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

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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 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 (Stawierska 1999, 111–17; Niezabitowska 2000; Machajewski 2001; Andrzejewski and Zórawska 2002; Rudnicka and Maczyńska 2002).

The finds of beakers with thread decoration are concentrated mainly in two regions: in Zeelând and at the territory of the Wielbark culture. There are also some in the area of the Przeworsk culture, the Czerniakowska 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 B₂/C₁–C₂, 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 (Stawierska 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.

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 spectrophotograph, 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% K₂O with Na₂O:K₂O ratio equal to or higher than 13:1 are called the soda 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 Al₂O₃ – 2%. The method involving (Na₂O+K₂O):(CaO+MgO) ratios reflects technological recipes (RN) used for glassmaking.

The raw materials are characterized by ratios with (K₂O) = (K₂O:Na₂O+K₂O) x 100% and (MgO) = (MgO:CaO+MgO) x 100% facilitating the calculation of the potassium fraction in the alkali 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 (e.g. crushed shell) (Stawierska 1988; 1993a; 1993b). Considerable Sb₂O₃ 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 Stawierska 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 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

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**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

<table>
<thead>
<tr>
<th>No.</th>
<th>site</th>
<th>Na₂O</th>
<th>K₂O</th>
<th>CaO</th>
<th>MgO</th>
<th>Al₂O₃</th>
<th>FeO₂</th>
<th>Sb₂O₃</th>
<th>MnO</th>
<th>type</th>
<th>RN</th>
<th>(K₂O)</th>
<th>(MgO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>418</td>
<td>Horodowcza</td>
<td>20.0</td>
<td>0.75</td>
<td>5.9</td>
<td>0.66</td>
<td>1.8</td>
<td>0.45</td>
<td>0.22</td>
<td>0.12</td>
<td>Na-Ca-Si</td>
<td>3.16</td>
<td>3.6</td>
<td>10.06</td>
</tr>
<tr>
<td>119</td>
<td>Śpicymierz</td>
<td>19.2</td>
<td>0.85</td>
<td>6.9</td>
<td>0.52</td>
<td>2.3</td>
<td>0.63</td>
<td>0.46</td>
<td>0.65</td>
<td>Na-Ca-Al-Si</td>
<td>2.70</td>
<td>4.23</td>
<td>7.00</td>
</tr>
<tr>
<td>190</td>
<td>Krusza Zamkowa</td>
<td>19.7</td>
<td>0.58</td>
<td>7.9</td>
<td>0.53</td>
<td>1.9</td>
<td>0.67</td>
<td>0.40</td>
<td>0.25</td>
<td>Na-Ca-Al-Si</td>
<td>2.48</td>
<td>4.21</td>
<td>8.20</td>
</tr>
<tr>
<td>178</td>
<td>Rostostyło</td>
<td>19.7</td>
<td>0.58</td>
<td>7.9</td>
<td>0.53</td>
<td>1.9</td>
<td>0.67</td>
<td>0.40</td>
<td>0.25</td>
<td>Na-Ca-Al-Si</td>
<td>2.48</td>
<td>4.21</td>
<td>8.20</td>
</tr>
<tr>
<td>185</td>
<td>Zdzisław</td>
<td>19.2</td>
<td>0.85</td>
<td>6.9</td>
<td>0.52</td>
<td>2.3</td>
<td>0.63</td>
<td>0.46</td>
<td>0.65</td>
<td>Na-Ca-Al-Si</td>
<td>2.70</td>
<td>4.23</td>
<td>7.00</td>
</tr>
<tr>
<td>193</td>
<td>Krusza Zamkowa</td>
<td>16.6</td>
<td>1.0</td>
<td>7.7</td>
<td>0.61</td>
<td>2.3</td>
<td>0.76</td>
<td>0.22</td>
<td>0.84</td>
<td>Na-Ca-Si</td>
<td>2.1</td>
<td>5.68</td>
<td>7.34</td>
</tr>
<tr>
<td>121</td>
<td>Mierzowice</td>
<td>~20.0</td>
<td>0.5</td>
<td>7.2</td>
<td>0.64</td>
<td>2.8</td>
<td>1.2</td>
<td>–</td>
<td>–</td>
<td>Na-Ca-Si</td>
<td>2.1</td>
<td>5.68</td>
<td>7.34</td>
</tr>
<tr>
<td>125</td>
<td>Igloń</td>
<td>15.4</td>
<td>0.7</td>
<td>7.9</td>
<td>0.71</td>
<td>2.6</td>
<td>0.60</td>
<td>–</td>
<td>1.6</td>
<td>Na-Ca-Si</td>
<td>1.86</td>
<td>4.34</td>
<td>8.24</td>
</tr>
<tr>
<td>118</td>
<td>Rostostyło</td>
<td>15.6</td>
<td>0.85</td>
<td>1.0</td>
<td>1.0</td>
<td>3.7</td>
<td>0.83</td>
<td>–</td>
<td>1.9</td>
<td>Na-Ca-Si</td>
<td>1.49</td>
<td>5.16</td>
<td>9.09</td>
</tr>
<tr>
<td>406</td>
<td>Mühlberg</td>
<td>20.0</td>
<td>0.7</td>
<td>6.6</td>
<td>0.60</td>
<td>2.70</td>
<td>0.62</td>
<td>0.57</td>
<td>0.05</td>
<td>Na-Ca-Si</td>
<td>2.88</td>
<td>3.38</td>
<td>8.35</td>
</tr>
<tr>
<td>179</td>
<td>Rostostyło</td>
<td>19.4</td>
<td>0.7</td>
<td>7.2</td>
<td>0.59</td>
<td>2.0</td>
<td>0.49</td>
<td>0.63</td>
<td>0.63</td>
<td>traces Na-Ca-Si</td>
<td>2.58</td>
<td>3.48</td>
<td>7.57</td>
</tr>
</tbody>
</table>

\[
RN = \frac{\text{Na}_2\text{O} + \text{K}_2\text{O}}{\text{CaO} + \text{MgO}}, \quad (\text{K}_2\text{O}) = \frac{\text{K}_2\text{O}}{\text{Na}_2\text{O} + \text{K}_2\text{O}} \times 100\% \quad (\text{MgO}) = \frac{\text{MgO}}{\text{CaO} + \text{MgO}} \times 100\%
\]

Complete results of analyses of glasses from Poland were published in Stawierska 1999, Annexes 1–2. Chemical characteristics of glasses from the Rhineland established on the basis of data analyses were published in Velde 1990; Stawierska 1984, Annexes 2–3; Stawierska 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 the Rhineland, the majority contain more than 2% of Al₂O₃.

The concentrations of iron oxides in glasses from Poland are relatively low: 0.45%–0.80% FeO₂; 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% FeO₂, 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 FeO₂ (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 Sb₂O₃ 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 decolourants 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 Frontimius; see Velde and Semnoquer 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 (Stawierska 1993a, 145).

![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 Stawierska 1984, Annexes 2–3; 1999, Annex 3)
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$_2$O$_3$ 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 decolourant 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 decolourant 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%; Stawierska 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$_2$O$_3$ 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$_3$/C$_1$–C$_2$) together with the E189 type beaker discussed above (Rostoty, Barrow 4; see Stawierska 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) (Stawierska 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 decolourants. 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 Novaes, Oescus, Trimontium, Odessus and Sirmium – Olezak 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 cannot 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.

REFERENCES


Stawierska, T., 1993b. ‘Chemical studies of ancient glasses in Poland (with particular reference to the Roman Period)’. Archaeologia Polona 31, 229-42.


