Ancient Monuments Laboratory
Report 83/93

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Summary

Building debris from an eleventh-century context included grozing debris and fragments of window glass. The glass proved to be potash glass with high lime, magnesia and phosphorous contents, which can be compared with contemporary material from Winchester and France.

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# ASSESSMENT OF WINDOW GLASS FRAGMENTS AND GROZING DEBRIS FROM WESTMINSTER ABBEY, LONDON

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An important feature of the 1986 excavations of the dorter undercroft at Westminster Abbey[1] was the discovery of a massive ditch (238), filled with a sequence of sandy silts containing refuse of various types. The function of the ditch is unclear, but it is thought that the contexts within it date from the period after 1050 but before the late 1060s/early 1070s (*ie* the period of Edward the Confessor's work at the site). Context 424, within ditch 238, included about 0.5kg of glass fragments, as well as oyster shells, animal bones and occasional pebbles. Much of the glass is in the form of tiny chips and grozing debris, but there are some larger pieces of window glass, including some with rounded edges. One fragment of Saxon vessel glass was also discovered at the site, but not in ditch 238; it is intended that this piece will be the subject of a later analytical programme.

The window glass debris was sampled to establish the type of glass being used at this time and to investigate the causes of its surface corrosion characteristics. There are few published examples of window glass of this period and the source of such glass (local or imported) is a matter of some debate. For this reason, the Westminster group merits detailed consideration, in particular, the type of glass used must be identified.

## Description of the glass fragments examined.

Much of the material examined has blue corrosion products on the surface, ranging from pale blue to dark blue. Some of this corrosion gives the glass a very crumbly appearance and the glass feels rather light, but in many of these cases, solid glass is preserved in the middle of the fragment. Much of the material is covered by further layers of concreted material, consisting of smaller chips of glass, pieces of stone and what appears to be mortar. A small proportion of the fragments are solid, relatively dense and still transparent, showing a natural mossy green colour. There are a few examples of brown-tinted or clear blue-green glass which is also well preserved.

With this range of visual characteristics, it is interesting to see if all the glass has similar compositions. Seven fragments were selected for chemical analysis, covering a range of appearances (see Table 1).

## Chemical analysis

Chemical analysis was performed using energy-dispersive X-ray micro-analysis in a scanning electron microscope (a Cambridge S200 SEM with Link Systems AN10000 X-ray analyser) as in previous projects (Mortimer 1991). Samples were also taken for analysis using inductively-couple plasma spectroscopy; the results of this investigation will be included in a future report.

Analysis showed that the samples are all chemically similar despite the range of appearances (Table 1). All the glass is potash glass, with high lime, magnesia and phosphorous pentoxide values. The results of analyses on a relevant glass standard suggest that the method is reasonably accurate and reproducible (Appendix).

## Discussion

Potash glass, also known as 'forest glass' or 'green glass', was a common type of glass in use during the medieval period. The major oxide contents of glass reflect the raw materials used; potash glass was made using plant ash (*eg* from trees and ferns) as alkali, together with a silica-rich material, such as sand. Apart from potash, such glasses typically have at least percent levels of calcium, magnesium, phosphorous and aluminium oxides, much of which originated in the alkali. Variation in oxide content may indicate the use of different types of plant, variation in the degree of purification of the raw materials or differences in high-temperature technology.

Material visually comparable with the Westminster samples formed the largest sub-grouping of early medieval window glass at Winchester ('non-durable' glass).[2] Analysis of seventeen fragments of this glass type[3] from early tenth century contexts at Wolseley Palace and Cathedral Green sites shows the material to be a potash glass with very similar chemical composition to the Westminster material, as a comparison of some of the major oxides demonstrates (Figs 1 and 2). At Lurk Lane, Beverley (Humberside), a ninth-century fragment of window glass was found to be high in potash, lime and magnesia.[4]

From the evidence at Winchester, it seems that this glass type was introduced during the ninth century, but only became common in the tenth and eleventh centuries, when it was used interchangeably with 'durable' *ie* soda-based window glass.[5] Subsequently potash glasses were commonly used for windows. Later (twelfth- to fifteenth-century) potash vessel glasses tend to have lower lime, phosphorous and potash levels;[6] analyses for later potash window glasses are not available. The evidence from the Westminster glass assemblage therefore conforms to this patterning.

The source of the eleventh-century potash glass from Westminster, and of the technology that produced it, is clearly of some interest. Potash glass is thought to have been introduced from the continent but it is not known whether potash glass was made in England at this early stage, or merely imported from other areas. The Westminster excavation did not produce furnace or crucible fragments, nor did it produce any molten dribbles or other waste, so it is unlikely that the glass was made on the site, or even that it was melted or worked at high temperatures at the site.

The Westminster material cannot be compared with excavated evidence for potash glassworking, since this is lacking for the eleventh century, both in this country and abroad. Evidence from two ninth- or tenth-century English glassworking sites have recently been examined, at Glastonbury Abbey, Somerset and Barking Abbey, London,[7] but the glass here is presumably soda glass, judging from its appearance.[8] Data for glassworking of this period in other areas of north-west Europe currently consists of small amounts of evidence (crucibles, droplets *etc.*) from a few sites, notably Paderborn and Cordel in Germany[9] and more substantial evidence from Haithabu, also in Germany.[10] The glass worked at Cordel was a mixed alkali glass (*ie* nearly equal amounts of soda and potash were present).[11] The majority of the glass worked at Haithabu was soda glass, but six potash glasses were identified through analysis as well as two beads of mixed alkali glass.[12] The Haithabu potash glasses are of two types, one of which has similar potash and soda contents as the Westminster glass, but lower lime levels (11.3-12%) and the other which has lower potash levels (8.6-11.6%) but lime

levels which are roughly comparable with the Westminster glasses (15.5-24%); phosphorous levels are uniformly lower than those at Westminster (2.05-3.48%) and alumina levels are higher (1.2-2.6%). So, although the Haithabu glassworking included potash glass, the type of potash glass is not directly comparable to the Westminster glass, as is shown by a plot of major oxides (Figure 3). The evidence at Haithabu does not contain material diagnostic of glassmaking, only of glassworking. Glassworking at the site was probably based on glass imported from other areas of Europe,[13] so the wide variety of glass types is not surprising. The Haithabu material pre-dates the Westminster material, since occupation at the site finishes by *c.*1000AD. The description of the finds at another early medieval glassworking site, San Vincenzo al Volturo (Molise, Italy), suggests that soda glass was worked.[14]

Evidence about the place of manufacture can be sought elsewhere, *eg* in the glass compositions themselves. Very little contemporary glass from the continent has been analysed. Three ninth- to twelfth century pieces from three sites in France are potash glasses with broadly similar compositions to the Westminster glass.[15] There are far more analyses of finished glass and of production debris from later periods, both in this country and on the continent.[16]

Different types of plant ash have different chemical compositions,[17] so attempts have been made to characterise chemically glasses made by particular traditions or in particular areas.[18] The small number of fragments currently available means that it is not practical to carry out such work on the early medieval period. In the high medieval and post-medieval period, compositional patterning can be seen between groups of debris from individual production sites,[19] but it is still not possible to provenance material by chemical means.

In summary, the Westminster glass could have been made on the continent, imported in the form of large rectangular sheets and the quarries shaped on site, producing the copious grozing debris. Equally, it is possible that the glass was made somewhere in England, transported from there and finished on site.

The variation in observed colour has no analogue in the compositional data; all the glass fragments analysed had similar compositions. Differences in preservation may be due to different deposition environments and differences in colour may be due to differences in the oxidisation states and relative quantities of iron and manganese.

## Conclusions

The type of glass found at the site has been established and comparable material identified. Further work on this assemblage is unlikely to tell us much more, unless detailed typological assessment reveals further significant sub-groupings. However, later researchers may find alternative analytical methods can be applied to the material and that an exploration of the corrosion products may have research potential.

## Notes

1. Details about the circumstances of discovery were provided by Peter Mills and John Shepherd, Museum of London

2. Group 4 in Biddle M and Hunter J 1990 *Early medieval window glass* in Biddle M 'Object and Economy in Medieval Winchester' Winchester Studies 7ii, vol i (Oxford); 350-386.

3. Samples from Wolvesey Palace (Newton R 1990 *Scientific analysis of the window glass: The initial results*) and Cathedral Green (Yates T 1990 *Scientific analysis of the window glass: X-ray fluorescence results from Groups 3 and 4*), both reported in Biddle *op cit* (429-431, 434-436).

4. Henderson J 1991, *The glass* in Armstrong P, Tomlinson D and Evans D H (eds) 'Excavations in Lurk Lane, Beverley 1979-1982'; 124-130, ref no 4. The phosphorous content was not determined.

5. Groups 1 to 3 in Biddle and Hunter 1990, *op cit.*

6. See for example, those in Mortimer C 1991, *Analysis of medieval and post-medieval glass from the City of London*, Ancient Monuments Laboratory Report no 135/91; Table 2

7. Heyworth M 1992 *Evidence for early medieval glass production in North-West Europe*, Preprint for Medieval Europe Conference, York 1992.

8. Chemical analysis has not been carried out on this material. Dates for the glassworking phases are also under review.

9. Evison V I 1989 *Le verre carolingien* in Foy D and Sennequier G (eds) 'A travers le verre' (Rouen); 137-144.

10. Dekówna M 1990 *Untersuchungen an Glasfunden aus Haithabu* in Schietzel K (ed) 'Berichte über die Ausgrabungen in Haithabu 27' (Neumünster); 9-63.

11. Evison *op cit*; 137

12. Dekówna *op cit*, Tables 3-11.

13. Dekówna suggests that Byzantine glassworkers and imported raw materials must have been needed if the soda glass found at the site was also made at the site; this seems rather unlikely. She does not speculate on the source of the potash glass (Dekówna *op cit*, 54-56).

14. Moreland J 1985 *A monastic workshop and glass production at San Vincenzo al Volturo, Molise, Italy* in Hodges R and Mitchell J 'The Archaeology, Art and Territory of an early medieval monastery' British Archaeological Reports (International Series) 252; 61-82. The glassworking material had not been analysed at the time of this publication.

15. Data taken from Annex III, Barrera and Velde 1989 *Barrera J and Velde B A study of french medieval glass composition*, Archéologie Médiévale 29 (1989), 81-130. The Periode I analyses are from vessels, not from glass production sites.

16. *eg* Kenyon G H 1967 *The glass industry of the Weald* (Leicester); Barrera and Velde 1989 *op cit.*

17. Sanderson D and Hunter J *Compositional Variability in Vegetable Ash*, Science and Archaeology 23 (1981), 27-30; Turner W E S 1956 *Studies in ancient glasses and glassmaking processes. Part V. Raw materials and melting process.* Journal of the Society of Glass Technology 40; 276-300..

18. *Eg* Barrera J and Velde B *op cit*, especially pages 92-94.

19. Barrera and Velde *op cit.*

**Table 1: Chemical composition of window glass fragments from Westminster Abbey, WST86, Context 424, SF 61**

| Sample / Oxide | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| $Na_2O$ | 0.6 | 1.0 | 0.7 | 1.0 | 0.6 | 0.9 | 1.0 |
| $MgO$ | 5.5 | 5.0 | 3.9 | 4.5 | 4.4 | 5.1 | 5.8 |
| $Al_2O_3$ | 1.1 | 0.8 | 0.5 | 0.7 | 0.4 | 1.0 | 0.9 |
| $SiO_2$ | 47.9 | 51.1 | 52.0 | 50.5 | 50.7 | 54.3 | 56.4 |
| $P_2O_5$ | 6.9 | 5.7 | 5.6 | 5.8 | 5.4 | 3.6 | 4.2 |
| $CaO$ | 21.9 | 19.5 | 19.6 | 19.0 | 17.3 | 19.5 | 22.0 |
| $K_2O$ | 13.9 | 16.5 | 18.3 | 16.3 | 15.8 | 12.9 | 11.3 |
| $TiO_2$ | 0.3 | 0.2 | nd | nd | nd | 0.2 | 0.1 |
| $MnO$ | 0.8 | 0.4 | 0.3 | 0.3 | 0.3 | 0.7 | 0.2 |
| $Fe_2O_3$ | 0.6 | 0.4 | 0.3 | 0.4 | 0.4 | 0.7 | 0.6 |
| Total | 99.6 | 101.2 | 101.5 | 98.9 | 95.6 | 99.1 | 102.6 |

Note: S, Cl, $Cr_2O_3$, $SnO_2$ and PbO were analysed for but were at, or below detectable limits in these samples (which are c. 0.2% for all except PbO, which is *c.* 0.1%). 'nd' = not detected.

| **Sample number** | **Sample description** |
|---|---|
| 1 and 2 | Thick mid-blue corrosion deposits (and some soil?), the original colour of the glass is not evident in the hand sample: pale mossy green in cut section, depth of corrosion at least 1mm. |
| 3 | Ditto, with added concretions |
| 4 | Tiny fragment from grozing, tinted pale green |
| 5 | Tinted - pale green, light corrosion deposits |
| 6 | Tinted - brown, light corrosion deposits |
| 7 | Tinted - strong blue-green, good preservation, small patches of concretion. |

Appendix

Comparison of results of three analyses by SEM-EDAX with the quoted values for the glass standard Corning D

| | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $P_2O_5$ | CaO | $K_2O$ | $TiO_2$ | MnO | $Fe_2O_3$ | CuO | $SnO_2$ | PbO | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.39 | 3.82 | 4.59 | 54.49 | 4.05 | 14.55 | 10.97 | 0.60 | 0.35 | 0.37 | 0.20 | nd | 0.23 | 95.84 |
| 2 | 1.44 | 3.95 | 4.64 | 54.27 | 4.14 | 14.76 | 10.91 | 0.53 | 0.74 | 0.45 | 0.49 | nd | 0.35 | 96.79 |
| 3 | 1.61 | 4.00 | 4.45 | 53.44 | 3.63 | 14.56 | 11.05 | 0.60 | 0.57 | 0.31 | 0.15 | 0.11 | 0.36 | 94.98 |
| Average | 1.48 | 3.93 | 4.56 | 54.07 | 3.94 | 14.63 | 10.97 | 0.58 | 0.55 | 0.38 | 0.28 | 0.04 | 0.31 | 95.87 |
| Quoted values | 1.32 | 4.09 | 5.43 | 55.24 | 4.00 | 15.05 | 11.46 | 0.40 | 0.57 | 0.50 | 0.40 | 0.13 | 0.27 | 98.86 |

**Sulphur, chlorine and chromium were not detectable by SEM-EDAX (detectable limits = *c.* 0.2%, in all cases); these elements were not analysed for in the quoted compositions for Corning D.**

Appendix

Comparison of results of three analyses by SEM-EDAX with the quoted values for the glass standard Corning D

| | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $P_2O_5$ | CaO | $K_2O$ | $TiO_2$ | MnO | $Fe_2O_3$ | CuO | $SnO_2$ | PbO | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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| Average | 1.48 | 3.93 | 4.56 | 54.07 | 3.94 | 14.63 | 10.97 | 0.58 | 0.55 | 0.38 | 0.28 | 0.04 | 0.31 | 95.87 |
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**Sulphur, chlorine and chromium were not detectable by SEM-EDAX (detectable limits = *c.* 0.2%, in both cases); these elements were not analysed for in the quoted compositions for Corning D.**

Fig 1: Early medieval potash glass; Westminster and Winchester finds

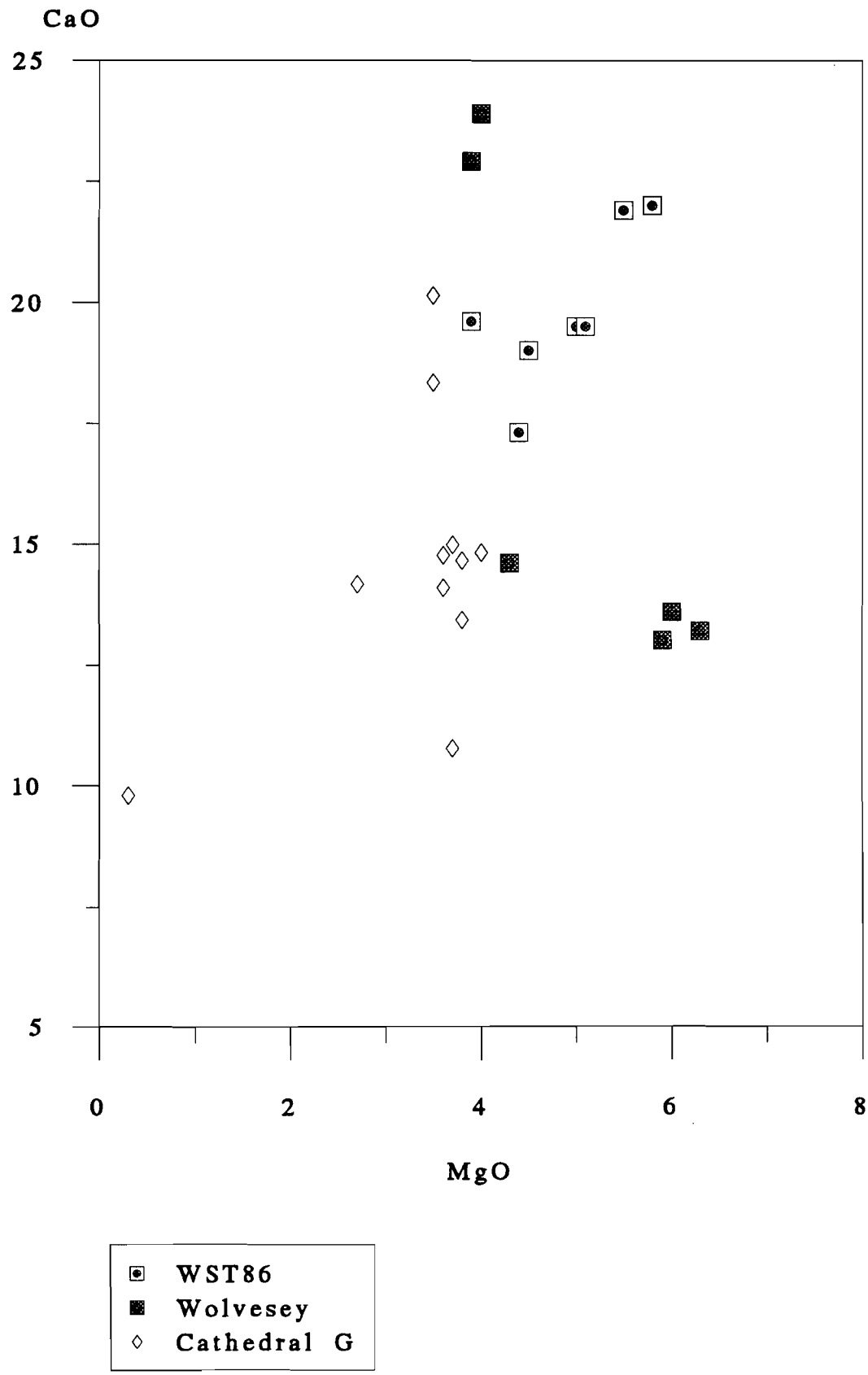


Fig 2: Early medieval potash glass; Westminster and Winchester finds

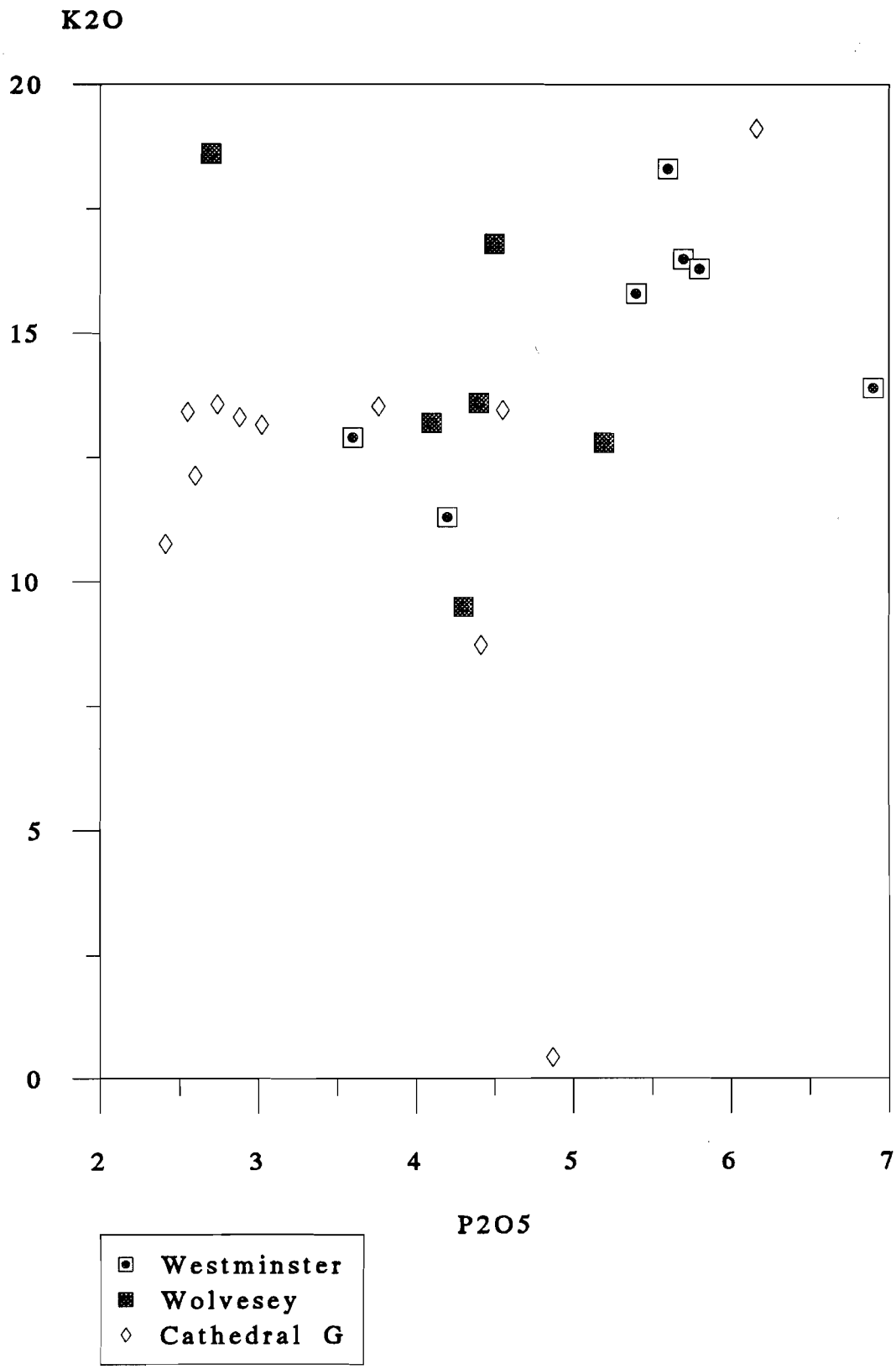
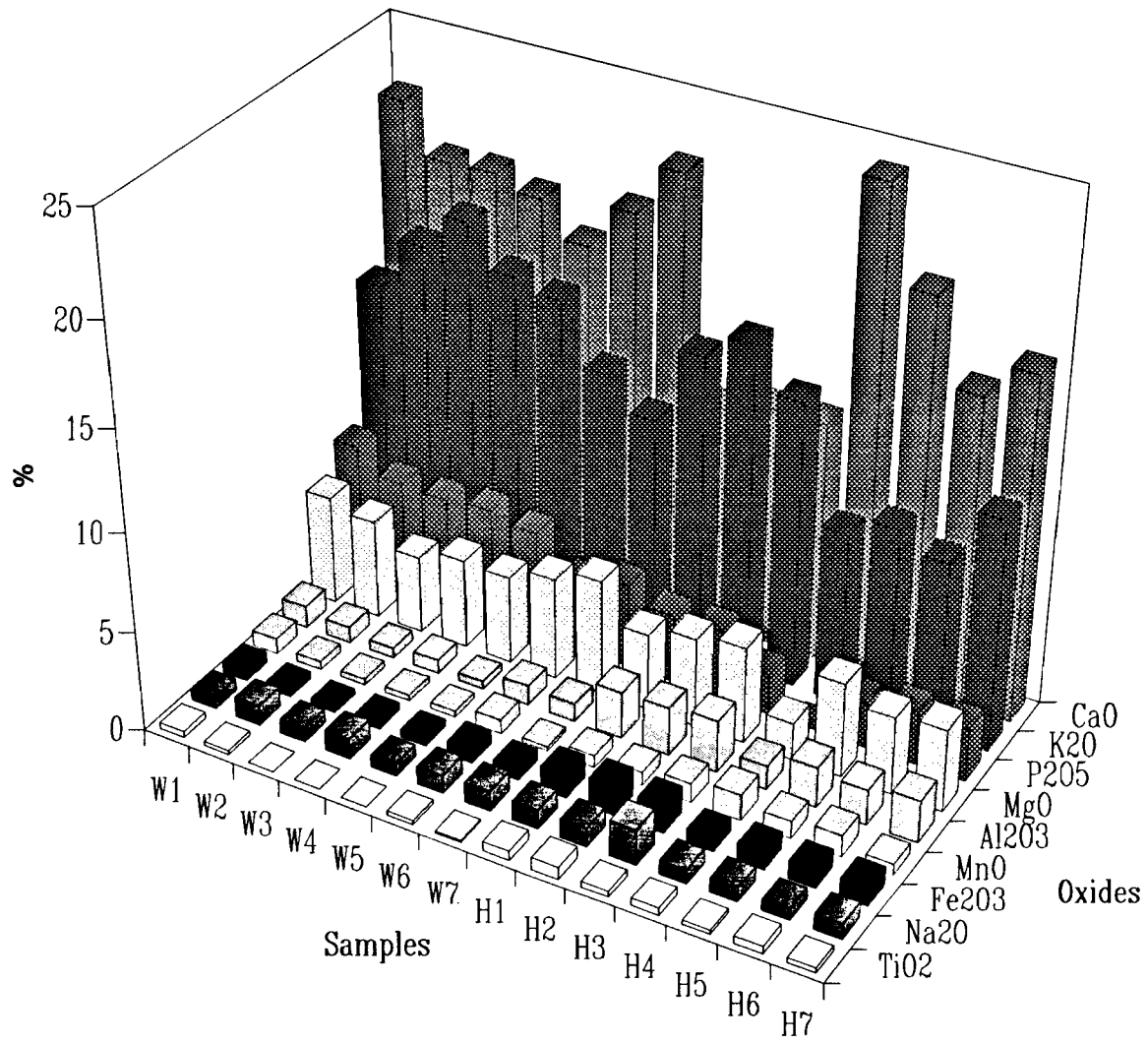


Figure 3: Comparison of Westminster and Haithabu potash glasses




Sample codes: W = Westminster, H= Haithabu