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Summary

Excavations in the Roman fort and its annexe discovered some 65 kg of iron smithing debris. A large quantity (c.30 kg were retained) of litharge cakes were also found. The latter are a by-product of extracting silver from argentiferous lead and are only known from a very few Roman sites in Britain.

Authors' addresses :-

Dr J Bayley
ENGLISH HERITAGE
23 Savile Row
London
W1X 1AB

Mrs K Eckstein
INSTITUT FR METALLKUNDE
TU Bergakademie
Gustav Zeuner Strasse 5
09599 Freiberg
GERMANY

Metalworking debris from Pentrehyling Fort, Brompton, Shropshire

Justine Bayley and Kerstin Eckstein

Introduction

Excavations within the Roman fort at Pentrehyling, and in the annexe on its south side, have been undertaken over a number of years by the Central Marches Archaeological Research Group (CMARG) under the direction of John Allen. More recently CMARG and Birmingham University Field Archaeology Unit jointly undertook an archaeological evaluation of a cropmark complex at Brompton, which included the fort, in advance of a road widening scheme.

Excavations produced some 65 kg of debris from iron smithing operations. Nearly 40 kg came from the annexe and a further 25 kg from inside the fort (Evans and Ferris 1992, 6). This is to be expected on any site of this type and date; its presence is not unusual. The finds examined included a few smithing hearth bottoms, amorphous pieces of smithing slag (much of it silica-rich and of low density), fuel ash slag and vitrified clay hearth lining. Hammer scale is also recorded from the site (Allen 1993, 14). The presence of these finds suggests iron smithing was carried out in or very close to the excavated areas. A large stone, almost certainly used as an anvil for smithing, has also been recognised; it came from Pit 3725 (Allen 1993, 11). Considering the total area excavated, this is a significant but not very large collection of material. There was no evidence of iron smelting.

The other group of metalworking debris from the site comprised fragments of litharge (lead oxide) 'cakes', which have not often be recorded and are thus of more intrinsic interest than the iron slags. The material is a by-product of extracting silver from lead. Much of it was found dumped in a group of pits in the annexe (Pits X in Trench 31). Over 30 kg were retained (Evans and Ferris 1992, 6) though a significant amount of further material was re-buried on site (J Allen, pers comm). Further fragments of litharge were also discovered in Trench 5 (Cane and Allen 1989, 7) though the total weight of this material was under 2 kg.

A number of features discovered in the course of the earlier excavations were provisionally described as 'furnaces'. Many of these features are situated in deep pits where both an adequate air supply and access to work them are difficult to arrange. There is no direct evidence associating them with either iron smithing or lead cupellation.

Silver extraction

Most silver sources in Britain are lead ores that contain some silver. Modern analyses of surviving ore bodies suggest their silver content is too low for its extraction to be viable, though Tylecote (1986, 69) notes that the silver content of lead ores is generally higher in the upper layers of a deposit. Richardson (1974) commented that "The Romans were lucky in working a number of lead deposits that had not been developed before ... and thus mined the silver-rich upper portion of the orebodies". The lead deposits at Shelve, Snailbeach and other sites in the area between Pentrehyling and Wroxeter are known to have been mined, apparently for the first time, by the Romans (Haverfield 1890-91, Scarth 1875). The finds of litharge cakes from Pentrehyling and also from Wroxeter (Bushe-Fox 1914, 11) show silver extraction took place in the Roman period, so the locally-produced lead must have contained sufficient silver to make this extraction economic.

The first step in extracting silver from a lead-silver ore is to smelt the ore. The product is metallic lead containing silver; the silver concentrates in the metal rather than in any slags. The silver is then recovered from the lead by cupellation, a process carried out at about 1000°C. It involves the oxidation of the lead to litharge (PbO), which is skimmed off the melt, lost as fumes or absorbed by a bone-ash or lime-rich (marl) hearth lining; the unaltered silver is left behind on the surface of the hearth. Gowland (1900) describes the operation of cupellation hearths and illustrates a reconstruction of one, based on Roman finds from Silchester and 19th century ethnographic evidence (*ibid*, Figs 2 and 3), though it should be noted he is dealing with smaller-scale silver-refining rather than primary silver extraction.

Lithage cakes

The litharge cakes found at Pentrehyling are examples of litharge-impregnated hearth linings. The more complete examples are all fairly flat with slightly convex under surface and a sunken area in the centre of the upper surface, which is where the silver would have solidified (Fig 1). They were somewhat irregular in plan, with diameters of around 0.5 m and are typically about 40 mm thick (Fig 2). The protruding edge of the step round the sunken area is quite rough and was probably chipped away deliberately as part of the silver extraction process. This part of the litharge cake is where some silver was likely to have been trapped so it would have been worth removing it and adding it to the next batch of lead that was desilvered.

Most archaeological finds of litharge cakes come from sites far from lead-silver sources (Bayley and Eckstein 1997, Fig 2). Although they were also the by-product of cupellation, the metal being cupelled was not silver-rich lead but debased, re-cycled silver. The metal was refined by melting it with lead and oxidising the lead to lithage, which dissolved the copper and other base metals from the silver. The litharge that soaked into the hearth linings in these cases thus contained significant amounts of copper and other metals, in contrast to litharge from primary extraction sites like Pentrehyling. The silver-refining litharge cakes are typically only 100-200 mm in diameter, but still roughly circular in plan with a depression in the upper surface.

Scientific analysis of litharge samples from Pentrehyling

The litharge cakes were all a pale buff-grey colour, on both original and fracture surfaces. The surface layer was powdery and X-ray diffraction (XRD) analysis showed it to be cerussite (lead carbonate, $PbCO_3$), a typical decay product found on buried lead in damp, temperate climates. A cut surface revealed that the bulk of the litharge cake had a bright orangey-red colour, typical of litharge (lead oxide, PbO) whose presence was also confirmed by XRD.

A thin section cut from one edge of a litharge cake fragment supplied by John Allen (Figs 1 and 2) was examined using both optical and scanning electron microscopy (SEM). Area analyses spanning the thickness of the litharge cake were made using the energy-dispersive X-ray analyser on the SEM; the results are given in Table 1. These show that the hearth lining had not been made of bone ash; the CaO/P_2O_5 ratio was far higher than the 1.0-1.5 that is typically of bone ash. The high levels of alumina (Al_2O_3) relative to other analysed litharge cakes shows the hearth lining used at Pentrehyling was a clay-lime mixture. The litharge had partly reacted with the hearth lining forming other minor silicate phases which were identifiable in thin section but were not present in sufficient quantity to be detected by XRD.

Table 1: EDX analyses of the litharge cake section (wt%)

Area analysed	SiO_2	Al_2O_3	CaO	MgO	K_2O	PbO	P_2O_5	CaO/P_2O_5
upper	3.6	0.5	1.8	ND	ND	93.7	0.4	4.3
upper	6.4	1.1	4.8	ND	ND	87.1	0.6	8.5
upper middle	6.6	3.6	11.5	0.7	ND	77.2	0.4	28.0
middle	6.7	2.6	9.2	0.4	0.8	80.3	ND	
middle	7.4	2.6	9.0	0.5	0.8	79.1	0.5	17.1
lower middle	10.7	2.7	9.7	0.5	1.0	74.9	ND	
bottom	5.9	0.9	7.1	ND	ND	81.3	0.4	19.3

Note: 1) Copper, tin and lead were sought but not detected in any of the areas.
2) The area at the bottom also contained 3% FeO, 0.9% TiO_2 and 0.5% MnO.
3) ND = not detected

Comparative data

Only three other Roman sites in this country — Chew Park (Rahtz and Greenfield 1977), Herriott's Bridge (*ibid*) and Green Ore (Ashworth 1961-2), all near the Mendips — are said to have produced litharge from primary silver extraction. In no case does the published data give a good idea of the quantities found. All other reported litharge finds contain significant quantities of copper (*eg* Bayley and Eckstein 1997) and so cannot have derived from the primary extraction of silver from argentiferous lead.

Chew Park and Herriott's Bridge are about 1 km apart in the area flooded by the Chew Valley Lake. The distribution of finds was used to suggest that the lead ore was smelted at the former site but that desilverisation was carried out at the latter (Rahtz and Greenfield 1977: 353). Most of the litharge found was described as having solidified in stalactite drips (*ibid*: 361), presumably having been raked over the edge of a cupellation hearth. No fully quantitative analyses were undertaken, but spectrographic analyses suggested a piece of litharge from Chew Park contained 0.1-0.5% Si, Al, Cd, Mg, Fe, Ni and Mn; silver was present at *c* 0.001%. By comparison the silver contents of galena and material described as 'extracted galena' from the same site was 0.1-0.5%, showing most of the silver had been separated from the litharge.

Conclusions

The presence of litharge cakes at Pentrehyling indicates that the lead ores mined from the local deposits by the Romans must have contained sufficient silver to make its extraction economically viable. As the site is a fort, it would appear that there was some official/military interest in the silver production. However, the main dump of litharge came from the area of the annexe which suggests the process may not have been carried out directly by the military.

Acknowledgement

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Fig 1: Photo of the analysed lithage cake fragment. The left hand edge is the original rim of the cake. Note the step in the upper surface marking the edge of the sunken central area (to the right).

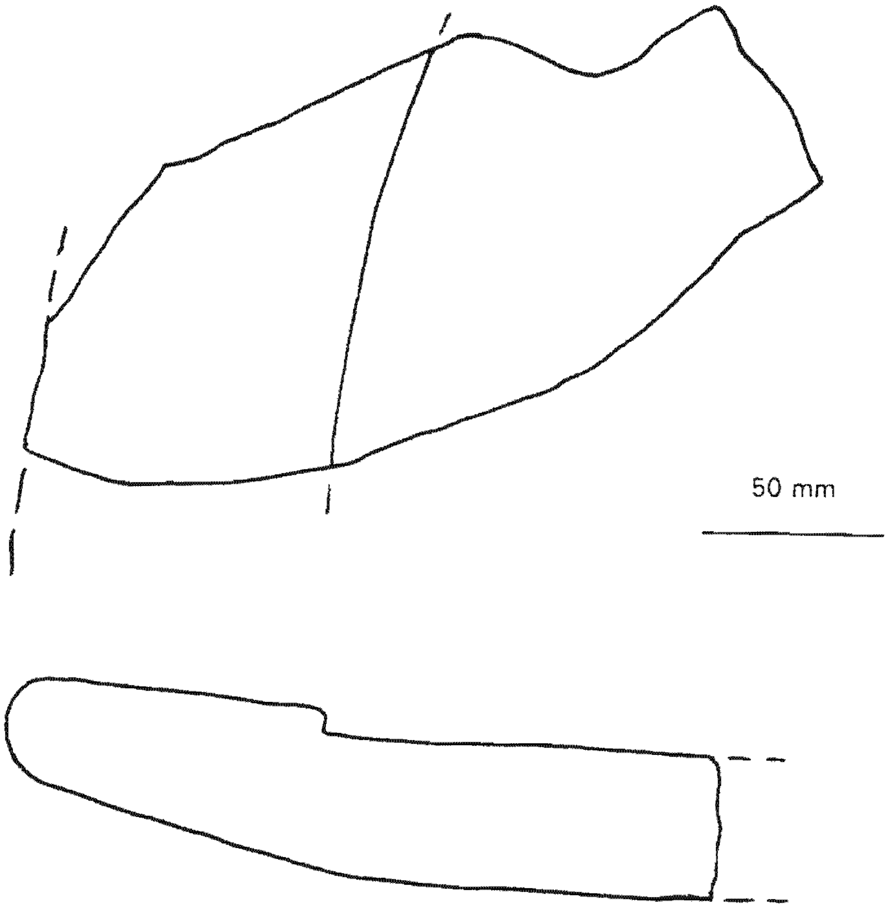

Fig 2: Sketch plan and section of the analysed lithage cake fragment. The left hand edge in the drawing is the original rim of the cake. The section was cut from the edge shown top centre in the plan, spanning the step in the upper surface.