ARCHAEOLOGY OF GLASS: MEDIEVAL AND RENAISSANCE PRODUCTION IN ITALY. CHARACTERIZATION AND CLASSIFICATION OF PRODUCTION INDICATORS: AN INTERDISCIPLINARY APPROACH

M. MENDERA, F. FENZI, M. GALGANI, E. GIANNICHEDDA, P. GUERRIERO, S. LERMA, B. MESSIGA, M.P. RICCARDI and P.A. VIGATO

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 relics 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).

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;
• culet — 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. 1 Location of the districts of Liguria and Tuscany
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 200nA. 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, Sienna, Arezzo, Lucca, Pistoia, Prato, Volterra etc) from the early 13th century by documents and archaeological research (Mendera 2002). The first
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 grey/green (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)Al2Si2O8], 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; for the 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, 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, 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 (=300nm) was detected, its composition being MnO 85.2, SiO 10.3, Al2O3 2.0, CaO 1.1, Na2O 1.1 and K2O 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 MnO2 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, techniques, 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 relics 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 archeometric publications.

REFERENCES


E. GIANNICHEDDA
ISCUUM
Via di Sottoripa, 5, 16124
Genova, Italy

B. MESSIGA, M. P. RICCARDI
Dipartimento di Scienze della Terra
Università di Pavia
Via Ferrata, 1, 27100 – Pavia, Italy