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RE-EXAMINATION OF FERROUS AND NON-FERROUS METALWORKING DEBRIS FROM GLASTONBURY LAKE VILLAGE

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Summary

The 1892-1907 excavations at the late Iron Age site of Glastonbury Lake Village produced a range of debris from high-temperature industries. A re-examination of these finds provided further evidence about the ferrous and non-ferrous metalworking at the site. Most of the slag is thought to relate to ironsmithing, rather than iron smelting; however, some dense ironworking slags were also noted. The evidence suggests that ironworking was carried out at a low level of intensity. The non-ferrous metalworking evidence demonstrates that copper alloys (probably bronzes) were melted and cast. Two types of crucible were identified, with higher concentrations noted in two locations; the different crucible types are likely to have been used for different processes. Another type of ceramic vessel was also examined and may have been used for high temperature purposes. There is no certain evidence for making lead, tin or lead-tin objects. Ferrous and non-ferrous metalworking were located in three cases; elsewhere the non-ferrous evidence was more broadly scattered than the ferrous evidence.

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Introduction

Glastonbury Lake Village, Somerset, excavated by Bulleid and Gray between 1892 and 1907 pioneered wetland archaeology in Britain. Evidence from the late Iron Age settlement included debris from both ferrous and non-ferrous metalworking. The exact nature of this activity is not made clear in the original publication of the site[1] where the term 'smelting' is applied to any high temperature process involving metals. In this report **smelting** is used in its more specific current usage; to indicate the primary production of a metal from its ore, **smithing** refers to the hot working of metals, whilst **melting** indicates heating prior to casting of (in this instance, non-ferrous) objects. Similarly, Bulleid and Gray use the term 'furnace' for any structure in which high temperature metal processing appears to have been carried out. This report will follow the current convention in which a **furnace** is an enclosed structure for the smelting of metal ores and a **hearth** is a much more open structure without specific purpose, unless further qualified, for instance as a **smithing hearth** for the hot working of iron. The fired clay structures described in the original report would therefore be termed hearths. In the absence of samples from these hearths, which could be checked for any vitrification resulting from temperatures in excess of those expected in domestic hearths, metalworking activities in them can only be identified from any closely associated metalworking debris.

The surviving 'slag' totals 6kg, a relatively small amount for any but very short term ironworking activity. The stored material appears to match the descriptions given in the report although the slag was quantified there only in the most general terms, such as 'some fragments'. It seems reasonable to assume that the assemblage has survived complete, however, the effectiveness of the excavators in recovering slag is not known. Contextual descriptions are, at best, to mound number and floor level but more commonly only to mound number. Approximately one third of the slag was unstratified. The assemblage is reported to have included unfinished items of iron, but no specifically metalworking tools have survived to be listed in the report.

It is not known whether the recorded non-ferrous metalworking debris is representative of the total assemblage at the site. It seems likely that most ceramic material would have been retained, since pottery has long held an important place in archaeological studies. However, it is curious that most of the crucible fragments are relatively large and it is probable that further small pieces were overlooked during excavation. Bulleid and Gray clearly recognised the importance of the crucible finds and devoted some effort to considering their significance, although there was little comparative material known at the time. No moulds were recovered or recognised at the site; mould fragments may not have survived because they are not as highly-fired as crucibles. Fragments from 25 'crucibles' (the term includes pieces unlikely to have been used in metalworking, see below) and 4 pieces of metalworking dross were examined. The metal content of 17 lead, tin and lead-tin objects was also determined; this includes two bars, a piece thought to be ore and an amorphous piece, all of which may have some relation to metalworking.

Slags and ferrous metalworking debris

All available slag was examined visually, classified to type and weighed separately as follows:

Table 1: Summary of metalworking debris from Glastonbury Lake Village

context	weight (g)	interpretation	comments
Mound 62 D30	2220	tuyère block	
Between mounds 4 & 5	467	vitrified hearth lining	
Mound 5	1123	vitrified hearth lining	
Mound 5	5	fuel ash slag	
Mound 5	51	cinder	
Mound 5	49	ironworking slag	
Mound 5 W.	108	ironworking slag	
Mound 5 W.	13	ironworking slag	
Mound 5 W.	84	vitrified hearth lining	
S. of mound 67	84	vitrified hearth lining	
Mound 71	265	smithing hearth bottom	85x85x40mm
Mound 75, base of	224	dense ironworking slag	
Mound 75, base of	117	frag. smithing hearth bottom	
Mound 75, base of	30	fuel ash slag	
Mound 75, base of	68	vitrified hearth lining	
Mound 75, base of	28	cinder	
Mound 75, base of	80	ironworking slag	
Mound 76	220	smithing hearth bottom	105x80x40mm cindery
Mound 76	357	smithing hearth bottom	105x80x50mm
Mound 76	295	vitrified hearth lining	
Mound 76	115	fuel ash slag	
Mound 76	84	frag. smithing hearth bottom	

Table 1: Summary of metalworking debris from Glastonbury Lake Village

context	weight (g)	interpretation	comments
Mound 76,surface of clay hearth on floor 3	1	fuel ash slag	
Mound 76, floor 2 (1906)	383	ironworking slag	
Mound 76, floor 2 (1906)	36	vitrified hearth lining	
U/S	235	smithing hearth bottom	95x80x35mm very cindery
U/S	184	smithing hearth bottom	100x80x35mm very cindery
U/S	228	smithing hearth bottom	100x85x35mm very cindery
U/S	741	ironworking slag	
U/S	203	fragments of tuyère block	2 adjoining
U/S	543	vitrified hearth lining	
U/S	147	cinder	
U/S	50	dense ironworking slag	
U/S	7	fuel ash slag	

Table 2: Slag weight totals

slag type	kg
smithing hearth bottoms	1.69
dense ironworking slag	0.27
undiagnostic ironworking slag	1.37
tuyère block	2.42
vitrified hearth/furnace lining	2.70
cinder	0.23
fuel ash slag	0.16
total	8.85

The most diagnostic debris was that classified as **smithing hearth bottoms.** These slag blocks are recognisable by their characteristic plano-convex form, having a rough underside and a smoother, vitrified upper surface often hollowed as a result of downwards pressure from the air blast of the tuyère. Hearth bottoms are normally largely fayalitic (iron silicate) in composition, resulting from high temperature reactions between the iron, iron scale and silica from either the sand used as flux or from the hearth lining during the smithing *ie* hot working of iron. The Glastonbury smithing hearth bottoms were unusual in being poorly consolidated, being easily broken apart by hand. Qualitative x-ray fluorescence (XRF) analysis showed unusually high levels of calcium, phosphorus and sulphur. The enhanced contents of these elements might be explained by the use of peat as a fuel during ironsmithing, analyses[2] have shown peat to have higher levels of these elements than charcoal. The weight and dimensions of these six smithing hearth bottoms are also very small in comparison to those of any other period.

Table 3: Glastonbury Lake Village smithing hearth bottom dimensions

	range	mean	std dev
weight (g)	180-360	250	50
length (mm)	85-105	100	10
width (mm)	80-85	80	2
depth (mm)	35-50	40	5

The contrast between the crumbly smithing hearth bottoms and the **dense iron working slags** suggests that the latter may derive from a different process. Similar material is known to be produced during iron smelting, *ie* the primary production of metallic iron from its ores. However, the limited quantities of this category and lack of supporting evidence would imply that iron smelting was not being carried out in the immediate locality of the excavation.

Another major component of the assemblage was that initially classified as undiagnostic **ironworking slag** because it could not be attributed to either smithing or smelting on morphological grounds. This material was, however, sufficiently similar to the 'crumbly' hearth bottoms to suggest that its origin was also iron smithing.

The largest category by weight in the assemblage was that identified as **tuyère block**, the remains of removable fired clay nozzles for the inlet of air into a furnace or hearth. Item D30 consisted of a largely complete tuyère block, the furnace end of which had been reconstructed with plaster of paris preventing examination of any heat/slag modified structure. Three further fragments of tuyère block (two of which could be fitted together), from an unstratified context showed moderate vitrification on the surface. It was not possible to determine the high temperature process from which these derived. A further tuyère block (D78) was also found at the site but has not survived for examination.

Another large component of the assemblage was the **vitrified hearth/furnace lining** which may derive from structures used for iron smelting, iron smithing or other high temperature processes and is therefore not diagnostic. The material forms as a result of high temperature reactions between the clay lining of the hearth/furnace and the alkali fuel ashes or fayalitic slag. A compositional gradient from unmodified clay on one surface to an irregular cindery material on the other may be evident. An associated material, classed as **cinder,** comprises only the lighter portion of this, a porous, hard and brittle slag formed as a result of high temperature reactions between the alkali fuel ashes and either fragments of clay which had spalled away from the hearth/furnace lining or another source of silica, such as the sand used as a flux during smithing.

Much smaller amounts of material were classified as **fuel ash slag**, a very lightweight, light coloured (grey-brown), highly porous material which results from the reaction between alkaline fuel ash and silicates from soil, sand or clay at elevated temperatures. The reaction is shared by many pyrotechnological processes and the slag is not diagnostic.

The largest number of diagnostic ferrous metalworking finds came from Mounds 5, 75 and 76, comprising 49% of the extant sample by weight (86% when only stratified material is considered). The number of finds is insufficient to suggest any difference in assemblage type between these three mounds. Vitrified hearth lining, fuel ash slag and cinder were also found mainly in these mounds, where stratified.

Non-ferrous metalwork and metalworking debris

Three types of fired pottery which had been classified as metalworking **crucibles** by the excavators, were examined. Although a representative sample remains for investigation, several of these finds now cannot be located. Metalwork from the site was not examined.

The most obvious metalworking crucible debris consists of fragments from vessels which are triangular in plan (**type 1** in Table 4). At least seven and originally up to nine examples of these crucibles came from Mound 5, where a tuyère (D78) and other high-temperature debris were also discovered (see above). Findspots for the other type 1 crucibles were scattered across the settlement, with two examples being found in Mound 76, three in Mound 44, two in Mound 74 and five other individual finds from various mounds. The fabric of these crucibles is generally rather friable, except at the edges of some examples, where vitrification has taken place.

The second most common form of fired pottery is the thumb pot (**type 2** in Table 4), of which six provenanced examples are known, three from Mound 62 and three others from other mounds. These are of various sizes, some very small (*eg* C14, 20mm high) and others rather taller (*eg* C9, 44mm high). These pieces are not heavily vitrified but they are, at least in part, reduced fired (some are oxidised fired at the base).

There are also three examples of a square-sided vessel form (**type 3**), which may also have been used for high-temperature purposes. Two of these were found in Mound 62, as was an unusual small pot (C12), possibly with a handle, which may have been used in high-temperature work. These pieces are not highly vitrified but are instead oxidised fired; this suggests that these examples are unlikely to have been used in metal melting procedures.

The association of the tuyère D30 with the thumb pots C9-C11 may be significant. Conversely, the lack of association between type 1 and type 2 crucible forms may also have some significance.

Type 1 and 2 crucibles are typical of those found in other Iron Age contexts[3] but parallels for the type 3 vessel form are not known.

All available fragments were submitted to surface XRF analysis in an attempt to identify types of metalworking that were carried out at the site. Analysis was concentrated on areas with evidence of vitrification or metal deposits. Many of the analyses did not demonstrate substantial evidence for non-ferrous metalworking activities; this may be due to surface loss during deposition, to washing after discovery or to metalworking processes which leave little trace on the available surfaces. Where pieces are oxidised fired, it is unlikely that metal melting was carried out.

Table 4: Complete ceramic vessel listing, including fragments no longer extant, but recorded by Bulleid and Gray

Number	Context	Type	Elements
C1	22	1	Cu Sn
C2	23	3	-
C3?	44	1?	Cu Sn (Pb
C4	44	1	Cu Sn
C5	45	1	Cu (Pb)
C6	44	?	Not extant
C7	24	1	Sn Cu Pb (Zn)
C8	62	3	(Cu)
C9	62	2	-
C10	62	2	Not extant
C11	62	2	Not extant
C12	62	Small, handle	-
C13	62	3	(Cu)
C14	64	2 small	(Cu)
C15	5	1?	Cu Pb (Sn)
C16	4,1	2?	Zn
C17	5,2	1	Cu Pb Zn (Sn)
C18	5,iv	1	Zn
C19	5,iv	1	Cu
C20	5,iv	1	-
C21	5	1	Cu Zn (Pb)
C22	5	1	Not extant
C23	5	1	Not extant
C24	5	1	Not extant
C25	71,2	1	Zn (Cu)
C26	76,2	1	-
C27	76,2	1	Cu Pb (Sn)
C28	74	1	Not extant
C29	74,4	1	Cu Pb (Zn)
C30	75	?	Not extant
C31	?	1	Not extant
C32	16	?	Not extant
C33	73	1	Not extant
C34	29	1	**Cu Sn** Pb
D49	?	2 large	Zn (Cu) (Pb)
D50	72	'funnel'	Not extant
D57	5	2 small	(Cu)
D63	3	2	Not extant

Codes for Table 4:
Number = published number (Bulleid and Gray 1911, 305-309); some of the attributions have become unclear. Context = Mound number (here given in arabic not roman numerals), followed by floor number, where known (5,iv is probably the same as 5,4).
Elements: Cu = copper, Sn = tin, Pb = lead, Zn = zinc. Iron was detected in all samples analysed and is therefore not noted separately.
All peaks relatively weak except those in **bold**, which are strong and those in brackets which are very small.

Type 1 (triangular) crucibles show the clearest evidence for copper-alloy working at the site. Analysis showed that many of the fragments have traces of copper, tin, lead and zinc on their surfaces in varying proportions; iron is normally present in clays and therefore in crucibles. The proportions of the elements detected are unlikely to be helpful in establishing the exact type of metal used. Zinc is a volatile element (it 'boils off' on heating) and a glass-forming element, so small amounts of zinc are often present, even amongst bronze working debris; copper alloys containing significant amounts of zinc are unlikely to be found at this period.

The type 2 (thumb-pot) and type 3 (square-sided) vessels show very low levels of non-ferrous metal concentration on the surfaces available for analysis (inside surfaces could not be analysed). Some of the metals detected may be present because of contamination in the burial environment. It is possible that a different type of metalworking - at lower temperatures - was carried out in these vessels or that they were not used. The oxidised-fired examples are unlikely to have been used in metal melting.

The non-ferrous metalworking carried out on the site is most likely to have been copper-alloy melting and casting. Bronzes (copper-tin alloys) are the copper alloy most likely to have been used.

Four pieces of amorphous non-ferrous **dross** were examined and analysed using XRF. A further eight fragments were recorded at the site but were not submitted for analysis.

Table 5: Complete listing of non-ferrous dross, including fragments not examined, but recorded by Bulleid and Gray

Numbers	Context	Elements/comments
E36	62	**Sn** (Pb)
E80	44	Not extant
E172	5	**Cu** Sn (Pb)
E184	30	Not extant
E214	20/42	Not extant
E226	44	Not extant
E235	71	Not extant
E253	74	**Cu Sn** Pb
E256	76,1	Not extant
E266	74,4	Not extant
E268	75,3	**Cu**
E271	75,2	Not extant

Codes as above. Zinc was not detected in any of the pieces. Iron was detected in all cases, as a contaminant from the soil.

Such metal droplets are often found at non-ferrous metalworking sites, indicating the spillage of small amounts of metal during casting. Analysis of the four extant pieces confirm that bronzeworking took place in or around Mounds 5, 74 and 75. The distribution of the recorded dross fragments conforms with the general pattern noted for the crucible distribution above, with activity being additionally represented at Mounds 30 and 20/42. There are slight indications of correlation between dross composition and ceramic form/use; Mound 62 produced a piece of tin-rich dross together with type 2 and type 3 fragments, Mounds 5 and 74 both produced a piece of copper- and tin-rich dross and type 1 crucibles. This could be taken to strengthen the argument that the different 'crucible' forms were used for different processes, but the data is by no means conclusive.

No other debris indicative of casting (eg casting sprues, miscasts) was found at the site; recycling may have been employed, ensuring that most scrap metal was recovered and reused.

Many **lead, tin and lead-tin objects** were recovered from the site. A selection was submitted for analysis.

Table 6: Extant lead, tin and lead-tin alloy objects

Number	Context	ID	XRF/comment
L2	Causeway	Sinker	**Pb** (Cu)
L3	Causeway	Sinker	**Pb**
L11	44	Bar	**Pb Sn**
L13	Palisading	Whorl	**Sn** (Pb) (Cu)
L15	7	Ring	**Pb**
L20	18	Whorl	**Pb Sn** (Cu)
L23	11,2	Lump/dribble?	**Sn Pb** (Cu)
L26	6	Pendant	**Sn** (Cu)
L29	4,1	Whorl	**Pb Sn**
L31	Causeway	Sinker	**Pb**
L39	83	Whorl	**Pb**
L40	Causeway	Sinker	**Pb**
L43	Causeway	Sinker	**Pb**
L46	?	Roll/weight	**Pb**
L48	?	Ore	**Pb**
L49	75,4	Bar	**Sn** (Pb)
L50	7	Bar/sceptre etc.	**Sn** (Pb) (on main body) **Cu Sn** Pb (Zn) (at end)

Codes as above. Iron was present in all samples, although at a lower level than in the copper-alloy dross.

The original excavation report successfully identified the alloy type in most cases. Some compositional patterning can be detected amongst these objects. The five 'sinkers' are made of lead, with traces of copper occasionally detected. Apart from the sinkers, there are three objects made out of pure lead, or lead with only traces of tin or copper (a spindle whorl, a roll and a ring) and a fragment labelled as 'ore'. The 'ore' is unlikely to have been galena, since it did not have the characteristic cubic form, but may have been the product of a metal refining process. Three objects are made out of tin, or tin with only small amounts of lead or copper (two bars - including the 'sceptre', see below - and a spindle whorl). Four objects have substantial amounts of both lead and tin present (two spindle whorls, a lump/dribble and a bar). The 'sceptre' (L50) is confirmed as being a tin bar with leaded bronze terminals. It is not possible to determine the precise composition of the bronze, without further sampling; the heavy corrosion in this area suggests the sampling would have to be very destructive indeed. The surface analysis did not reveal any gold, which had been detected during the earlier investigations, nor is there any visual evidence for gilding.

The four spindle whorls are made of three different types of metal. This could suggest that tin and lead were not clearly differentiated at this time, both having low melting temperatures and being malleable at room temperature; however, the five sinkers are all made of lead. The lump of lead ore (L48) and the tin-lead lump/dribble (L23) with a 'melted' appearance suggest that lead may have been exploited and tin-lead alloys may have been worked at the site, although none of the analytical evidence from crucible fragments confirms this. Unusual characteristics of ore fragments (visual appearance and weight) may have caused L48 to be retained out of curiosity, rather than for use and L23 may be an accidentally-melted object, since tin-lead alloys melt at low temperatures, which are found in a domestic fire. None of the findspots for the lead, tin and lead-tin objects has any significant correlation with findspots for non-ferrous metalworking debris.

Conclusions

The metalworking slag assemblage from Glastonbury Lake Village, although of small size, contained a variety of ironworking debris. The only fully diagnostic slags were those associated with ironsmithing, *ie* hot working of iron, and it is likely that most of the undiagnostic slags also derive from smithing rather than smelting activities. The only possible evidence for iron smelting was a few uncharacteristically well consolidated 'dense ironworking slags'. The surviving assemblage from Glastonbury is insufficient to support suggestions that iron smithing and particularly iron smelting were important activities on the site, which would have produced much larger quantities of metalworking debris. Mounds 5, 75 and 76 are likely to have been the foci for this activity.

The non-ferrous metalworking evidence is sufficient to suggest that copper alloys were melted and cast at the site. Three types of fired pottery were identified, two of which were likely to have been crucibles and the third possibly for another type of high-temperature industry. The two different types of crucible may have been used for different processes.

Mounds 5 and 62 are likely to have been the foci for the non-ferrous activity. Different forms of crucible prevail at each of these Mounds; the largest concentration of the crucible form with strong evidence for copper-alloy melting (type 1) was found in Mound 5. Finds from Mounds 75 and 76 also constitute significant groupings. There is a broad scatter of crucible finds in other locations, some of which may relate to chance deposition/re-deposition, rather than metalworking activity at each location. There is no certain evidence for making lead, tin or lead-tin objects at the site. An unstratified find of lead ore may suggest some lead smelting at the site, but other explanations can be proposed.

Our evidence suggests that both ferrous and non-ferrous metalworking were carried out at three locations - Mounds 5, 75 and 76 - although there are relatively few recorded non-ferrous finds from Mounds 75 and 76. This supports the hypothesis that at least some of the non-diagnostic slags may have originated during non-ferrous metalworking and has implications for the interpretation of craftworking activities[4] at the site.

Notes

1. A. Bulleid and H.Gray, *The Glastonbury Lake Village Vol I and II* (The Glastonbury Antiquarian Society, 1911).

2. J. Percy, *Metallurgy; Fuels; Fire-clays; Copper; Zinc; Brass* (London, 1861), 76 and R. Tylecote, *The Prehistory of Metallurgy in the British Isles* (London, 1986), 224.

3. See *eg* Tylecote 1986 *op cit*, 96-100.

4. There is no evidence for glassmaking or glassworking at the site, although glassworking was discovered at the neighbouring site of Meare Village East (Henderson J *The archaeology and technology of glass at Meare Village* in Coles J M *Meare Village East; The excavations of A Bulleid and H St George Gray, 1932-1956* (Hertford, 1987), 170-182). Most of the glass at Glastonbury Lake Village is in the form of beads; a piece of fused glass (G23, Mound 70) and a lump of 'glass slag' (G27, Mound 65) may have been accidentally melted. These pieces were not examined in this study.