Villa Aldobrandini. It is similar to representations on gems which show him in profile.

The plaque was acquired for the Townley Collection in the late 18th century. Charles Townley (1737–1805) was a collector of Roman sculpture of major importance. Educated at Douai (Paris) he succeeded to the family estate while still a child, returning to England to claim his inheritance in 1758. He started collecting in Italy in 1768 and had formed the core of his collection by 1773 (Cook 1985); while he did not return to Italy after 1777, he continued to collect until his death, when his collection was purchased by the British Museum (Wilson 2002). Most came to the Museum in 1805 but the *Bonus Eventus* plaque was part of a second group which reached the Museum in 1814.

The entry in the manuscript catalogue of the Townley Collection states 'Bonus Eventus B:R [i.e. bronze]: in imitation of lapis lazuli came from the Museo Sabatini in Rome' (Townley Collection ms). The catalogue represents the collection *c*. May 1785 – May 1786, but many of the leaves were written earlier and the *Bonus Eventus* plaque was evidently acquired from the Museo Sabatini in Rome before 1782.

Although it is said here to be of bronze in imitation of lapis lazuli, a number of 19th-century authors identify the material of the plaque as lapis. For example, Taylor Combe in a preface, written 7 November 1817, to his book *A Description of the collection of ancient marbles in the British Museum* Part III (1818) says

> The substance which this bas-relief is engraved, is an argillaceous stone of a rich blue colour, sprinkled with white spots, and sometimes with grains of pyrites. It was known to the ancients by the name of sapphire, and also by that of cyanus; they frequently used this substance to engrave upon, (though from its softness it is ill adapted for the purpose,) and in general their engravings on this stone are of a very inferior degree of excellence. The present specimen is by far the best, as well as the largest piece of sculpture on lapis lazuli, with which we are acquainted.

Reinach (1912, 462) still considered the plaque to be made of lapis lazuli. However, Wallace-Dunlop (1883, 182) had earlier inferred that it was glass and Dillon, five years before Reinach, wrote

> When the glass paste, in a fluid or semi-fluid condition, is pressed into a mould, we have a simple method for making either imitations of cameos and intaglios or again small articles of *verroterie* … The large plaque of this blue paste, inscribed BONO EVENTUI, seems to have been finished with a tool, but we cannot look upon it as throughout the work of the sculptor (Dillon 1907, 56).

Already in 1889 Friedrich Hauser had considered the plaque a fake, but he identified the figure as Hermes and stated it to be made of lapis lazuli. This interpretation was repeated by Amelung (1908) but the material is not stated. Amelung showed a relief (1908, 631–6) showing Hermes on a candelabrum which is very similar to *Bonus Eventus*

TABLE 1 COMPOSITION OF THE BONUS EVENTUS PLAQUE AND COMPARATIVE GLASSES

	1 Bonus Eventus Plaque Bulk	**2 Plaque feature 1 (typical area)**	**3 Plaque feature 2 (typical area)**	**4 Roman tesserae (n=7)**	**5 Smalt (n=8, Ciliberto)**	**6 Smalt (Middleton & Cowell)***	**7 Smalt (Gratuze)**	**8 Tassie glass paste (Viles)**
SiO_2	62.9	64.7	57.7	64.19	71.30	67.0	63	49.26
TiO_2	<0.1	<0.1	<0.1	<0.10	0.21	ND	NR	NR
Al_2O_3	1.6	0.7	0.8	1.99	0.57	1.2	1	**
FeO	2.6	3.1	2.7	0.92	2.25	1.0	1.4	0.5**
MnO	<0.1	<0.1	<0.1	0.85	NR	NR	NR	NR
MgO	<0.2	<0.1	<0.1	0.57	2.22	0.4	0.3	NR
CaO	1.0	0.7	1.07	6.97	4.03	1.0	2	2.17
Na_2O	0.3	0.3	0.4	15.46	0.84	0.8	0.3	0.88
K_2O	13.2	13.9	13.9	0.62	12.01	14.3	17	10.40
P_2O_5	<0.2	<0.2	<0.2	<0.10	NR	ND	NR	NR
CoO	3.2	4.06	3.4	0.25	1.91	1.7	1.3	NR
As_2O_3	6.3	8.1	7.8	<0.30	2.69	5.3	2.6	3.08
SnO_2	0.7	<0.5	<0.5	<0.30	NR	ND	NR	NR
PbO	5.9	2.5	10.0	2.26	NR	ND	NR	33.54
NiO	0.7	0.8	0.7	<0.10	0.61	PR	2	NR
Bi_2O_3	1.1	1.1	1.2	<0.10	0.93	ND	NA	NR
Cl	0.2	0.1	0.2	0.62	NR	0.3	NR	NR
Sb_2O_3	<0.3	<0.3	<0.3	4.46	NR	ND	NR	NR

* Smalt of Middleton and Cowell also contains 6.9% BaO; **Al_2O_3 and Fe_2O_3 reported together
NR = Not reported; ND= Not detected, in practice typically less than 0.2%; NA = not analysed, PR= present, not quantified

and from which the plaque may have been copied. Also mentioned are two mosaic reliefs in Naples, one of which is illustrated by Kurz (1962) who, pointing to a series of 18th-century recipes that describe how to imitate *lapis lazuli* (Bonanni 1720), states firmly that the plaque is not ancient, but is made of granular stone covered by a thick layer of blue paint.

The plaque was included in the exhibition *Masterpieces of Glass* (Harden *et al.* 1968) as a genuine Roman glass object of the 1st century AD, but not in *Glass of the Caesars* (Harden *et al.* 1987). In 1986 it was excluded from the *Bonus Eventus* entry in *LIMC* so it must have been queried at that time. However, in *Five Thousand Years of Glass* Hugh Tait (1991) writes under 'Faking'

> Surprisingly, there has even been a reappraisal of the famous 'Bonus Eventus' plaque ... the result of recent scientific test have been inconclusive, even though they have revealed a slightly unusual composition ... Therefore, until further tests have been carried out ... it is too early to cast any doubt on its genuineness.

However, by the time of the first paperback edition of *Five Thousand Years* (Tait 1995) it was recognized as a clever pastiche or fake, following the initial interpretation of the chemical analysis reported here.

STRUCTURE AND COMPOSITION

The plaque measures 180 x 180 x 9mm. The relief appears to have been initially moulded, but was enhanced by cutting, engraving and polishing, as revealed by tool marks around the figure and undercut features which cannot have been the result of moulding alone. The front is opaque blue with irregular yellowish-white flecks and patches. Four small patches of bright blue glass without flecks have been inserted in damaged areas, two just above the bottom right-hand corner of the plaque, on the right buttock, and on the left lower wrist (COLOUR PLATE 124). Several hair-line cracks are visible.

The back of the plaque is matt and the original surface is discoloured, as if weathered. The back surface is wrinkled in places, with an appearance rather like the skin on hot milk which has been chilled. A large area in the centre has spalled off, revealing a fresh deep blue material with a matt hackly surface. Deep shrinkage cracks are prominent but most of them do not pass right through the object. No yellowish-white flecks are visible on the back, nor on the sides of the plaque, indicating that they are a feature of the front surface only.

The flecks on the front face of the plaque were analysed with a Raman microscope, and found to be composed predominantly of quartz.

A small sample was removed from the back of the plaque and analysed by energy dispersive X-ray analysis in the scanning electron microscope. TABLE 1 (column 1) provides the 'bulk' analysis of the plaque, which was carried out by scanning the SEM beam over a polished sectional area of several square millimetres; instrumental accuracy and precision are discussed by Freestone *et al.* (2000).

The plaque is essentially a potash-silica glass, containing 13.2% potassium oxide, K_2O. However, it has a complex composition and also contains a range of other components including lead and tin oxides (5.9% PbO and 7% SnO_2). Tin oxide is an opacifier, which was typically added to glass in the presence of excess lead. The colorant responsible for the blue is cobalt (3.2% CoO), and associated with it are the oxides of nickel (0.7% NiO), arsenic (6.3% As_2O_3), bismuth (1.1% Bi_2O_3) and iron (2.6% FeO), all of which can be associated with cobalt ores. Also present are minor amounts of alumina and lime.

The microstructure of the glass is shown in the SEM image (FIG. 1). Four main types of feature may be observed:

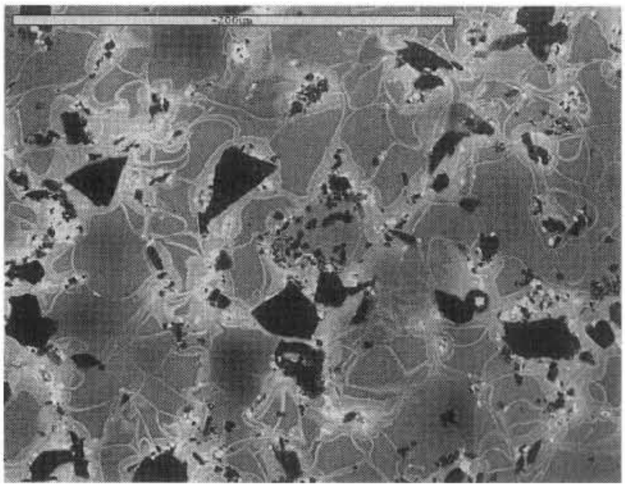

FIG. 1 Microstructure of the plaque, seen in the scanning electron microscope. Scale bar is 200 μm.

1 The bulk of the sample comprises grains around 50μm (0.05mm) across of a glass that appears mid-grey in the image. These have sinuous boundaries, outlined in pale grey. This glass is close to the bulk composition but has lower lead and very low tin (TABLE 1, col. 2).

2 The second feature is a glass that appears a pale grey. It occurs in patches and also forms boundaries around the grains of the first glass. It has a similar composition but has an enhanced level of lead oxide, to typically around 10% (TABLE 1, col. 3).

3 Associated with the lead-enriched areas are the bright white specks, which comprise grains of tin oxide.

4 Finally, the large dark angular areas appear to be mainly fragments of potassium feldspar, a mineral with the formula $KAlSi_3O_8$, with some silica-rich grains (probably quartz).

This microstructure appears to have formed from a mixture of a translucent deep blue cobalt-bearing potassium silicate glass, calcined lead-tin oxides and a material rich in feldspar and quartz. These three components were milled and pressed into a sand or sand-clay mould to take the impression of *Bonus Eventus*. They were then heated, possibly being pressed from time to time to force the glass into the mould. At a relatively low temperature, the lead oxide began to react with the potassium silicate glass, to form a low melting potash-lead-silica glass. This low melting glass, seen as the pale grey areas in the micrograph, behaved effectively as a lubricant. As the material was heated and pressed into the mould, the lead-rich glass flowed around the other particles, forming the bright boundaries seen. Unlike the lead, the tin oxide did not melt or react with the glass, and remained concentrated in the original lead-tin rich areas. Similarly, the feldspar did not react strongly with the lead oxide, and remained as hard, angular particles.

The quartz which comprises the yellowish-white flecks on the surface of the object may represent material incorporated from the mould or a release agent. Thus, while the flecks help to emulate lapis lazuli, their presence may be an incidental result of the moulding process.

DATE OF MANUFACTURE

TABLE 1 compares the composition of the plaque with those of a number of other glasses. There are clear differences between the plaque and typical opaque blue Roman glass, for example mosaic tesserae (TABLE 1, col. 4). Roman glass is typically high in soda and low in potash, in contrast to the plaque. Furthermore, Roman glass was typically opacified with compounds of antimony, whereas the plaque contains not antimony but tin. Other differences include the lower lime content of the plaque as well as its high arsenic content. To our knowledge, high arsenic has not been reported from any Roman glass, even those coloured with cobalt. Thus the possibility that the plaque might be Roman can be dismissed on virtually every aspect of its composition, which is completely at variance with that of Roman glass.

The plaque is very unusual in its high silica and potash and low lime. Potash-rich glasses were, of course, characteristic of the medieval and early post-medieval periods in Europe, but these were also rich in lime, typically containing well in excess of 10% CaO, whereas the plaque contains only 1%. Furthermore, relative to most deep blue glasses, the contents of cobalt and related elements are very high. Cobalt rarely exceeds 0.5% in transparent blue vessel glass, for example. However, the composition does resemble that of smalt, the cobalt rich glass made from the roasted ore, which was used as a pigment in painting or added as a concentrated colorant to glass and glazes, and which was the form in which cobalt pigment was typically traded in the post-medieval period.

With the exception of its contents of lead and tin, which were added to opacify the glass, the plaque compares well with grains of smalt used as pigment on a bas-relief in Sicily, dated to 1506, and analysed by Ciliberto *et al.* (1994) (TABLE 1, col. 5). Similar smalts have been analysed from a mid 18th-century English porcelain factory in Staffordshire (TABLE 1, col. 6: from Middleton and Cowell 1993 – note that this example contains 6.9% barium oxide, not shown here), and also from Sainte Marie-aux-Mines in France (TABLE 1, col. 7: Gratuze *et al.* 1996). The similar potash-silica base glasses and comparatively high contents of cobalt and associated elements, such as nickel, arsenic and bismuth in these glasses indicate that the blue glass used as the major component of the *Bonus Eventus* plaque was essentially a pure smalt, which had not been diluted with window or vessel glass.

Gratuze *et al.* (1992; 1995; 1996) observe that cobalt associated with nickel and arsenic was the dominant type used in Europe from around AD 1500 on. The inter-element ratios of cobalt, nickel and arsenic in the *Bonus Eventus* plaque fall within the range of glasses of this type analysed by these authors. They attribute this cobalt to a source in the Schneeberg district of Germany, where exploitation of cobalt is recorded as beginning in 1520. Bismuth is also associated with the Schneeberg ores. By the time the plaque was acquired, other mines were producing similar cobalt, for example, at Bieber in Spessart, cobalt-nickel-arsenic ores with bismuth were being exploited between 1731–1869 (Wagner and Lorenz 2002). The use of this type of cobalt ore firmly dates the plaque to later than *c.* 1500, when this pigment is first found in glass, ceramics and paintings.

Given that the plaque postdates the medieval period, it was most probably made to satisfy the growing demand for antiquities from rich collectors in the 18th century, shortly before it was acquired for Townley. It is therefore likely to have been intended to deceive.

The craftsman

Lead and tin oxides are not characteristic of smalt and these appear to have been added separately to the plaque to opacify the glass and to lighten the colour. As has been seen, the lead had the added advantage of softening the glass and making the plaque easier to cast. Feldspar and quartz were not widely used as opacifiers in glass at this time. However, closely similar particles have been observed in a significant number of tin-opacified lead-rich glazes on Italian maiolica pottery (Tite 1991; Viti *et al.* 2003). They appear to be grains of *marzacatto*, which was a material added to maiolica glazes and which, according to the 16th-century writer Piccolpasso (1980), was produced by reacting sand with calcined wine lees (potassium tartrate). Smalt was also widely used to colour pottery glazes. Thus, taken together, the materials of the plaque are those closely associated with the manufacture of Italian maiolica, rather than glass. They suggest that the plaque was made in Italy using potter's materials. The perception of the plaque as a 'Masterpiece of Glass' (Harden *et al.* 1968) is therefore somewhat misleading, even though the plaque is glassy.

The quality of the casting also argues against the involvement of a skilled glassworker in the production of the plaque. It is slightly distorted, shows extensive shrinkage cracks, has a large spall which has broken off on the back and repairs inserted in the front. Whether the maker was a potter by profession, or simply had access to pottery raw materials, is unclear. However, he clearly was not skilled in the manipulation of the material in the way used to produce the plaque.

It should not be a surprise to learn that the maker of the *Bonus Eventus* plaque was not a glassworker. After all, James Tassie, who specialized in producing glass imitations of Roman gemstones in glass in London in the late 18th century, did not have a background in glassmaking. Tassie was said to have developed a special vitreous paste, made according to a secret formula for his work. However, a late 19th-century analysis of the paste reported by Viles (1968) and reproduced here in Table 1, col. 8, reveals a standard English potash-lead glass of the period, containing some arsenic which was commonly used as an opacifier at that time. The lead-rich formulation would have produced a fluid glass, easy to cast, but skills in the formulation of glass compositions would not appear to be a requirement of this type of work. The quality of the Tassie medallions would appear to have resulted from the quality of the moulds, and the skill in casting.

The plaque was clearly finished by lapidary work. However, the distribution of the thin layer of quartzose flecks and patches on the front surface of the relief indicates that the primary shaping was due to the mould in which the object was cast, and that over most of the object relatively minor amounts of material were removed by cutting.

Changing perceptions

As the understanding of the material of the plaque has evolved, it has been evaluated as a bronze, as 'by far the best, as well as the largest piece of sculpture on lapis lazuli, with which we are acquainted', as a 'Masterpiece of Glass' and a as 'a clever pastiche or fake'. However, the results of the present examination demand that a further issue be considered. Were the features that gave the object credibility as a piece of lapis lazuli, such as the repairs, cracks and pale flecks originally intended by the maker? Does the plaque represent a clever or outstanding example of a faker's work, or were some of the most convincing features the result of lucky accident, rather than design? Once again our changing understanding of the material is challenging our perception of the object and those who made it.

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TOWARD AN UNDERSTANDING OF NINETEENTH-CENTURY IMITATIONS OF MAMLUK ENAMELLED AND GILDED GLASS

STEFANO CARBONI AND JULIAN HENDERSON

INTRODUCTION

This paper was prompted by our co-operative efforts in compiling a catalogue of Mamluk enamelled and gilded objects in the collection of the National Museum of Qatar (Carboni 2003). Among the objects we studied, three in particular were eventually excluded from the catalogue because they are most likely either late 19th or early 20th-century imitations or straightforward forgeries of original Mamluk objects. Part One of this joint paper deals with the art historical aspects and the known history of these three objects as well as of others that could belong to the same groups. Part Two focuses on the technology of Mamluk glass and on its chemical composition vis-à-vis 19th-century objects.

We would like to emphasize from the start that we are not inevitably condemning all the pieces we discuss in this paper as imitations or forgeries, but we simply intend to isolate them as priority subjects for an investigation in this field, the study of which is still in its infancy. The art historian has more doubts than certainties at this stage whereas the scientist's interpretation of 'objective' scientific data is more straightforward, but we both feel that it is important to make a common effort to separate grain from chaff in order to achieve a better understanding of a phenomenon that began as a worthy technical and artistic challenge in the latter part of the 19th century and later turned into an exploitation of the newly acquired knowledge for the purposes of profit. But even if forgery was never intended and these objects were fairly marketed as modern imitations when they were produced, poor records and the passage of time have unfortunately muddied the waters, so that the modern student is faced with the formidable challenge of differentiating between the medieval and the modern productions. In many instances the two productions are so similar under close visual scrutiny that even the best 'curator's eye' can be inadequate.

The known history of an object can be very helpful in determining its authenticity. Unless contradictory, ground-breaking information on 19th-century glass production comes to light, a safe *post quem* date can be placed around 1865, the time when Brocard and Salviati began to proudly present their technological and artistic achievements at the World Fairs. Thus, objects for which some scholars have raised eyebrows because they are atypical of the known Mamluk production are instead perfectly safe, as corroborated also by scientific investigation.

PART ONE

One of the three objects in Qatar under consideration is a large basin with a wide flaring rim, a shape often described as that of a spittoon (COLOUR PLATE 125). Unknown until recently, it appeared at auction in 2001 as having belonged to Emanuele Filiberto of the Italian royal family of the Savoia (d. 1931) and then to a European family (Sotheby's 2001, lot 97). Sold as Mamluk, it was hailed as a companion piece to the celebrated Cleveland Basin (inv. no. 1944.235; Hollis 1945; Carboni and Whitehouse 2001, 272–3) (COLOUR PLATE 126) to which it is virtually identical in shape, dimensions, decoration, and colours. However, scientific investigation surprisingly suggested that the Savoia Basin was modern.

The obvious question is, of course, whether the Cleveland object, which no one has questioned thus far, and which was recently included as an original Mamluk piece in the *Glass of the Sultans* exhibition, should be re-evaluated. In attempting to trace the history of the Cleveland basin it was impossible to document it prior to 1913. Pierpont Morgan acquired the basin some time before his death in 1913; his son lent it to the Metropolitan Museum from 1925 to 1944 when Morgan's entire estate was put up at auction from where the Cleveland Museum acquired it (Parke-Bernet 1944, lot 120). A mystery, however, surfaced from the research and remains unsolved. In 1930 the Detroit Museum of Art included in an exhibition a basin described as having the same appearance and dimensions; the New York dealer Gabriel Demotte owned the object, or had it on commission, and lent it to the exhibition (Detroit 1930, 40). Since the Cleveland Basin was Morgan property and on view at the Met in 1930, and the Savoia Basin was supposedly in Europe all this time, it may be surmised that there exists (or existed) a trio, rather than a pair, of identical basins, one of which, perhaps, provided the original model.

The second enamelled and gilded vessel in Qatar is a tall footed bottle (*c.* 450mm in height; inv. no. GL.07.97) in brownish glass, with a large inscriptional band around the body (COLOUR PLATE 127). At first sight its enamels and surface condition are quite convincing in suggesting a Mamluk attribution but some doubts were raised during investigation regarding the quality of the calligraphy and the shape of the neck. The neck is larger and less elegant than on the majority of bottles, where the ring is usually placed near the mouth making the neck graciously flared above it. Scientific tests on the body and the enamels confirmed our suspicions and we consequently removed the object from the catalogue.

To date, four more bottles seem to belong to this group of objects with a tall foot, bulging neck, a broad inscriptional band, coloured trefoil patterns, and narrow, sketchily decorated bands. The most convincing object, because of its more complex and accomplished inscription, is also in Cleveland and was acquired in 1944, the same year as the basin, after having belonged to the dealers Dikran Khan Kelekian and Hagop Kevorkian (inv. no. 44.488; Hollis 1945). It is as tall as the bottle in Qatar, but its decorative programme, including also a phoenix that encircles the neck, is more refined than the others in the group. For this reason, the Cleveland bottle is the best candidate to be the model for the group, if a model indeed existed.

Two almost identical bottles of smaller dimensions (height 280mm) with no ring around the neck but with a similarly bulging profile and general shape are in the Metropolitan Museum and in the Khalili Collection in London. The former entered the New York collections in 1925 as an anonymous gift and was catalogued as a 19th-century French forgery (inv. no. 25.126). No records exist as to the reason why the donor, a dealer himself, considered it a modern piece. Most likely he acquired it through a short chain of ownership that could be traced back to the maker himself. That the bottle is suspicious was confirmed by Lisa Pilosi in the Objects Conservation Department of the Metropolitan Museum, where it was pointed out that the absence of a pontil mark and the density of the enamels at the bottom of a given area suggest that the firing occurred as a static process inside a kiln. As far as is known, Mamluk pieces were typically fired on the pontil by slowly spinning them at the glory hole.

The Khalili bottle (inv. no. GLS 172) was unrecorded before it was bought at auction in 1988 but it has been published as an original 14th-century piece without having been compared to the Met object (Christie's 1988; Piotrovsky and Vrieze 1999, 203). As a matter of fact, not only do the two bottles have almost identical dimensions, proportions and decorative programmes, but they also share the absence of a pontil mark. A thorough investigation of the Khalili vessel would therefore be timely.

A third very similar bottle was acquired in 1953 by the Merseyside County Museums in England from a private donor (inv. no. 53.114.448; Merseyside 1979, 36). Catalogued as 14th-century Syrian, we have not investigated the object directly but it has similar dimensions and decoration as the Metropolitan Museum and the Khalili Collection bottles. An interesting detail described in a catalogue entry is that 'the junction between body and foot is marked by a blue enamelled collar with a ruby glass insert in the interior'. Perhaps the cataloguer regarded it as a modern repair on an otherwise medieval object, but this ring instead seems to provide further proof of the recent manufacture of this bottle and may also offer a clue as to its manufacturer.

The third object in Qatar from this group is a mosque lamp of typical shape inscribed with the name of the Mamluk sultan Shaᶜban II (r. 1363–76), which was found to have a modern glass composition (inv. no. GL.05.97; COLOUR PLATE 128). This was a surprising result, since a similarly decorated bowl-shaped lamp of the same greenish glass colour and texture, has instead a composition in accordance with medieval parameters and was therefore included in the catalogue. Further research, however, confirmed that the Shaᶜban lamp finds close parallels in a few late 19th and early 20th-century objects. The lamp in Qatar is almost identical to another in the Museum of Islamic Art in Cairo (inv. no. 267; Schmoranz 1898, fig. 48; Wiet 1929, 7–8), which was removed in the late 19th century from the *madrasa* of Sultan Barquq (r. 1382–99; the building was finished in 1386) – that the lamp was found in a building dedicated to a close predecessor of Shaᶜban but of different lineage is an unusual, suspicious occurrence. Prince Yusuf Kamal commissioned for his palace in Cairo a third lamp, now in the Gazira Museum, at the beginning of the 20th century; most likely one of a series, it was reportedly made in France in the early 20th century (inv. no. H107; Carboni 2003, 53).

These three lamps can be better attributed by comparing them to another one in the Khalili Collection, which is dated by its Arabic inscription to 1910 and carries the name of the Egyptian khedive ᶜAbbas Hilmi II (r. 1892–1914). Stephen Vernoit suggested that this lamp was one of a series made for the imposing mosque al-Rifaᶜi, completed in 1912 and designed by the Austrian architect Max Herz Bey who was also the director of the Museum of Islamic Art in Cairo at the time (Vernoit 1997, 234–5). Vernoit pointed out its similarity to the lamp in the name of Shaᶜban in Cairo and surmised that the latter might have provided an Austrian or Bohemian glassmaker the model for producing the khedive's series. It is more likely, however, that the entire group, including the Cairo Museum lamp, was made in the same European centre over a number of years. Mosque lamps were the most commonly imitated enamelled and gilded Islamic glass vessels in modern Europe and it has become particularly urgent to make an effort to distinguish between the two productions.

Part Two

The manufacture of glass during the Mamluk period is thought to have involved the combination and melting of two primary ingredients – silica, in the form of ground-up quartz pebbles, and plant ash which would also introduce the calcium oxide component (Brill 2001; Henderson 2000, 84). The introduction of lead oxide to a translucent glass occurred in the 19th century and later.

Chemical analysis of the objects in the Doha collection was performed using electron-probe microanalysis (Henderson 2003, 29). Micro-samples of both the body of the vessels and of differently coloured enamels used to decorate the vessels were removed, mounted in an epoxy resin block and polished so as to remove any weathering (Henderson 1988). The results were quantified using geological and Corning glass standards (Goodhew *et al.* 2001, 200). Rather than provide the results of the individual vessels described in Part One, a global comparison of Mamluk and 19th-century glass vessels in the Doha collection will be presented here. In this case the three vessels discussed in Part One all fall into a definite technological tradition.

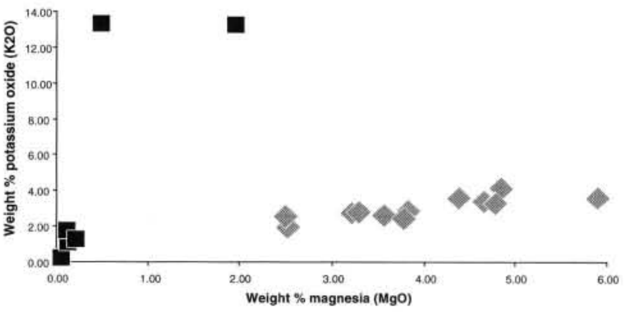

FIG. 1 A bivariate plot of wt% magnesia (MgO) *versus* wt% potassium oxide (K_2O) in 12th to 14th-century Mamluk vessel bodies (lozenges) and 19th-century vessel bodies (squares)

The first subject to be discussed is the chemical compositions of the bodies of the mosque lamps. A comparison of the chemical analyses of Mamluk and of 19th-century vessel bodies shows quite clearly that it is easy to distinguish between the two productions using the relative levels of magnesium and potassium oxides (FIG. 1). Mamluk and 19th-century glasses have different magnesia:potassium oxide ratios. One reason for this is that magnesia, as well as potassium oxide, are impurities found in the plant ash used to make the glass. On the other hand, the 19th-century mosque lamps contain either minimal levels of magnesia or high levels of potassium oxide. Nineteenth-century glassmakers apparently used a pure mineral source of soda with low impurities of magnesium and potassium oxide (Freestone 1998, 126). In addition, they appear to have used a second kind of flux, potassium oxide, probably in mineral form. This has also been found in 'modern' Venetian copies of Roman glass vessels (Page *et al.* 2001, 134, table 2). High levels of potassium oxide have never been detected in Mamluk glasses. So, as one might hope, it is clear that quite distinct kinds of raw materials were used to make the bodies of the Mamluk and the 19th-century vessels.

The vessel bodies of the basin, the bottle and the lamp described in Part One were made from a soda-lime-silica glass using rather pure raw materials which have introduced low impurity levels and therefore fall into the 19th-century group. All three vessels also contain a low impurity of arsenic, which is not found in ancient faintly tinted translucent glasses and is therefore another indication of a more recent production date (TABLE 1).

The relative levels of sodium and potassium oxides in the glasses and enamels decorating them is a reflection of the alkali types used. Firstly, the pale-green 19th-century bodies of the vessels contain lower potassium oxide than the Mamluk vessels. Secondly, the opaque red, blue, and white Mamluk enamels contain higher soda levels than their 19th-century equivalents. This compositional difference alone distinguishes between the medieval and 19th-century enamels. A fundamental reason why the basic compositions of the Mamluk and of the 19th-century enamels are different is that the Mamluk enamel makers added colorants to the same basic glasses as they used to make the vessel bodies, whereas 19th-century glassmakers added colorants to quite a different glass than that used to make their vessel bodies – a basic lead oxide-silica glass. The result is that the 19th-century lead-rich enamels contain negligible soda levels compared with Mamluk enamels.

TABLE 1 A COMPARISON BETWEEN THE CHEMICAL COMPOSITIONS OF EXAMPLES OF MAMLUK AND 19TH-CENTURY TRANSLUCENT GLASSES

	Mamluk glass	C19th glass
Na_2O	11.69	3.8
MnO	0.8	3.84
SO_3	0.14	0.3
K_2O	4.13	13.2
MgO	4.86	1.97
FeO	0.33	0.16
SnO_2	nd	nd
Cl	0.7	0.13
As_2O_5	nd	0.27
CoO	nd	nd
CaO	7.85	6.43
PbO	nd	nd
Al_2O_3	1.24	0.87
NiO	nd	nd
Sb_2O_5	nd	nd
BaO	nd	0.06
SiO_2	65.4	66.76
CuO	nd	0.05
TiO_2	0.08	nd
Cr_2O_3	nd	0.06
P_2O_5	0.27	0.2
ZnO	nd	0.14

Note: the principal alkali used in the19th-century glass is potassium oxide (K_2O) and in the Mamluk glass is soda (Na_2O). The 19th-century glass is further characterized by the presence of arsenious oxide (As_2O_3)
nd=not detected

The relative levels of two major ingredients – calcium and silicon oxides – indicate that Mamluk glasses mainly contain higher calcium oxide levels than in the 19th-century enamels and glasses. It is also worth noting that many of the 19th-century vessel bodies have higher silica levels than the Mamluk glasses, thus conferring a higher melting temperature on the glasses.

Yellow enamels, however, do not conform to the expected compositional pattern by their association with either Mamluk or 19th-century vessels. It is also apparent that there are some similarities between the compositions of Mamluk green and yellow enamels and that most red and blue enamels contain higher silica and calcium oxide levels than found in the green and yellow enamels. The reason for these characteristics is that the basic opacifier used in many Islamic enamels (in the form of tiny crystals) is tin oxide (Henderson and Allan 1990; Freestone 1998, 125; Henderson 2003, 30, fig. 1). By itself tin oxide produces opaque white enamel. When combined with lead it produces a complex crystal, lead-tin oxide, which is an opaque yellow colour. If copper (cupric oxide) is added to the yellow enamel, an opaque green enamel results. Thus, with the addition of lead oxide to the enamels one can see why opaque white, yellow and green enamels are related compositionally; they are united by the presence of tin oxide and elevated lead oxide levels. The 19th-century white enamels tested were found to be opacified with lead arsenate and traces of antimony in some, but no tin oxide was detected at all. Opaque green 19th-century enamels were opacified either by lead arsenate or by calcium antimonate. It is therefore clear that different raw materials were used to colour and opacify white and green enamels in the 12th–14th and 19th centuries.

Returning to the red and blue enamels, the compositional characteristic that unites Mamluk opaque red and blue enamels (when compared to white, green and yellow) is a lack of lead oxide. An iron-rich mineral was used to produce red enamel; for blue enamels, ground lapis lazuli was added to the base glasses in all cases (Freestone 1998, 123, fig. 27.1; Henderson 2003, fig. 2). The result is that there are elevated levels of silica and calcium oxide in almost all Mamluk red and blue enamels because no lead was present in the colorant compound used. In contrast to the Mamluk enamels, 19th-century blue enamels are coloured by an excessive amount of cobalt rather than lapis; the only 19th-century red enamel that was tested surprisingly was found to be opacified with cuprous oxide. It contained impurities of arsenic, barium and antimony oxides, impurities not normally found in Mamluk enamels.

A close investigation of the five yellow samples, all but one of which should be of a Mamluk date, shows some interesting features that provide us with clues as to their date of production. Firstly we have established that all Mamluk yellow enamels should be opacified with lead-tin oxide, whereas the 19th-century enamels all appear to be opacified with lead antimonate. Secondly, the yellow enamel with the highest lead and lowest calcium oxide has an arsenic impurity and is almost free of other impurities. However, two out of the three enamels containing between 0.5% and 3% calcium oxide from Mamluk lamps also contain 'modern' impurities of arsenic and zinc oxides. These two enamels with 'modern' impurities could therefore be more recent additions to the lamps; one of these two vessels had an enamelled base added in the 20th century, so this would have been an opportunity to touch up the original. So we seem to be able to provide an explanation for the unusual yellow enamel compositions that do not fit exactly the established distinction between Mamluk and 19th-century enamels.

Overall, these results show a clear distinction between the Mamluk and the 19th-century vessels. Even though the bodies of both sets of vessels have the same basic soda-lime recipes, the associated impurity levels reveal clearly that purer raw materials were used to make the 19th-century vessels. The compositions and colouration of the enamels are also quite different in the two periods of production. One reason why such clear distinctions are apparent is that Islamic glass and enamel makers generally used well-defined recipes to make both the translucent vessels and each enamel colour.

Conclusion

As remarked at the beginning, we are not stating that every object mentioned in this paper is modern, but that certain assumptions as to their identities should be questioned and thoroughly investigated by curators, conservators and scientists alike. It is true that collections may end up being poorer after such a focused study. What comes to my mind is an Italian proverb, *mal comune mezzo gaudio* – a trouble shared is a trouble halved.

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FRANCESCO SIBILIO AND THE REUSE OF ANCIENT ROMAN GLASS IN THE NINETEENTH CENTURY

Martine S. Newby

In the last 20 years a number of 19th-century tabletops inlaid with a veneer of reworked fragments of ancient mosaic glass, at times combined with coloured marbles, have appeared on the art market. Six of the nine known published pieces (see Appendix at the end of this paper) may be assigned to the Roman marble craftsman and merchant Francesco Sibilio. Surprising little is known, however, about the life and work of this great master who was active in Rome during the second quarter of the 19th century. The only study devoted to Sibilio's work is a short article written by Alvar Gonzalez-Palacios in *Casa Vogue Antiques* in March 1991 that was subsequently reprinted with fewer illustrations in 1997.

Francesco Sibilio was a Roman marble craftsman (*marmista*) and dealer of antiquities, possibly even a *maestri* in the Reverenda Fabbrica di San Pietro. He catered to the fashion for collecting specimen marbles, semi-precious and hard stones, which were mounted in cabinets or inlaid into marble tabletops. These tabletops with geometric designs were a speciality of Roman workshops, probably due in part to the plentiful supply of interesting archaeological marbles as well as wealthy potential customers visiting the city while on the Grand Tour. Sibilio also produced objects made of semi-precious stones like two skilfully carved columns 0.3m high in malachite and lapis lazuli, inspired by those of Trajan and Marcus Aurelius, which he signed and dated 1833 (Gonzalez-Palacios 1991, 84, illus.).

The golden age for the study and collection of specimen marbles was the first half of the 19th century (Gnoli 1971, 81–3). The English archaeologist and traveller, Edward Dodwell (d. Rome 1832), formed an important collection of ancient and modern marbles that was bequeathed to the Università della Sapienza by his widow. Dodwell personally knew the three foremost dealers and collectors of the day: Faustino Corsi and two brothers, Tommaso and Francesco Belli. Tommaso also left his collection to the Sapienza and it is from the manuscript tickets for individual marbles from these two collections that we find Francesco Sibilio being frequently mentioned as their supplier. When Francesco Belli eventually sold his collection together with a catalogue to Count Stefano Karolyi he named three stones specifically after Sibilio. The first, *Granito Mischio di Sibilio* (Belli 1842, no. 10), was known from a column fragment acquired by the 'valente petrajo Signor Francesco Sibilio' from the river bank by the Porto di Trajano, from which he made 'un grand lagrimatorio, ed una bella tazza con manichi di oltre 3 palmi di diametro.' The next was, *Porfidi Bigio di Sibilio* (*ibid*, no. 63), of which 'il Sig. Francesco Sibilio ne possiede un frammento di colonna proveniente da alcuni scavi fatti nel 1838 presso la basilica di S. Paolo' and lastly, *Lumachella Rossa di Sibilio* (*ibid*, no. 286).

Francesco Sibilio himself collected a variety of antiquities not just marbles – the Vatican, for example, acquired his collection of over 400 ancient coins. As the first known craftsman who combined fragments of ancient glass with specimen marbles he must either have collected or had access to collections of such fragments. Certainly during the 19th century large collections of fragmentary ancient glass were formed by both European and American collectors (*cf.* Saguì 1998 for pieces in the Gorga Collection in Rome). According to David Grose (1989, 243–4) the vast majority of those in the Toledo Museum of Art collected by Charles Coleman may be traced back to antiquity dealers in Rome. These dealers acquired them locally and enhanced their market value by repolishing their surfaces before wrapping them in cardboard mounts with gilded edges like precious gems and cameos. Other fragments were repolished and mounted in gold and used in jewellery or set into smaller marble objects like paperweights (J. Raccanello, pers. comm.). Bracelets were especially popular, like the example illustrated in COLOUR PLATE 133 and another with nine rectangular sections flanked by hemispherical sections at both ends set with ancient mosaic glass that appeared on the BBC Antiques Roadshow in 1998 and was later sold at Phillips (1999, lot 18).

In the Victoria and Albert Museum among a collection of 1152 ancient glass fragments, purchased from F. Turchi in Rome in 1885 for a total of £317. 16s. 4d., are two mosaic glass disks. These are *c.* 57mm in diameter, and are also made from reworked fragments of ancient mosaic glass and set onto clear glass backs (R. Liefkes, pers. comm.). It is unclear whether they were made as furniture inlays or as souvenirs of ancient glass in their own right.

All the mosaic glass fragments in these tabletops are of ancient manufacture, mostly dating to the 1st century BC/1st century AD. Some of them come from flat glass plaques or inlays often made in imitation of more costly marbles and banded semi-precious stones like porphyry or agate respectively. Other fragments, however, come from cast vessels, mostly bowls or dishes some of which had strongly curved walls. In the case of the vessel fragments it has not been possible to determine whether they have been gently reheated and pressed flat and then, once cold, cut into the desired shape as alluded to in a contemporary catalogue description of the tabletop now in The Corning Museum of Glass (COLOUR PLATE 132; App. no. 7; Governo Pontificio 1867, 107, no. 94). Alternatively, as ancient cast mosaic glass is generally quite thick it is possible that the fragments were ground flat, shaped and polished rather than being reheated. Close examination of the *guéridon* (COLOUR PLATES 130, 131; App. no. 6) has revealed that all the fragments were arranged in a circular metal tray that had previously been lined with a metallic foil. This would have had the effect of reflecting light back through the glass and so enhance its bright colours. At the present time it has not been possible to ascertain whether this method was also used for some or all of the marble examples. In the case of the bracelet illustrated in COLOUR PLATE 133 only the outer surface has been ground flat and polished; the side nearest the skin was left untouched and several of the fragments still bear traces of iridescence and light surface pitting.

There are two tabletops signed by Francesco Sibilio (App. nos 1 and 2) and dated 1823 and 1824 respectively. From stylistic comparisons etc, I believe it is possible to assign a further four pieces to his workshop (App. nos 3–6). For example, the central stylized six-pointed star filled with ancient mosaic glass against a background of glass *verde antica* (see COLOUR PLATE 129; App. no. 3) occurs on the tabletop dated 1824 (App. no. 2) and also on two of the unsigned tabletops (App. nos 3 and 4). In the case of App. no. 4, the mosaic glass is not contained within a thin band of contrasting opaque glass. The fifth example has a mask of a Gorgon in its centre surrounded by a wide band of mosaic glass. According to the Semenzato catalogue (1987, lot 169) this piece is signed by Sibilio and dated 1824 although this was not recorded by Christie's (1987, 123) and the signature is not visible in any of the illustrations. The outer bands with geometric motifs in monochrome glass on this tabletop, however, are almost identical to those on App. nos 2–4, while the circular band of mosaic glass with fragments arranged into two discernible rings also occurs on the *guéridon* (COLOUR PLATE 131, FIG. 1; App. no. 6).

The *guéridon* (App. no. 6) is more unusual in that only the roundel was probably made in Rome. Research by Johannes von Auersperg (pers. comm.) has revealed that the gilt-wood stand was most probably commissioned from a south-German workshop in the second quarter of the 19th century. The F-H-C monogram on the socle indicates that this piece was made originally for Friedrich, Prince von Hohenzollern-Hechingen and his consort, Princess Caroline Amélie, née Princess von Hohenzollern-Sigmaringen, possibly for the occasion of their wedding in January 1839.

While the previous six pieces may be assigned to the workshop of Francesco Sibilio, Giovanni Rossignani, a *maestri* in the Reverenda Fabbrica di San Pietro in Rome, is credited with the production of a tabletop now in The Corning Museum of Glass (COLOUR PLATE 132; App. no. 7). Rossignani's name appears at the head of the description of the tabletop in the catalogue of objects sent by the Vatican to the Paris International Exhibition of 1867 (Governo Pontificio 1867, 107, no. 94). The catalogue entry describes that the aim of this table was to display an exceptional collection of ancient glass fragments that had been subjected to 'the test of fire to level and smooth them'. They were then arranged into stars and concentric rows together with fragments of graduated 'ancient Etruscan' glass that imitates rare yellow marble, *giallo antico* (*ibid.*). It would appear that this tabletop is the only published

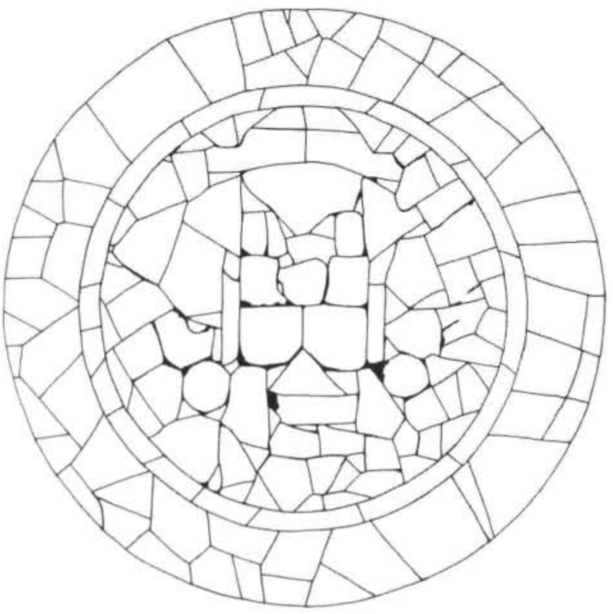

FIG. 1 Drawing showing the outlines of all the ancient glass fragments used in the top of the *guéridon* (no. 6). © Martine S. Newby

example attributable to Rossignani. The last two (App. nos 8 and 9) are of unknown manufacture and date, although an attribution to the third quarter of the 19th century seems justified. They were, however, almost certainly made in the same workshop, as they are identical except for the guilloche border and lozenge motif that appears on App. no. 9.

It is hoped that as more examples of these tabletops and other works of art by Francesco Sibilio and Giovanni Rossignani come to light it will be possible to ascertain more about the life of these two craftsmen and the relationship they had with the antiquities trade and the manufacturers of other 'Grand Tour souvenirs' that utilized fragments of ancient glass.

APPENDIX OF TABLETOPS INLAID WITH FRAGMENTS OF ANCIENT MOSAIC GLASS

The following appendix of nine tabletops and *guéridons* has been arranged in chronological order and according to probable manufacturer.

1 Specimen marble tabletop signed and dated by Francesco Sibilio, 1823

Circular tabletop made from porphyry, serpentine and monochrome opaque glass. In the central circle a parcel-gilt hexagon with curved sides and a star formed from thin intersecting black and red strap work, surrounded by four concentric bands of porphyry and serpentine filled with 72 radiating rays of contrasting marble or glass, in a portor border that bears the dated signature 'F. Sibilio 1823'.

Diam: 640mm

Provenance: Christie's 1994, lot 244; Christie's 1999a, lot 87 (unsold); Christie's 1999b, lot 128 (unsold); Christie's 2000, lot 267

Literature: Gonzalez-Palacios 1991, 86, fig. on p. 85; *ibid.* 1997, 98, fig. 50

2 Marble tabletop inlaid with ancient glass signed and dated by Francesco Sibilio, 1824

Circular white marble tabletop inlaid in the centre with a five-petalled motif within a rope-twist ring and a stylized six-pointed star filled with a garland of assorted ancient mosaic glass fragments all against a background of glass *verde antica.* Outside this are two bands of brightly coloured red, blue and yellow glass arranged in a classical wave and a geometric pattern and, finally, a band of ancient mosaic glass *verde antica* sandwiched between two white marble bands, the inner of which is inscribed 'F. Sibilio 1824'.

Diam: *c.* 850mm

Literature: Gonzalez-Palacios 1991, 86, figs on p. 86; *ibid.* 1997, 98, fig. 51

3 Marble tabletop inlaid with ancient glass in a star motif (COLOUR PLATE 129)

Circular white marble tabletop inlaid in the centre with a Romano-Egyptian inlay fragment surrounded by three thin rings composed of another Romano-Egyptian inlay with a wave pattern, red porphyry, and *reticelli* glass. A wider band composed of *verde antica* marble fragments outlined in opaque turquoise glass follows this. The same turquoise glass is also used to outline a six-pointed star filled with a garland of assorted ancient mosaic glass fragments against a background of glass *verde antica.* Outside this are three bands of brightly coloured yellow, red and blue monochrome glass arranged in geometric patterns and finally, a band of ancient glass *verde antica* sandwiched between two off white marble bands.

Attributed to Francesco Sibilio, Rome, *c.* 1825

Diam: 850mm

Provenance: Edric Van Vredenburgh Ltd, London

4 Marble tabletop inlaid with ancient glass in a star motif

Circular white marble tabletop inlaid with ancient polychrome mosaic and monochrome glass. A band of ancient green glass *verde antica* surrounds two formed of opaque yellow, orange, blue and red glass arranged in geometric patterns and separated by a thin rope-twist ring in opaque white and brown. In the middle a stylized six-pointed star filled with a garland of ancient mosaic against a background of glass *verde antica* and in the centre within a thin gilt band, glass *verde antica* and red porphyry and a Romano-Egyptian glass rosette inlay.

Attributed to Francesco Sibilio, Rome, *c.* 1825

Diam: 830mm

Provenance: Christie's 1992, lot 143

5 Marble and ancient glass tabletop with Medusa bust

Circular tabletop with in the centre a mask of a Gorgon, probably Medusa, set against an opaque sky-blue background, the hair and wings with incised feather detailing, the two snakes tied under her chin formed from ancient glass imitating *verde antica.* This is surrounded by a wide circular band composed of ancient mosaic glass fragments arranged in two rings and then two further bands of brightly coloured yellow, orange, blue, green and red glass arranged in geometric patterns and finally, a band of dark brown marble sandwiched between two of white.

Attributed to Francesco Sibilio, Rome, *c.* 1825

Diam: 675mm

Provenance: Christie's 1987, lot 123; Semenzato 1987, lot 169; Mansour Gallery, London

6 Guéridon with a top veneered with ancient mosaic glass (COLOUR PLATES 130, 131, FIG. 1)

The circular top is mounted in a gilt-bronze frame with two concentric outer rings made up of 57 fragments of glass imitating *verde antica* and 15 of *porfido rosso* respectively. The central ring comprises almost 100 fragments that fall into three main groups: Romano-Egyptian inlays mainly concentrated in the centre, each cut and arranged to form a mirror image; *reticelli* and striped mosaic vessel fragments and lastly, composite mosaic glass fragments (see FIG. 1 for pattern). The roundel supported on a gilt-wood column with acanthus-leaf decoration resting on three seated putti made of gilded plaster and set on a tripod base with bronze castors. The monopodium base with three rectangular panels decorated with the monogram 'F-H-C' in ligature surmounted by a royal crown.

The inlaid top attributed to Francesco Sibilio, Rome, *c.* 1825, and the gilt-wood stand to a south-German workshop, *c.* 1839

Ht: 925mm; diam: 282mm

Provenance: collection of the Princes von Hohenzollern-Hechingen; Rainer Zeitz, London

7 Marble tabletop inlaid with ancient glass by Giovanni Rossignani, c. 1866 (COLOUR PLATE 132)

Circular white marble tabletop inlaid with *c.* 1200 pieces of ancient glass with a sun-burst in the centre containing a Romano-Egyptian mosaic inlay in the middle and a radiating pattern of 40 triangles of ancient mosaic glass fragments alternating with graduated monochrome opaque yellow pieces arranged in seven rings, within a border of octagonal reserves filled with opaque turquoise stars on alternate opaque yellow and red grounds and against a background of ancient amber-coloured and white mosaic glass. Split into two pieces, repaired and rebacked with a separate piece of marble.

Diam: 760mm

Provenance: Sheppard and Cooper Ltd, London; Christie's 1991, lot 300; Hadji Baba Ancient Art, London; The Corning Museum of Glass, Corning, New York, inv. no. 97.3.10

Exhibited: Paris, International Exhibition, 1867

Literature: Governo Pontificio 1867, 107, no. 94; Gonzalez-Palacios 1991, 86, fig. on p. 87; Whitehouse 2000, 24, no. 16

8 Marble and ancient glass tabletop with vase motifs

Guéridon with a white marble circular top inlaid with ancient polychrome mosaic glass and set on its original wooden stand with a baluster stem and tripod foot surmounted by three gilded sphinxes. The top with eight classical vases of diverse forms arranged around an octagon within a circle all composed of ancient polychrome mosaic glass within an octagon.

Probably Rome, mid-19th century
Ht: 840mm; diam: 520mm
Provenance: Italian auction house in the 1980s
Literature: Gonzalez-Palacios 1991, 88

9 Marble and ancient glass tabletop with vase motifs

White marble circular top with a guilloche border and four classical vases alternating with lozenge motifs centred around an octagon, all filled with fragments of ancient mosaic glass, mounted on a later gilt-bronze stand with legs in the form of bamboo, joined by stretchers.
Probably Rome, mid-19th century
Ht: 460mm; diam: 520mm
Provenance: Sotheby's 1996, lot 248

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INDEXES

AUTHOR INDEX

SUBJECT INDEX

NB This index provides a brief guide to the principal topics and countries dealt with by the papers. It does not duplicate major headings as given in the contents list.