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Matthew Ponting

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Summary

Six fragments of Coade Stone from West Dean College were investigated using low power optical microscopy, X-ray fluorescence spectrometry and scanning electron microscopy with energy dispersive analysis. Two of the fragments were found not be Coade Stone, but lime mortar used for a restoration treatment. The other four samples had compositions and structures similar to a published example. The components of Coade Stone can be confirmed as clay, flint, sand, ceramic grog and glass. Minor differences in composition suggest a change in the source of grog used in the recipe for the West Dean Coade Stone from the piece analysed earlier.

Keywords

Ceramic
Technology
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Author's address

Centre for Archaeology, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth PO4 9LD.
Telephone: 023 9285 6782. Email: matthew.ponting@english-heritage.org.uk

Introduction

Six fragments of concrete-like material were submitted for investigation prior to a visit by summer school students from West Dean College. The fragments came from two female statues in the grounds of the College (designated North Figure and South Figure respectively) which are known to be made of an artificial stone called Coade Stone. This material was developed in the late 18th century by Mrs Eleanor Coade as a ceramic stone substitute. It became a popular substitute for marble because of its colour and durability compared to traditional terracotta and was used by many leading architects to embellish buildings, including those of royalty and the aristocracy. Mrs Coade established her factory on the south bank of the river Thames at Lambeth in 1769 where it continued in production until 1840. The plinth of one of the West Dean statues carries the inscription 'Coade Lambeth 1793' (Fig 1).

Fig 1. Plinth inscription on one of the West Dean Statues (Photo: Pat Jackson)

Little information is available on the composition and production of Coade Stone. Hamilton (1954) summarised the information available at that time, based primarily on work conducted by the Building Research Station (BRS) and London County Council (LCC) which had not been fully published. Interest in Coade Stone had been kindled by the unearthing of part of Mrs Coade's factory during preparations for the Festival of Britain in 1951. Hamilton concluded that that the raw materials for Coade Stone were a kaolinitic clay to which a flux had been added, probably calcareous clay or feldspar. Firing experiments at BRS conducted on raw materials retrieved from the Lambeth site suggested that temperatures of 1100°C to 1150°C were used, but this figure was contested by experiments conducted by the LCC, who claimed that a temperature of only 950°C was required. In 1984, the British Museum (BM) Research Laboratory conducted further research into the material based on the detailed analysis of a piece of Coade Stone from Mrs Coade's house in Lyme Regis (Freestone et al, 1984). This study confirmed the higher firing temperature suggested by the BRS experiments and established the chemical composition by a combination of optical microscopy, scanning electron microscopy (SEM), energy dispersive microprobe (EDS), atomic absorption (AAS) and X-ray diffraction (XRD). The analyses suggested that the clay used was more likely a secondary ball clay rather than a kaolinite because of the relatively high TiO_2 content (>1%). The general compositions of the matrix and the grog inclusions were shown to be consistent with ball clays from Dorset and Devon, although the higher lime and soda contents suggested the addition of soda-lime-silica glass (ibid, 299). The non-plastic

inclusions were identified as quartz sand and flint together with grog that, it is suggested, came from crushed terracotta rather than re-cycled Coade (ibid, 300). All these ingredients were listed by Fowler (1850) in his 'Remarks on Terracotta and Artificial Stone as connected with Architecture' as being used for the production of artificial stone. The proportions of the ingredients were estimated to be 10% grog, 5-10% flint, 5-10% fine sand, 10% crushed glass with the remainder being ball clay, figures that agree remarkably well with Fowler's recipe for artificial stone. Freestone et al. acknowledge that their work was based on a single sample and that they were therefore unable to comment upon the consistency or otherwise of the composition. However, they were able to suggest that the similarity between the composition of their sample dating to 1784 and Fowler's recipe from 1850 indicates that little change occurred to the recipe in the intervening years and that this may indicate that the recipe was closely maintained and followed.

The analysis of the two West Dean Coade Stone figures allowed comparisons to be made between the Coade Stone of 1784 analysed by the BM and Coade Stone made nine years later.

Method

Examination and analyses were carried out using low power optical microscopy, X-ray fluorescence analysis (XRF) and scanning electron microanalysis (SEM-EDS). Three fragments from the North Figure and three from the South Figure were mounted in epoxy resin and then ground and polished to a 1 micron finish. Low power optical microscopy was conducted at X16 and X40 and images captured digitally. XRF analysis was by an EDAX Eagle standardless system operating at 40 Kv and 200 mA, counting for 200 secs. A LEO stereoscan 440 scanning electron microscope with an Oxford Instruments Gem detector and ISIS 300 analysis suite standardised on geological standards was used for analysis of selected phases. Both instruments were checked against certified standard reference materials (glasses Corning A and D) to confirm accuracy.

Results

Low power microscopy revealed a fine-grained matrix that in all but two of the samples is highly vitrified. The un-vitrified samples are also different in terms of colour and the size and appearance of the inclusions.

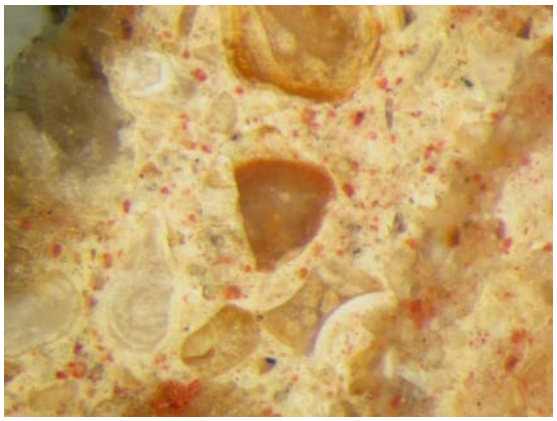

Fig 2. Un-vitrified body x40

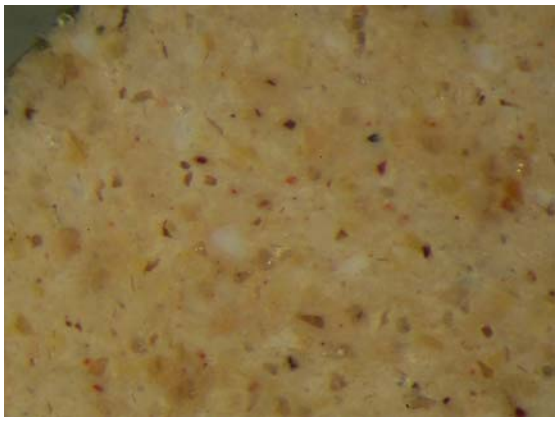

Fig. 3. Vitrified body x 40

This can be explained by the fact that some of the fragments submitted for analysis were loose pieces associated with both the statues and not actually removed from them, and these included the un-vitrified samples (one from each statue). Thus the identification of the non-vitrified samples as being fragments of the original Coade Stone statues is purely circumstantial and is further called into question by their obvious

physical difference. The largest piece analysed, the fragment from the base of the South Figure, has a partial surface coating that appears as a quite distinct layer, although it is also heavily vitrified (Fig 4).

Fig. 4. Optical micrograph of fragment of the base of the South Figure showing surface coating.

Various non-plastic inclusions are visible and included quartz, flint and pieces of grog, all consistent with the earlier study.

The XRF chemical analysis of the samples was obtained by focussing the X-ray beam on small areas of matrix between the largest inclusions. Several locations were chosen and the data presented (Table 1) are the average values. Some of the larger grog inclusions were also analysed.

Table 1. Semi-quantitative XRF analyses

Sample description	Na2O3	MgO	Al2O3	SiO2	K2O	CaO	TiO2	Fe2O3
South Figure base	0.6	1.4	26	65	1.7	0.2	2	2.3
South Figure base edge	0.0	1.1	25	66	1.8	2.6	1.9	2
South Figure 1	2	0.4	2.7	17	0.8	71	0.9	4
South Figure 2	0.7	1.9	21	66	2	3.8	1.9	2
South Figure base grog	0.7	0.9	18	74	1.5	0.1	2.3	1.4
South Figure base grog	0.4	1	15	79	1.4	0.1	1.3	1.4
North Figure base	0.9	1.3	26	65	2.1	0.3	2.0	2.6
North Figure 1	0.9	1.5	25	65	2.0	0.4	1.8	2.2
North Figure 2	1.1	0.3	2.4	21	0.9	69	0.5	3.7
North Figure grog	2.3	1.9	24	64	2.1	0.1	2.0	1.6

The main feature of these data is the very different composition of South Figure 1 and North Figure 2 compared to the rest of the samples. These are the samples picked out as different by microscopic study and are characterised by the high lime and low alumina and silica contents; the samples can be classified

as lime mortar and not Coade Stone. The remainder of the bulk analyses (the Coade Stone samples) are all broadly the same and are in close agreement with the bulk figures given by Freestone et al. (1984). The additional surface layer on the base of the South Figure (designated 'edge' in the table and illustrated in Fig. 4) is of similar composition to the bulk although containing a larger amount of lime, and is probably a fine finishing layer added to the surface of the base prior to firing.

The grog fragments set within the matrix are generally less than 0.2mm across, although there are some much larger pieces. Under the SEM the grog can be distinguished from the matrix in backscatter mode as it has a slightly higher average atomic number and so appears slightly lighter (Fig. 5). The grog is also distinguishable by the degree of vitrification with some pieces having large bloating pores indicating that it had initially undergone firing at higher temperatures.

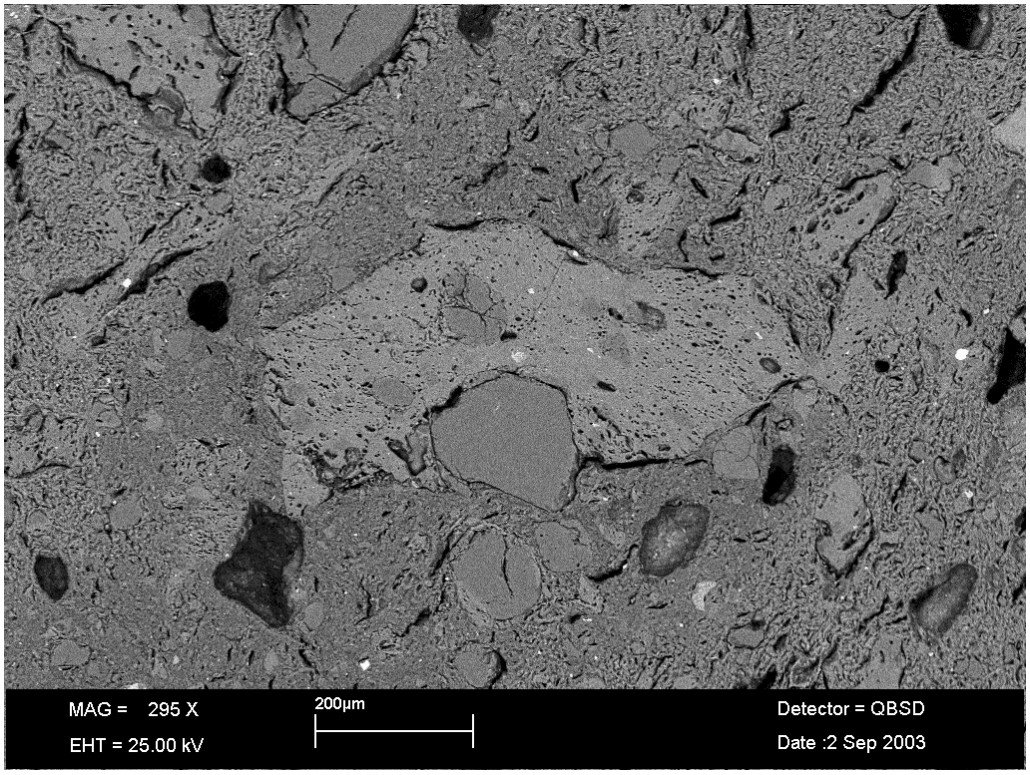

Fig. 5. Note smaller grog inclusion with large bloating pores to the upper right and very top left.

The composition of the grog is generally similar to the matrix, although the more vitrified pieces tend to be richer in silica and the calcium contents are generally lower. This observation is again consistent the work of Freestone et al. (1984).

SEM-EDS was used to analyse inclusions as well as the bulk composition, selecting areas 100 microns square between inclusions for the latter. This probably gives a better indication of the matrix composition as the area can be identified as free from inclusions with greater certainty than is possible with the XRF.

Inclusions in the lime mortar were analysed and found to be made of calcium carbonate. Bright areas observed in grog inclusions in backscatter mode were identified as titanium-rich.

Table 2. Quantitative SEM-EDS analyses

Sample description	Na2O3	MgO	Al2O3	SiO2	K2O	CaO	TiO2	Fe2O3
South Base (mean)	0.41	0.54	26.54	67.20	2.19	0.30	1.43	1.24
South Figure (mean)	0.84	0.72	30.97	61.01	3.08	0.96	1.27	1.09
South Figure base grog 1	0.43	0.4	21.73	72.2	1.46	0.13	1.22	1.08
South Figure base grog 2	0.77	0.64	31.15	58.84	2.78	0.11	1.13	1.31

Discussion

The similarity of the West Dean Coade Stone and the Lyme Regis Coade Stone analysed by Freestone et al. is strong. The only significant differences are that the West Dean Coade Stone contains less lime and soda and the titanium levels are the same in both matrix and grog. The differences in lime and soda may reflect the use of flint with less chalk adhering (less calcareous) or possibly a slightly lower amount of glass being added as a vitrification agent. The increased compositional similarity between the grog and the matrix may also suggest that at this time crushed Coade Stone was being used instead of or together with crushed stoneware. No quantitative estimate of the relative proportions of the non-plastic inclusions could be made, although visual comparison with the published photomicrographs certainly suggests very similar proportions are present in the West Dean and Lyme Regis Coade Stone. Certainly the composition of the Coade Stone is very consistent for all the West Dean samples, and also for the earlier piece from Lyme Regis and suggests that the recipe was followed closely. The use of similar raw materials can be postulated, with some minor variation in flint and glass suggested by the slight difference in lime and soda contents. Firing temperature was not investigated, although the visual examination showed that similarly high temperatures to those identified by earlier workers must have been employed.

The identification of two of the fragments initially thought to be of Coade Stone as lime mortar is also significant. They relate to recent conservation and restoration attempts and show that both statues had been treated in a similar way.

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