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Lead Glazing Technique from a Medieval Kiln Site at Hanley Swan, Worcestershire

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SUMMARY

Fieldwork has recently located the site of a kiln at Hanley Swan in Worcestershire. This was partially excavated, and among the finds there were sherds of pottery with a white coating. Analysis by scanning electron microscopy and X-ray diffraction confirms that the coatings are unmatured pottery glaze. Lead oxide had been applied, without admixed material, and the glaze formed by reaction with the body.

INTRODUCTION

Our understanding of medieval glazing techniques generally depends upon a limited number of early references, notably that of Eraclius, along with replications in the workshop or laboratory (Barton 1990, Griffiths and Redknap 1991). The subject of the present paper is a group of excavated material which offers direct evidence of the glazing process.

Medieval pottery production in the Malvern area of Worcestershire has been well known since Vince (1977) identified Malvernian wares on sites in the Midlands through the identification of mineral inclusions. Documentary evidence suggests that the potters were based in the parish of Hanley Castle and in the vicinity of the forest or chase, between the Malvern Hills and the River Severn.

Fieldwork was undertaken in 1987–1992 in the parish of Hanley Castle, in order to follow up the documentary evidence for potters working in the parish and to locate sites associated with this ceramic industry.

An area of about 250 hectares to the east of Hanley Swan was scanned by fieldwalking. This was followed by more intensive fieldwalking of selective areas. Geophysical survey and augering was subsequently directed towards areas where finds concentrations had been located (Hurst 1994, 119). Several sites associated with ceramic production were identified, including the site of the first kiln structure for this major industry to be discovered (HWCM 9685; SO 826427), and this was partly excavated. The structural remains and related artefactual evidence have been published (Hurst 1994, 120–4), and only a brief account is provided here. This article reports on the investigation of certain sherds that were found in association with the kiln site.

KILN AND ASSOCIATED FEATURES

Little of the kiln survived, except for a possible internal floor of flat roofing tile. *In situ* bricks suggested that at least the lower part of the walls of the kiln were built of brick. A concentration of pottery, roof tile and saggers was found inside the kiln; it presumably represents debris from the final firing. No internal structure was identified, but the survival of glaze marks on the floor (made from flat roof tile) suggest that the kiln was probably stacked without a separate internal floor. The structure had certainly been fired, as the natural clay underneath the structure was scorched.

To the south-west of the kiln there was a pit or ditch which was partly infilled with a dump of pottery, some of which was highly friable, probably as a result of being poorly fired. A number of these sherds were coated with a white deposit, and it is this pottery that was analysed and is reported here.

Large clay pits were identified in the general vicinity of the kiln. These survive as slight depressions, but augering showed them to have been up to 1–2m in depth. Clay and sand pits were also attested in 19th-century field-name evidence immediately to the east of the kiln site, and are probably the same clay pits referred to in other documents dating from the 16th century onwards (Hurst 1994, 125).

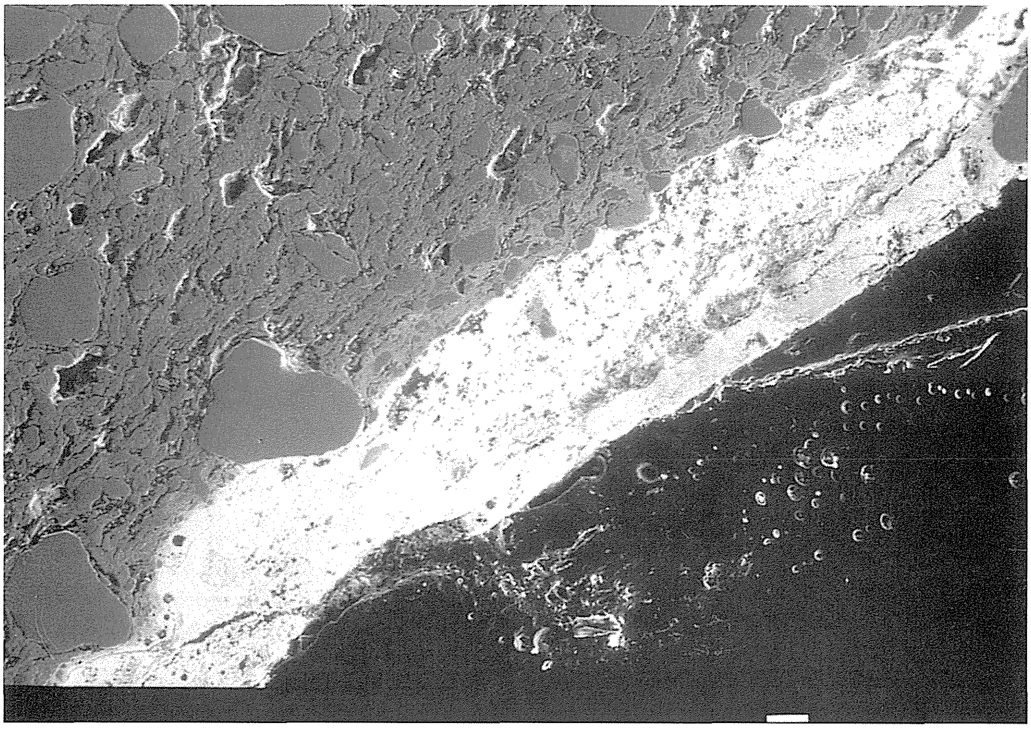

Fig. 1. Scanning electron photomicrograph of the surface of coated sherd BMRL 47260Y. The white zone is the lead-rich coating. The smooth particles jutting into the coating from the body are quartz grains. (White horizontal scale bar represents 100 microns, i.e. 0.1mm).

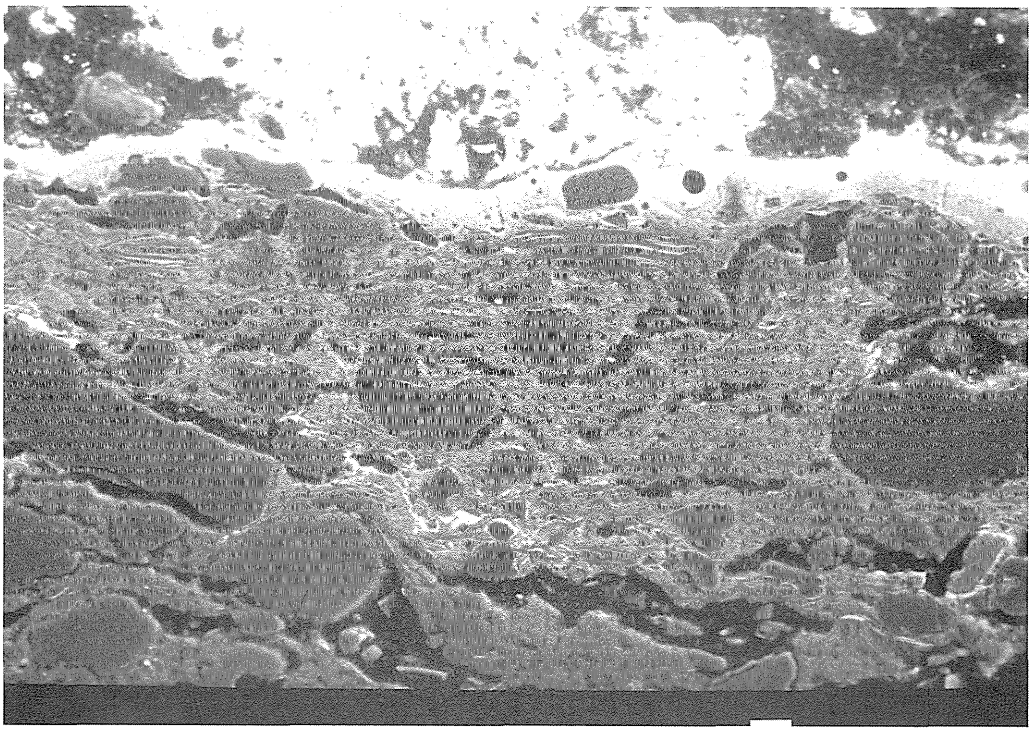

Fig. 2. Interactions at the boundary between the white surface coat and the body (sherd 47260Y). This micrograph is a magnified view of the area just to the right of the large quartz grain which juts from the body into the coat in Fig. 1. At the top of the micrograph may be seen the lead-rich coat (white, plucked out of the section at either side, leaving holes). Immediately below are two very thin layers (white and grey continuous) formed by interaction of the lead-rich layer with the body. Below this is a relatively thick zone of the body which is enriched in lead (light grey with smooth quartz grains and irregular cracks). At the bottom left is typical body material (scale bar 10 microns).

Table 1. Energy Dispersive X-ray Analysis of Surface Coatings and Ceramic Bodies

	1 White coating	2 Interaction layer	3 Interaction layer	4 Interaction layer	5 Coated body	6 Glazed body	7 Glaze
SiO_2	0.9	28.5	36.1	53.2	69.9	67.3	30.0
TiO_2	<0.2	0.3	0.4	0.9	0.5	0.9	0.5
Al_2O_3	<0.2	4.9	12.3	13.1	13.9	14.4	4.7
FeO	<0.3	2.2	4.3	4.9	5.5	6.1	2.3
MgO	<0.2	1.0	2.8	2.1	2.3	3.9	1.1
CaO	2.8	0.2	<0.2	0.9	1.0	1.2	0.6
Na_2O	<0.3	<0.3	0.5	1.2	1.0	0.6	<0.3
K_2O	<0.2	0.4	2.9	3.2	3.6	4.2	0.8
P_2O_5	7.3	<0.3	<0.3	2.6	1.2	0.3	<0.3
Cl	1.9	0.2	0.2	0.4	<0.2	<0.2	0.2
PbO	85.8	62.1	40.1	17.2	0.5	0.7	59.3

Notes Analyses normalised to 100%. Due to the heterogeneity of the materials, the accuracy and precision of these analyses cannot be quoted in the normal way. Columns 1-5 are from underfired sherd 47260Y, and columns 2-4 represent the glaze-body interaction layers, passing from the thin layer of glaze adjacent to the raw glaze coat (column 2) through to the contaminated body (column 4). Columns 6 and 7 are from glazed sherd 47262W.

THE POTTERY

The pottery associated with the kiln was all of oxidised Malvernian fabric (fabric 69 in Hurst and Rees 1992, 208), and jar and bowl forms were well represented, all datable to the 15th to 16th century. For the first time, saggers were identified in association with the Malvern industry.

Sherds with white coating

A large proportion of the pottery, including jars and ridge tiles from the fill of a pit or ditch adjacent to the kiln, was unusual in having a white coating, which had clearly been applied before breakage in antiquity. Since Malvernian potters rarely used white slip, and the white coating was always unglazed, it was considered that these sherds might represent unfinished pottery where the glaze had remained unmatured. This presented a rare opportunity to analyse the original composition of a glaze, which could provide information about an important aspect of medieval pottery production.

METHODS OF ANALYSIS

Samples were removed from one of the white-coated pottery sherds and two sherds with fully matured glazes, and mounted as cross-sections in epoxy resin blocks. They were ground, polished with diamond paste down to 1μm (0.001 mm), and coated with a thin layer of carbon for examination in the scanning electron microscope (SEM). Elemental compositions were determined using the attached energy dispersive X-ray analyser (EDXA). In addition, samples of the white coat from two sherds were examined by X-ray powder diffraction (XRD) using Debye-Scherrer cameras.

RESULTS: WHITE-COATED SHERDS

In the SEM, the white coat was revealed as a continuous fine-grained layer up to about 0.5mm thick (Fig. 1), essentially homogeneous, with no evidence for admixed material. The composition of this coating, given in Table 1 (column 1) indicates that it is predominantly lead oxide (PbO) with less than 1% of silica (SiO_2) and about 7% of phosphorus pentoxide (P_2O_5). XRD showed that the coat was composed primarily of a lead phosphate (pyromorphite) and subordinate lead carbonate (cerussite). This is unlikely to represent the original composition of the coating; buried ceramics are commonly contaminated with phosphate and lead phosphate is often a weathering product of lead-bearing materials (Freestone, Middleton, and Meeks 1985). The coating is, therefore, likely to have consisted originally of either lead oxide which has weathered to lead phosphates and carbonates, or lead carbonate which has partially weathered to phosphate. The lime (CaO) and chlorine (Cl) in the analysis (Table 1) are also likely to represent contaminants (these are probably in solid solution with the pyromorphite as apatite; see Freestone et al., op. cit.). No evidence for the presence of metallic lead or lead sulphide (galena) was detected, although these might not have survived well in the burial environment. However, the very fine, compact nature of the layer supports the view that these coatings were originally lead oxide or carbonate.

Beneath the oxide coating some interaction with the body has taken place: in Figs. 2 and 3 there are essentially three layers between the body and the coating. Immediately below the white coating, there is a smooth glassy layer with no discernible internal structure. This second layer, which is about 10μm (0.01mm) thick, appears to be a very thin layer of

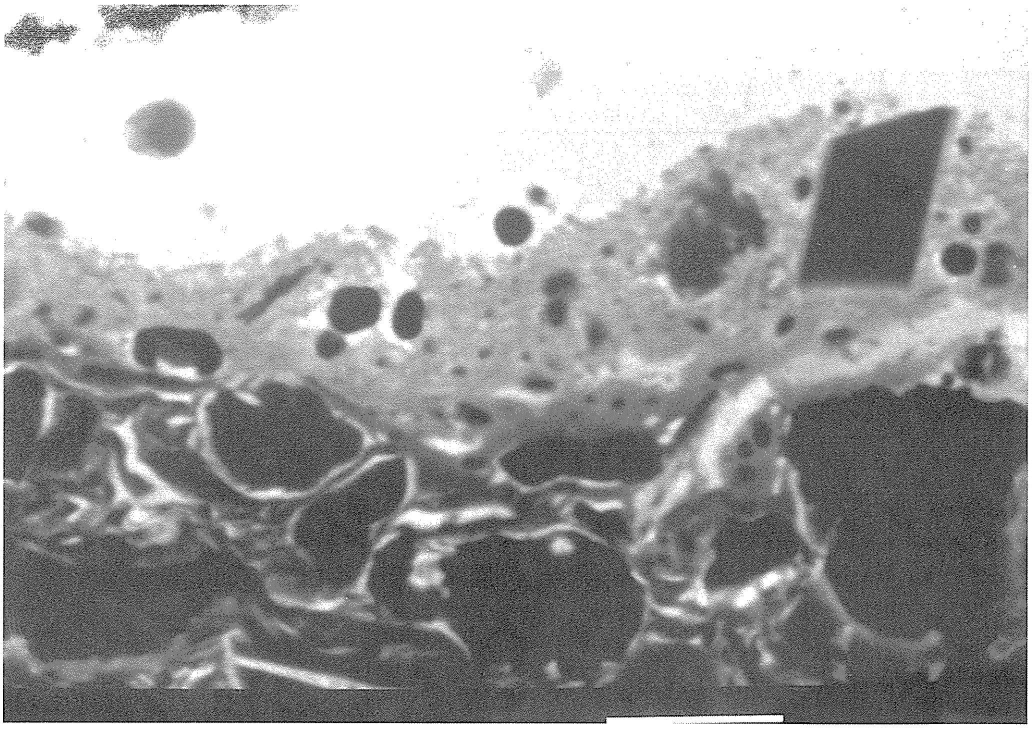

Fig. 3. Magnified view of body-coating interface showing glassy layer (white, top) and molten ceramic (middle). The body, occupying the lower half of the micrograph, contains streaks of lead-rich material (white). (Scale bar 10 microns).

glaze. Below this is a layer of similar thickness but which is partially crystalline and contains small vesicles (gas bubbles); it represents partially melted body material with a lower content of lead oxide. Finally, the outer zone of the body is contaminated with lead oxide, which appears to line the cracks and voids in the fired clay (Figs. 2 and 3). Compositions of the three layers between the coating and the body are given in Table 1, columns 2–4. The lead contents increase progressively from the body to the coating.

RESULTS: COMPARISON WITH GLAZED SHERDS

The bodies of the coated sherds and those with fully matured glazes appear similar in the SEM, with common sub-angular quartz grains around 0.1mm diameter and occasional coarser grains about 0.5mm. Elemental analysis also shows that coated and glazed bodies have closely similar compositions (Table 1, columns 5 and 6). These sherds are clearly products of the same kiln, using essentially the same clays, and in the same fabric.

Analysis of the mature glaze (Table 1, column 7) reveals it to contain around 60% lead oxide and to be very close in composition to the thin glaze layer developed immediately below the white coat (Table 1, column 2). The white coating, therefore, appears to represent a raw glaze coat which has only partially reacted with the body of the sherd, and is not fully matured.

Examination of the microstructure of the body indicates that the degree of vitrification is low, suggesting firing temperatures greater than 800°C but below 950°C, sufficient to melt a lead glaze. No significant differences were observed between the degree of vitrification of the coated sherds and that of the glazed sherds. Furthermore, the occurrence on the white-coated sherds of a thin glaze layer which is almost identical in composition to the mature glaze suggests that very similar temperatures were attained by both groups of material. Thus it seems likely that the glaze did not mature on the white-coated sherds because the firing was of too short a duration, rather than of too low a temperature. This may have been due to a failure of the firing, or possibly poor positioning of the pots in the kiln.

DISCUSSION OF ANALYTICAL RESULTS

The raw glaze appears to have been lead carbonate or lead oxide. No evidence of lead metal or sulphide was observed. Furthermore, there is no evidence for any addition of quartz or clay to the raw glaze to improve glaze quality or to bind the raw glaze to the body. It is possible that an organic binder, such as flour or starch was used (Newell 1995); however, such a binder would have burned off and would not be detectable even in these underfired sherds.

Development of the glaze depended upon the reaction of the lead oxide coat with the body. The sherds reveal the stages in the development of a glaze of this type. First, some of the lead oxide appears to undergo limited vaporisation and impregnate the outer layers of the ceramic. Where the concentration of lead is high, near the surface, the body fuses and a partially molten layer forms. As more lead oxide diffuses into this layer, a fully mature glaze is formed.

To produce *lead carbonate* in medieval times, lead metal was reacted with vinegar fumes, as in the production of lead white artists' pigment (Harley 1970). While this procedure would have undoubtedly produced a good-quality glazing material, it was time consuming and expensive. Furthermore, it was unnecessary, as *lead oxide*, of a quality sufficient for pottery glazing, could be produced by melting metallic lead in the kiln and skimming off the oxide layer that formed on the surface, a cheaper and simpler approach. This method is described in the context of the production of lead-tin oxide glazes in Renaissance texts such as those of Birunguccio and Picolpasso, and in earlier writings such as those of Eraclius (DeBouard 1974) and the twelfth-century *Mappae Clavicula* (Smith and Hawthorne 1974, ch. 142). It is most likely that the potters of Hanley Swan produced their glazing material in this way. The lead oxide could be applied to the surface of the pot by dipping, pouring or, perhaps most likely, brushing (Newell 1995).

CONCLUSION

Fieldwork has located the site of a kiln at Hanley Swan, Worcestershire, built at least partly of brick. Saggers were in use and these would probably have had a dual role for stacking, and for protecting finer vessels, in particular the drinking cups, from damage during firing. Analysis of the unmatured glaze suggests that lead oxide was applied directly to the surface of the pot, without admixed silica or clay. Thus the potters were routinely heating lead as part of the process of pottery manufacture, indicating that the glazing of the pottery involved a set of processes all of its own. This analysis has, therefore, provided some insight into a little-studied aspect of medieval ceramics.

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Résumé
Des travaux sur le terrain ont récemment isolé l'emplacement d'un four de potier à Hanley Swan dans le Worcestershire. Celui-ci fut en partie fouillé, et parmis les objets recueillis furent des tessons de céramique à enduît blanc. L'analyse aux moyens du passage au microscope à electrons, et à la diffraction aux rayons-X ont confirmé que ces enduits consistèrent de terre-glaise non-maturée. De l'oxide de plomb y fut rajouté, sans apport de materiel externe, la glaçure étant formée de la réaction avec le corps du vase.

Zusammenfassung
Arbeit im Gelände machte jüngst einen Brennofen in Hanley Swan, Worcestershire ausfindig. Eine Teilausgrabung brachte unter anderen Funden Töpferscherben mit einem weißen Überzug zutage. Analysen mit Hilfe von Elektronenmikroskopie und Röntgenstrahl Beugung bestätigten, daß der Überzug aus ungebrannter Glasur bestand. Bleioxyd ohne Zumischung wurde aufgetragen, wobei sich die Glasur durch Reaktion mit dem Scherben bildete.