30/10/80

Colchester, Essex : Technological finds from the Sheepen excavations

Part 1: Descriptive catalogue

SLAG

AM No.	Site No.	Description
722379	94	Iron-rich fuel ash slag
722381	750	Hearth lining (thin)
722382	1338	Smithing hearth bottom
722383	1683	Smithing slag and fuel ash slag with copper alloy
722384	1404	Hearth lining (thick)
722385	1405	Smithing hearth bottom
722386	1406	Smithing slag
722387	1407	Smithing slag, fuel ash slag and hearth lining including a possible tuyere
722388	1408	Fuel ash slag
722389	1409	Hearth lining and iron-rich fuel ash slag
722390	1410	Smithing slag (denser than usual), hearth lining and iron-rich fuel ash slag
722391	1499	Smithing slag including a hearth bottom and hearth lining
722392	1767	Hearth lining and iron-rich fuel ash slag
722395	1770	Fuel ash slag and hearth lining with attached smithing slag
722397	1772	Fuel ash slag with copper alloy
722398	1773	Hearth lining
722399A	1775	Hearth lining, smithing slag and fuel ash slag
722399B	1776	Smithing slag
	slag 2	Smithing slag including a hearth bottom and hearth lining
	slag 3	Hearth lining, fuel ash slag and smithing slag
	slag 4	Fuel ash slag
	slag 5	Hearth lining and fuel ash slag with copper alloy
	slag 6	Smithing slag and fuel ash slag
	slag 7	Smithing slag including hearth bottoms and iron-rich fuel ash slag
	slag 8	Fuel ash slag and a tuyere with a hole of c.3 cm diameter
	slag 9	Hearth lining and smithing slag
	slag 11	Fuel ash slag
	slag 12	Fuel ash slag, hearth lining and smithing slag
	slag 13	Iron-rich fuel ash slag

Glossary of slag descriptions

Smithing slag is produced in relatively large quantities when iron blooms from a smelting furnace are forged down to make iron bars and also, in smaller quantities, when the bars are further worked and turned into objects. The smithing slag from this site is most probably of the latter type. Some of it is in the form of hearth bottoms, the solidified pool of slag that collects in the base of a forge hearth. Most smithing slag is very dark grey-brown, highly vesicular and relatively dense. Some of the slag from this site (eg 722390) is denser than normal and correspondingly less vesicular. This is usually an indicator of a higher than normal temperature in the hearth though this is not the only factor which affects the appearance of the slag.

Fuel ash slags are the products of the ash from a fire reacting with a siliceous material (usually clay or sand) at high temperatures. They are effectively accidentally formed glasses and are usually,

though not necassarily, associated with metalworking. They are relatively light in weight and may or may not appear glassy and/or vesicular. Iron-rich fuel ash slags are intermediate in properties between smithing slags and fuel ash slags and are usually an indicator of iron-working, though ash reacting with eg a ferruginous sand in a fire can also produce them. Some fuel ash slags contain blobs of non-ferrous metals (eg AM 722397) and some are coloured red in parts by traces of copper. Both these types suggest an origin in a copper alloy melting hearth.
A hearth is often just a hollow in the ground and the surface of the hollow that is in contact with the fire may become coated with fuel ash slag. Pieces of this hearth lining can be readily identified as they are vitreous on one surface and grade through overfired clay to ordinary baked clay on the other.* Sometimes pieces of hearth lining include what may be described as a tuyere - the opening where a bellows was put to blow up the fire in the hearth.

METALLIC IRON

AM No.	Site No.	Description
722380	174	Strip fragments
722383	1683	
722387	1407	
722392	1767	
	slag 1	Plano-convex bun
	slag 3	
	slag 5	
	slag 6	
	slag 9	Nails
	slag 10	
	slag 12	Bar of rectangular cross-section, tapering to one end (?cf a 'currency bar')
	slag 13	Nails
(from Pit 283)	AE 551	Fragments including sheet

Those pieces without a description are miscellaneous lumps and fragments without a discernable form. None have been x-rayed which might show more detail. They are listed here only because they were submitted for examination as part or all of a 'technological' sample. They are no more likely to be related to the iron-working on site than many of the 'iron objects' of similar size and lack of shape. Some may be offcuts or raw material (?slag 12) for the smith but others are objects (slag 9) or parts of them (AM 722380). The only piece of definite technological significance is the plano-convex bun (slag 1) which is described in detail in Part 2.

Insert at * above

The thickness of the lining depends mainly on the intensity of the fire; the hotter it is and the longer it is burning the more deeply altered is the hearth fabric and the thicker the resulting hearth lining (up to a limit of a few cm.)

COPPER ALLOY

AM No.	Site No.	Description
722382	1338	Blob
722383	1683	Dribbles
722397	1772	Blob with/in fuel ash slag
	slag 5	Blobs in fuel ash slag which is also coloured red in parts
722362	926	Dribble
722363	940	Dribble
722364	949	Pool
722365	977	'As cast' blowholey piece. The corner (or ?end) of a rectangular ingot, varying in thickness from 13-15 mm
722366	1044	Casting sprue - the surplus metal filling the runner and in-gate of a mould. The in-gate was about 2.5 cm square with an offset runner of approx. circular cross section (9-11 mm diameter). There is no trace of a flash line suggesting it was formed in an investment mould or in a runner bush temporarily attached to a piece mould.
	AE 551	Fragments of rod and sheet metal, some of the latter with rivets through it. Probably parts of broken objects, possibly for remelting and re-use. No definite off-cuts or folded-up packets of sheet noted but most of this material was deeply corroded and thus altered in size and shape since burial. Also a pool of spilt molten metal
(from pit 283)		Blob, D-section strip, square section rod and sheet fragments.
(from pit 164(1))		Small dribble

A number of these pieces have been examined metallographically and most have been analysed qualitatively by x-ray fluorescence. The results are given and discussed in Part 2.
In addition to the above finds the excavations also produced a large sheet of brass (AM 751820) which has already been published in some detail (Musty 1975).

CRUCIBLES

AM No.	Site No.	Description
722275	4	A nearly complete shallow hemispherical bowl (diameter 6 cm) with a pouring lip pinched out of the rim and walls c.7 mm thick (cf Hawkes and Hull 1947, Fig 65-1). The fabric is a reduced fired sandy ware with some larger semi-rounded quartz grits. There is a thick glassy layer all over the inside, over the rim and slightly down onto the outside. This is weathered on the surface but appears to be mainly green with patches of amber and especially opaque red near the rim. X-ray fluorescence detected mainly lead with small amounts of iron and copper. An area including two small metal droplets near the rim gave similar signals suggesting they were of lead. The crucible fabric appears little affected by heat except for two small areas near the rim which are slightly vesicular.

AM No.	Site No.	Description
722276	5	A rim fragment of a rather deeper vessel (cf Hawkes and Hull 1947, Fig 65-3) with a diameter of about 10 cm and walls 7-10 mm thick. It appears handmade and is reduced fired and of a similar fabric to AM 722275, though somewhat softer. The exterior surface shows slight traces of a vesicular structure but there is no evidence what, if anything, was melted in this vessel.
722277	6	Body sherd from a vessel of similar form and fabric to AM 722276. It is oxidised fired (but with a reduced core) and shows no sign of having been used as a crucible.
722278	7	Rim fragment with a pinched out spout from a vessel of thickness 5-9 mm and diameter probably over 10 cm. Fabric similar to AM 722276 and form again a hemispherical bowl (cf Hawkes and Hull 1947, Fig 65-2). There is a small glassy patch on the inside near the base but x-ray fluorescence analysis failed to detect any elements except those of the clay fabric so it is probably a fuel ash glaze (see glossary of slag descriptions). There is no evidence to suggest what was melted in this vessel.
722279	8	A body sherd from a (?)bag-shaped crucible with a maximum diameter of about 7 cm and wall thickness of c.9 mm. The fabric is similar to that of AM 722276 but the form cannot be paralleled among Hawkes and Hull's (1947) published crucibles, being relatively deeper and with the mouth smaller than the maximum diameter of the vessel. The exterior surface is vitrified, appearing pale green (colour due to iron from the clay fabric) with small red patches (colour due to copper). The outer third of the fabric is vesicular indicating that the crucible has been strongly heated from below. X-ray fluorescence detected iron, titanium (both probably from the clay fabric), copper and zinc on the inside surface.
722280A	10	Three rim sherds from three different vessels. (1) Fabric similar to AM 722276 and the form, a shallow hemispherical bowl, similar to those illustrated by Hawkes and Hull (1947, Fig 65), but with the difference that the rim of this example is not thinner than the rest of the vessel (c.13 mm). The crucible had a diameter of 10-13 cm and had been strongly heated, the fabric now being extensively vesicular near the rim and somewhat vesicular on its outer surface. The glassy deposit inside near the base was pale grey-green and similar to that in AM 722278. There was no evidence no suggest what had been melted in this vessel. (2) Form and fabric similar to AM 722275. The sherd was 7 mm thick and came from a crucible of diameter c.6 cm. It had a thick glassy deposit on its inner surface with a ridge of glass running parallel to the rim and about a centimeter from it, apparently the edge of a pool of molten glass it had contained. The glass appears dark but on closer examination it can be seen to be mainly amber coloured. Near the rim where the glass was thinner it appeared

AM No.	Site No.	Description
722280A (cont)		green with red patches. X-ray fluorescence analysis of the glass detected lead, tin and also some iron and copper. (3) Form and fabric similar to AM 722275. The sherd was c.7 mm thick and came from a vessel of about 8 cm diameter. It had a thick ridge of glass parallel to the rim and two cm from it, similar to the example above. The glass appeared black on the surface but below this weathering skin patches of green, amber, purple and red were visible. X-ray fluorescence analysis of the glass detected lead together with iron and copper. A corroded metal blob (probably of copper alloy) was noted stuck in the glass.
722281	68	Unlike the rest of the crucibles, which are hand-made, this one is wheel-turned and of a far harder and finer fabric. It has a flat base with the walls rising upwards and outwards from it. The walls are 12 mm thick and the base has a diameter of 6.5 cm. This was a far larger vessel than the other crucibles. The outside was coated with a thick layer of less refractory clay which is extensively vitrified and highly vesicular (present thickness 10-15 mm). The outer surface of the crucible proper is also slightly vesicular. The extra, outer layer is similar to that illustrated by Hawkes and Hull (1947, Fig 65-4) - see discussion in Part 2.
722282	11	A small rim fragment of fabric similar to AM 722276. It appears to be far thicker than most of the crucibles but the form of the vessel is not clear. It is reduced fired but shows no signs of vitrification nor any traces of metal to suggest a use.

MOULDS

AM No.	Site No.	Description
722274	1180	Four pieces of clay mould (none joining) of a similar fabric to the softer crucibles (eg AM 722276). They are oxidised fired with a thin reduced layer next to the modelled surface. The objects being cast appear to be basically cylindrical with ribs running round them and diameters of a few cm. They may be similar to the mould fragments reported by Hawkes and Hull (1947, 346). It is impossible to say if these pieces come from piece moulds or from investment moulds as they have no indicative features.
722283	903	Two edge pieces of coin blank moulds, both with parts of five pits surviving. There were red vitreous specks near the rim of one pit which suggest that the metal used in that mould contained copper. These are examples of the same type of object as those described by Hawkes and Hull (1947, 129-30 and Pl XVI). (Similar examples are also known from Old Sleaford, Rochester and Gorhambury.) These moulds were used as described by Tylecote (1976, 50-1) for melting weighed amounts of metal under a charcoal blanket to give spherical blanks for

AM No.	Site No.	Description
722283 (cont)		coining rather than as a mould for molten metal as Sellwood (1976, 65) suggests. The label 'mould' is misleading in this context as the metal was not intended to conform to the shape of the pits in the clay slabs.
722284	294	The in-gate and runners part of a clay mould. The main runner is about 6 mm in diameter and it then splits into two, both with a diameter of about 4 mm. The diameter of the top of the funnel-shaped in-gate is about 11 mm. This is where the metal entered the mould and was distributed to the various parts of it. Traces of copper and zinc were detected (by x-ray fluorescence) suggesting that the mould was being used for casting brass.

OTHER FIRED CLAY

AM No.	Site No.	Description
722270	1	Part of a high-fired brick. Most probably modern.
722271	2	Brick(?) fragment, not very high fired or homogeneous. It is 6 cm thick at the edge but 7 cm thick 3-4 cm from the edge where there is a hole (diameter 1.5 cm) straight through. A similar sized brick with a perforation has recently been noted among finds from Wroxeter.
722272	3	Part of a high-fired brick. Most probably modern.
722273	319	Poorly baked clay fragment, about 12 cm long. It appears to be the end of a prop or stand and is made of a coarse fabric with a roughly smoothed surface. It is reduced fired.

PIGMENTS

AM No.	Site No.	Description
722286	66	Pellet of Egyptian Blue; diameter 2 cm.
722287	67	Pellet of Egyptian Blue; diameter 2 cm.
722288	856	Lump of soft powdery haematite about 2 cm across.
	150	)
	162	)Egyptian Blue. (Not seen but reported with glass)
	165	)

Egyptian blue is a glass frit and was ground up and used as a blue pigment in wallplaster painting. It is interesting to note that Hawkes and Hull (1947, 345) report "pieces...of a blue vitreous substance, ... blue frit." but they suggest it may be associated with enamelling.

Haematite is commonly used to provide reds in wallplaster painting so this piece could have been intended for this purpose. It could also have been used as a fine abraisive eg in the polishing of bronze work, and as such may be associated with the metal-working on site.

Part 2: Discussion and Interpretation

The two main industries represented are iron working and copper alloy working. In addition there are small numbers of finds suggesting other processes were also being carried out. The evidence for each is discussed below.

The lack of hearths among the excavated features may at first sight seem a little worrying in a supposedly industrial area but it should be remembered that the original ground surface has been largely removed. The hearths were probably not very massive so total destruction is quite possible. In the main, all that has been recovered from the site is the rubbish deposited in pits. This would not normally have included the hearths which would have been 'fixtures' in the workshops. Some of the burnt daub found may be from the hearths and the slags do include some pieces of hearth lining (see above).

The distribution of the finds associated with the various processes is interesting, showing an almost total separation of iron and copper alloy working. (These comments are based on the finds submitted to the A.M. Lab. for examination. The draft excavation report mentions eg. copper alloy scrap and a crucible fragment which have not been seen. The total finds may not therefore fit the spatial and temporal distributions suggested here.) Both industries require similar facilities - sheltered working space and a fire blown up to give higher temperatures than those available in a domestic hearth being the most important - so it is possible to envisage 'metal workers' sharing facilities. On Sheepen this appears not to be the case; presumably both industries were too large to work together so the easiest way to arrange matters was to group craftsmen working with the same materials together.

All the industrial waste associated with copper alloy working was found in area I. This includes the slags containing copper alloy, the scrap metal, the crucibles and the moulds (except the coin pellet mould which is Belgic rather than Roman). It has been suggested (see excavators draft) that the scoops in compound 1 were associated with the copper alloy metal working and certainly the Claudian deposits in area I did produce the majority of the copper containing slags and scrap metal, however the crucibles and moulds all came from Claudio-Neronian or Neronian deposits. It is not easy to explain this split of material which may be fortuitous or due to the irregular distribution of the relatively small quantity of finds. Some or all of the later material may be residual. In summary, copper alloys were certainly being worked in area I in the Claudian period and this industry may have continued later on too.

The iron working initially appears less concentrated with smithing slag found in areas I, II, III, IV and VI. The majority however was found in areas II and III, in the former throughout the Roman occupation of the site but in the latter case only in Neronian or Boudiccan levels. These appear to have been the major iron working areas while the occasional pieces found in the other areas may just be chance finds not necessarily related to the industrial activity in those areas.

Iron Working

Iron working as a general term can cover the smelting of iron from its ores, the smithing of the crude blooms to give workable iron and the manufacture of objects from this iron.

On a site like Sheepen where features such as hearths are generally not preserved, the only evidence for iron working is the presence of slags of various types and metallic iron other than finished objects. Where there is some indication of iron working, the iron objects themselves may be seen as additional evidence for the type of things being made.

The slags (see Part 1) provide no evidence for iron smelting but one piece of metallic iron ("slag 1") was examined by Prof. R. F. Tylecote who described it as follows :-

"This was a highly magnetic "cake" measuring about 15 cm diameter and having a maximum thickness of 3 cm. It was plano-convex in shape and weighed 1 kg. A section was removed from the edge. This showed a laminated effect, with metal cemented by films of rust or slag. It seemed that drops of metal had fallen and flattened before they solidified. It consists mainly of pearlite with corroded grain boundaries which may have been ferritic. The structure is mainly equiaxed but here and there are groups of columnar grains which look rather like the long grains of cementite that one gets in a white cast iron. The hardness was fairly consistent varying from 210 to 224 HVI which is in agreement with a ferrite + pearlite structure. I would put the carbon content at about 0.6%, in which case the melting point would be about 1490°C."

He compared it to a similar object from Gestingthorpe (a Roman site also in Essex) of which he commented :- "I think it is very unlikely that this is a smithing product as it is completely devoid of a slag phase except on the surface. I would favour a smelting origin. We have found (Tylecote et al 1971) that if the fuel/ore ratio of a smelting operation is raised, it is possible to get cast iron which displaces the slag and falls to the bottom of a bloomery furnace." It should be noted however that such a piece of iron would not have been workable in the way that normal blooms were; it contains more carbon than ordinary wrought iron and is therefore much harder. Perhaps that is why it survives complete, kept as an intractable curio by a puzzled blacksmith.

Apart from the piece described above, the iron working debris is almost certainly all associated with iron smithing, the production of iron objects from metal bars. There is slag, hearth lining including at least one tuyere (slag 8) and metal scrap (see Slag and Metallic Iron sections of the catalogue for details). The size of the tuyere (diam 3 cm) means it is more likely to be associated with iron than copper alloy working; in the latter case tuyere diameters of 1 - 2 cm are more common.

Two pieces of metallic iron were examined metallographically by Prof. R. F. Tylecote who reports as follows :-

" "Slag 12" contained a piece of typical bloomery iron, well forged and fairly free of slag. The carbon content varies from 0 to about 0.4% and the widmanstätten structure shows that it has been cooled fairly rapidly to give a ferrite + pearlite structure. The pearlite is not resolvable at X 400 showing that it was not slow cooled through the 800° - 600°C range. The hardness of an area with 0.1% carbon is 234 HVI which is high for a pure steel and which suggests that it contains phosphorus or some other solid solution element.

An iron lump (part of 722392) was mostly ferrite with nitride needles. It was difficult to etch up the grain boundaries in Nital and there was marked evidence of "ghosts" (of high-P ferrite) both of which suggests a high phosphorus content. This is a form of coring indicating phosphorus segregation round the low carbon areas, while the higher carbon (still in the solid solution range of 0.02%) etches a little. The hardness was in the range 214 HVI (no nitride) to 330 HVI (with nitride). Clearly this is a high phosphorus wrought iron with high nitrogen in some places. It has been cooled slowly enough in the low temperature range (300° - 400°) to precipitate the nitrogen as nitride. Normally the nitrogen comes from the air blast; I do not think that it has been introduced by some form of cementation in dung. "

Copper Alloy Metal Working

In the Roman period objects were made of copper alloys in two main ways. They were either cast, in piece moulds or investment moulds, or they were smithed. In the latter case an ingot or cast blank was hammered into sheet or bars or rods and the objects then made from these semi-manufactured materials. Some composite objects have both cast and smithed parts.

On Sheepen there is no evidence that copper was being smelted from its ores but it is clear that copper alloys were being melted and cast. There are crucibles, coppery slags, clay moulds, a casting sprue and many blobs, dribbles and pools of spilt molten metal. (See Copper Alloy and Crucibles sections of the catalogue for details.) On the smithing side the evidence is less clear. There are many scraps of smithed copper alloy - rods of varying cross-section and sheet of different thicknesses. Much of this material however may be parts of broken objects rather than objects in the making. There are no pieces that can be positively identified as offcuts and many are obviously parts of objects (eg. pieces of sheet held together with a rivet and a D-section strip with an engraved design).

The large brass sheet (AM 751820) and the (?) ingot corner (AM 722365) are probably best interpreted as raw materials for this metal working industry. The small corner has definitely been cut (with a large chisel) from a bigger piece, perhaps ready to go into a crucible for remelting. The crucibles are not very informative as only one (AM 722279) provides any positive evidence for copper alloy melting although the majority were probably used in a similar way (but see Other Processes below).

Much of the scrap metal was examined to see what sorts of copper alloys were being used. It is known that the Romans used many different alloys - brasses (copper and zinc), bronzes (copper and tin) and gunmetals (copper and tin and zinc), and all but the brasses with varying amounts of lead added too (Bayley et al forthcoming).

Metallographic sections were made by Prof. R. F. Tylecote and his descriptions appear below. Metallography shows the structure of the metal and its working history - whether it is "as cast" or has been smithed and/or annealed. It cannot differentiate between fairly small amounts of tin and zinc in an alloy as the metallographic structures they produce look the same. The hardness of the metal can sometimes suggest one or the other as more probable.

Most of the pieces were also analysed by x-ray fluorescence. This indicates the elements present in the surface of the object. When metal alloys decay some elements react more readily than others with the ground water so the composition of corrosion products is usually not very closely related to that of the original object. For this reason no attempt has been made to quantify the results, the elements are ranged in decreasing order of signal strength detected. It should be noted however that eg. 10% of tin in a bronze gives a far weaker signal than 10% of zinc in a brass so the order in which the elements appear is not necessarily their actual % order.

As can be seen from the Table below there is a wide range of alloy type though most seem to contain detectable amounts of both tin and zinc (detection limits for zinc are well under 1% and for tin not that much higher). The lead content varies widely and is probably detectable by x-ray fluorescence at levels too low to be seen metallographically.

The wide range of alloys detected in the spilt molten metal suggests that the objects made here were of variable composition. The finished objects from the site (with the exception of the brooches) have not been analysed so it is not possible to say if they mirror this variability. The brooches however are mainly brasses (see seperate report for details).

Metallographic report on copper alloy pieces (by Prof. R. F. Tylecote)

Pit 283

Sections were made from three seperate pieces :

(1) Sheet 2 mm thick. A well-alloyed copper-base solid solution, fine grained, equiaxed and twinned. The hardness is 153 HVI which suggests a well-homogenised high tin bronze or a worked brass. As there are no signs of cold working it seems that it must be a bronze with about 13% Sn.

(2) A "D"-sectioned strip. Less yellow than the above but this shows signs of the delta phase and is cored. The hardness is 125 HVI which indicates a cast tin bronze with about 13% Sn.

(3) A bar approximately 3 mm square. Far more coppery than either of the above. A copper-base solid solution which was difficult to etch. The hardness is 168 HVI which suggests a gun-metal with at least 10% tin equivalent ($Sn+\frac{1}{2}Zn$). It shows no trace of coring and therefore has been well homogenised.

722383

Copper-base alloy lumps. Three pieces were cut from these.

(1) A corroded cored tin bronze with delta but no lead. The hardness is 140 HVI. This is a cast tin bronze with about 15% Sn.

(2) A cored alpha copper solid solution. The hardness is 83 HVI. It could be a cast and homogenised brass or a low tin bronze.

(3) Rather like (1). A cored tin bronze with enough delta to indicate about 11% Sn. The hardness is 110 HVI. No lead is present (i.e. less than 1%).

AE 551

A pool of spilt molten metal. A copper-base solid solution, equiaxed and homogenised containing no delta and no lead. The grain size is large but no twins are visible. The hardness is 83 HVI. A well-homogenised cast brass or bronze with low tin content. In view of its coppery colour I would favour the latter.

Pit 164 (1)

A copper-base alloy dribble. This is an equiaxed grained copper solid solution with a little delta phase and some intergranular corrosion. It shows signs of residual coring. The hardness of 83 HVI suggests low tin content. Therefore I would suggest that this is a fast-cooled tin bronze which has been post-heated enough to remove much of the coring but not to dissolve the delta phase. It probably contains about 7-8% Sn.

Table X-Ray Fluorescence Analyses

722382	Cu Zn Sn Pb
722383 (1)	Cu Zn (Sn)
(2)	Cu (Sn Zn)
(3)	Cu Zn (Sn)
Slag 5 (1)	Cu Zn Pb Sn
(2)	Cu Pb Zn Sn
(3)	Cu Zn (Pb Sn)
722362	Cu Pb Sn
722363	Cu Sn (Zn Pb)
722364	Cu (Zn) Sn Pb
722365	Cu Sn (Zn Pb)
722366	Cu Pb Zn Sn
AE 551	Cu Zn Sn
Pit 283 (1)	Cu Zn (Pb Sn)
(2)	Cu Pb Sn (Zn)
(3)	Cu Sn Pb (Zn)
Pit 164	Cu Zn Pb Sn

Key Cu = copper Sn = tin
Zn = zinc Pb = lead

The elements in brackets are not detected with any certainty or at such low levels that they are unlikely to be deliberate additions to the alloy.

Other Processes

One interesting group is the three crucibles with thick glassy deposits in them (AM 722275, 722280A (1) & (2)). The analyses all show the presence of considerable amounts of lead indicating that these are deliberately made glasses rather than accidentally produced slag deposits. Considerable numbers of similar crucibles have been found in first century levels in Chichester (Bayley 1978, 254 - 5) where it was suggested that the (high lead) opaque red glass they contained had been used as enamel. Most Roman enamels of whatever colour contain at least some lead (Bateson & Hedges 1975, Biek et al forthcoming) though the quantity can vary considerably, some colours needing larger amounts than others to develop fully. Both iron and copper (the other elements detected in the glass deposits) can give rise to a number of different colours depending on their concentration and oxidation state. The variety of colours noted here may therefore just be a product of inhomogeneity in the glass compounded with varying oxidation states. In the Roman period high lead glass is not only used for enamelling but also for small objects such as beads and gaming pieces. Without further evidence it is not possible to say exactly how the glass from the crucibles was used.

In a complementary sense it would be interesting to know if the blue frit Hawkes & Hull (1947, 345) mention is in fact blue enamel or whether it is the pigment Egyptian blue. Although there is no reason why Egyptian blue should not be melted down to make a glass (Brill (19 , 126) suggests it as a possible step in the discovery of glass) it seems an unnecessarily complicated and long-winded procedure.

The presence of pigments among the finds is something of a surprise as no stone buildings were found. It is unlikely that timber or wattle and daub structures, which must have had a limited life, would have been painted with exotic, and presumably expensive, colours such as Egyptian blue.

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