Early Medieval Copper-Alloy Metalworking at Rendlesham, Suffolk, England

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THE 5TH- TO 8TH-CENTURY METAL-DETECTED ASSEMBLAGE FROM RENDLESHAM includes material representing the manufacture of copper-alloy and precious metal objects in the later 6th and 7th centuries. This study of the copper alloys focuses on the evidence for manufacturing technology, sets it against the evidence for alloy compositions and metal supply from the wider assemblage, and considers the scale and organisation of production at the site. Examination by optical microscopy of key traits on metalworking waste and unfinished objects has made it possible to identify the types of mould being used and to reconstruct a sequence of manufacture for objects made at Rendlesham. Compositional analysis by XRF and SEM-EDS shows the expected range of alloys for 5th- to 8th-century England and confirms recycling as the main source of metal. Lead isotope analysis, applied here for the first time to early medieval copper alloys from England, also indicates recycling over the long term. There is no evidence for a supply of fresh metal, or for working in brass, before the 7th century. The results contribute to a wider understanding of copper-alloy metalworking practice and metal supply in early medieval England, and establish the potential of metal-detected material as evidence for the study of non-ferrous metalworking.

The early medieval settlement complex at Rendlesham, in the valley of the river Deben in south-eastern Suffolk, is known from a programme of systematic metal-detecting supplemented by geophysics, analysis of aerial photography, and trial excavation.[4] The distribution of metalwork in the plough soil and the extent of archaeological features indicates settlement and related activity over an area of c 50 ha during the course of the 5th to 8th centuries. The finds assemblage, which includes gold and gold-and-garnet jewellery and both Merovingian and English gold coinage, indicates an elite presence from the late 6th to the early 8th centuries. The place can be identified confidently as the East Anglian *vicus regius*, or royal settlement, recorded by Bede in a context of AD 655x663.[5]

Two main areas of habitation can be defined within a broader zone of activity: an area of settlement and burial in use from the 5th century and, to its south-west and separated from it by a small tributary valley, a high-status establishment on a promontory overlooking the river Deben where the cropmark of a probable timber great hall has been identified (Fig 1). The elite establishment thus appears to have been founded in the later 6th century immediately adjacent to an existing settlement and from this date the complex as a whole is interpreted as a central place from which royal rulership was exercised over an extensive region.[6] It was the focus of entangled social, jurisdictional and economic geographies at a range of scales and can be seen as a periodic royal residence and arena for the theatre of rulership, a tribute centre where the land's wealth was collected and redeployed, a farming settlement and centre for agrarian administration, and a place of exchange and craft production. As an elite centre it was the focus of inter-regional social and exchange contacts, and was an early centre of coin use and monetisation.[7]

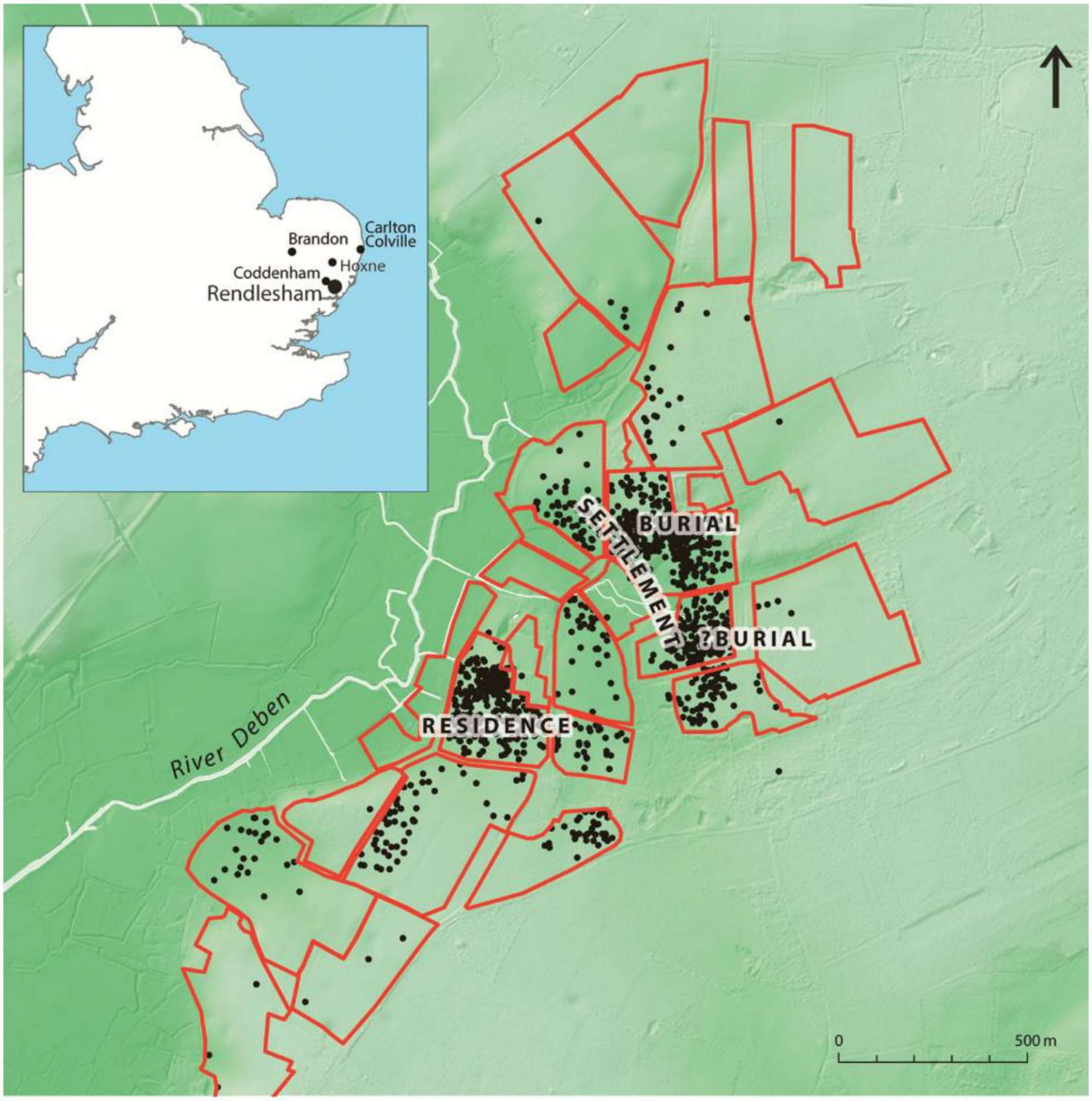

Figure 1 - Location map showing Rendlesham, and other East Anglian places mentioned in the text; and plan of the Rendlesham survey areas (outlined in red) showing the distribution of metal finds of the 5th to 8th centuries. Illustrations by Stuart Brookes

The site, its material culture assemblage and its contexts have been the subject of detailed analysis for the project *Lordship and Landscape in East Anglia CE 400–800*, funded by a Leverhulme Trust Project Grant, and a monograph publication is in preparation.[8] This paper draws on a wider study of the non-ferrous metal objects from Rendlesham for which full reporting and analytical data will be made available as online resources through the Archaeology Data Service (ADS).[9] A small sample of material from the metal-detected assemblages at Coddenham and Hoxne, both high-status sites in Suffolk contemporary with

Rendlesham and with similar evidence for non-ferrous metalworking, was included within this wider study and is referred to in this paper where relevant.

THE FINDS ASSEMBLAGE AND METALWORKING EVIDENCE

The systematic metal-detecting survey has recovered 5,201 material culture items of archaeological significance dating from prehistory to c 1650. Although objects of pottery, ceramic, flint, stone and glass were recovered and recorded when seen, these comprise only 7% of the material. The metal-detectors were set to discriminate against iron because of the very high quantities of early-modern and modern iron scrap in the ploughsoil and so the assemblage includes only 13 iron objects, 0.2% of the total. Of the metal finds, 66% are copper alloy, 23% silver, 2.4% lead, and 1.6% gold.

Excluding coins, 1,109 objects have been dated to the 5th to 11th centuries, around 65% of which are datable to the 5th to 8th centuries. These include closely datable items that provide direct evidence for the manufacture of objects in copper alloy or precious metal, and there is further material that cannot be closely dated but which very probably derives from early medieval activity.[10] Because the finds assemblage is from the ploughsoil, typologically undiagnostic material cannot be dated by stratigraphic context.

No mould or crucible fragments have been recovered but one piece of slag (RLM 043 1139) may be casting hearth waste. Otherwise, non-ferrous metalworking is represented by scrap metal, melt and other debris, sprue reservoirs discarded after casting, failed castings and unfinished items, and lead models. Among the melt are droplets of gold and silver. The failed castings, unfinished objects and lead models provide unequivocal evidence for early medieval metalworking (Fig 2). Hack metal and scrap fragments from identifiable objects of the 5th to 7th centuries are also strongly indicative, as are unused individual components of composite objects. Melted metal, sprues and undiagnostic scrap are not in themselves closely datable but in the absence of any direct evidence for earlier or later metalworking it is overwhelmingly likely that most, if not all, of this material is contemporary with the datable material. This conclusion is supported by compositional analysis, which is consistent with the recycling metal economy of the 5th to 7th centuries.[11]

Figure 2- Evidence for early medieval non-ferrous metalworking from Rendlesham. Top, left to right: unfinished and finished examples of buckle loop, bag-catch and disc-headed pin. Bottom, left to right: lead models for sword ring and buckle loop, and unfinished Style II mount. Copyright - Suffolk County Council Archaeological Service.

The unfinished copper-alloy objects are castings discarded before the flashing, sprue or channel metal was trimmed. There are 18 certain examples, all but one representing types of the late 6th and 7th centuries: seven small buckle loops of Marzinzik types I.9 and I.10d-ii, very probably from buckles of Høilund Nielsen type BU7, six pins of Ross type L, two bag catches, and a Style II mount (Fig 2).[12] Less closely datable, but probably of the 7th to 9th centuries, is a small key for a mounted lock, probably a box or casket. There is also an unfinished gold belt-fitting of the later 6th or earlier 7th centuries (RLM 059 1162), and a copper-alloy casket mount (RLM 038 1196) and copper-alloy harness mount (RLM 036 1001) of the same date-range may also be unfinished items. A copper-alloy pin of Ross type LXX, which may be a damaged item rather than a failed casting, is probably 8th-century or later.[13]

There are two lead models of the later 6th or earlier 7th centuries: one for a fixed sword ring of Evison's type 3, the other for a loop from a buckle of Høilund Nielsen type BU3, both of which can be considered status items.[14] There are four lead hooked-tags of the 8th century or later, any or all of which may also be models.

The evidence from Rendlesham thus indicates non-ferrous metalworking from the later 5th to the earlier 8th centuries with some later, perhaps sporadic, activity into the 9th to 11th centuries. The most intensive activity was during the late 6th and 7th centuries, which saw metalworking activity in copper alloy, silver and gold. Production included both elite metalwork items in precious metal and lower value utilitarian items in copper alloy. Some of the latter — notably the bag-catches — may have been fittings for more costly composite items. The relatively high number of small buckles, bag-catches and pins of Ross type L among the wider late 6th- and 7th-century metalwork assemblage, which is greater than would be expected from the proportions of these types in contemporary cemetery and settlement assemblages, is probably due to them being manufactured on site. It is also likely that coinage was struck at Rendlesham in the 7th and 8th centuries by goldsmiths whose skills were as well suited to coin production as to jewellery.[15]

AIMS AND APPROACHES

Evidence for non-ferrous metalworking from excavated early medieval settlement sites in England is usually in the form of crucibles, mould fragments and metal waste, and comes predominantly from sites of the 9th to 11th centuries.[16] Elsewhere in Suffolk, copper-alloy working at the 6th- to 8th-century settlement at Bloodmoor Hill, Carlton Colville, is represented by two mould fragments, scrap metal, and at least 138 crucible fragments, and at the 7th- to 9th-century site at Staunch Meadow, Brandon, by a small assemblage of scrap.[17] The metalworking evidence from Rendlesham is therefore important for our understanding of craft practice and the metal economy in the 5th to 8th centuries, and unusual in that it lacks moulds, crucibles and slag but represents the products and by-products of manufacture. Whether this is solely an artefact of the retrieval method, or represents to some extent a genuine difference, is considered further below. Either way, it precludes easy comparison with assemblages from excavated sites and requires a different approach.

This paper focuses on the copper alloys rather than gold and silver because they provide the most complete information about metalworking and metal supply. Our intention is to characterise the technology and craft practice at Rendlesham, set this against the wider regional and interregional picture of alloy use and metal supply, and consider the implications for the scale and organisation of metalworking. In doing so, we aim to demonstrate the potential of such metal-detected material if properly interrogated.

ANALYTICAL METHODS

Manufacturing techniques were characterised by examination of the artefacts and metallurgical waste by optical microscopy, and composition by X-ray fluorescence (XRF), scanning electron microscopy with energy-dispersive X-ray (SEM-EDX) analysis, and multicollector inductively coupled plasma mass spectrometry (MC-ICP-MS). Analysis by XRF and SEM-EDX was carried out on small areas prepared to expose the core metal so as to avoid contamination by surface corrosion products. Full details of the SEM-EDX, ICP-MS and MC-ICP-MS setup, calibration and data can be found in the reports archived on the ADS.[18]

Following a screening study of 313 copper-alloy objects using an Olympus Innov-X Delta Premium Portable X-ray fluorescence spectrometer (pXRF), 145 objects were selected for optical examination and for SEM-EDX which was carried out using a Carl Zeiss scanning electron microscope equipped with an Oxford Instruments X-sight energy dispersive spectrometer. This sample targeted failed castings, unfinished objects and sprues, and objects likely to have been manufactured at Rendlesham, but also included a selection of other 5th- to 7th-century artefacts, a small sample of later material of the 8th to 11th centuries, and some undiagnostic casting waste. The XRF tended to over-estimate tin and lead contents, probably because corrosion products were still present in the spots analysed. The SEM-EDX data were more precise, with less contamination from corrosion products due to the better imaging and smaller beam size provided by the technique. Samples from 48 objects were analysed for their lead isotope compositions using MC-ICP-MS for comparison with the isotopic signatures of known copper ore deposits in Europe.[19]

To assist comparative analysis, a dataset was compiled of previous analyses of early medieval copper-alloy objects. This drew principally on PhD research, supplemented by site- or object-specific studies including the qualitative analysis of the copper-alloy artefacts in the Staffordshire Hoard.[20]

TECHNOLOGY AND MANUFACTURE

Three main types of moulds are known to have been used for copper-alloy casting in early medieval England.[21] The simplest is the single-sided open mould in which the metal casting is exposed to air as it cools, resulting in oxidation and a rough surface, and therefore suitable only for simple flat objects. More complex is the piece mould, comprising two or more elements fitted together and sealed before casting so that no air can enter. Potentially, piece moulds can be reused several times, depending on the material they are made from and the amount of fine detail. Two-piece moulds are the simplest but multiple piece moulds can be used to create more complex three-dimensional objects or even multiple objects. Both single-sided open moulds and piece moulds are formed using a metal or wooden model but in the third technique, lost wax casting, a wax model is covered in clay and melted out to form a void into which the metal is poured. Lost wax allows the manufacture of complex objects but because the mould is broken to retrieve the artefact it can produce only single items.

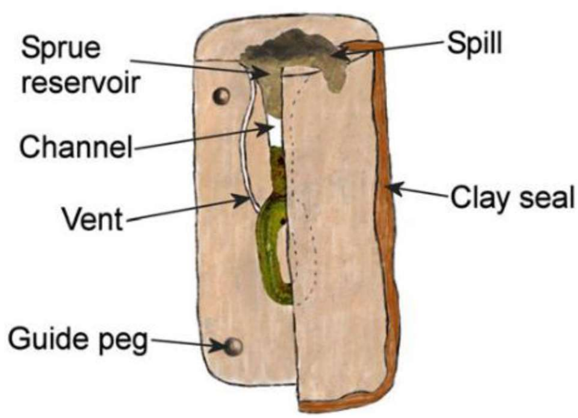

Figure 3 - Illustration showing the mould terminology used in this paper; lost wax moulds would be a single piece of clay and would not need guiding pegs or clay seals. Illustration Copyright Eleanor Blakelock.

Mould elements and their terminology are shown in Figure 3. A major feature of any mould is the sprue reservoir, where the metal is poured, sometimes also called an inlet or pouring cup/basin.[22] Here, we use the term channel for the gap between the reservoir and object to be cast, to differentiate it from the reservoir shape. Occasionally, with complex objects, a vent is used to allow any trapped air to escape. In piece moulds, however, some air can escape through the interface of the pieces or through the clay itself and so vents are more often found on lost wax moulds.

Evidence for casting technology at Rendlesham is embodied in failed castings, unfinished objects, and sprues. The remaining pieces of casting waste are undiagnostic drips and droplets — probably metal that has fallen out of the crucible into the hearth, accidental spills when handling the crucible, or spills overflowing the mould.

The 38 sprues show a range of forms, sizes and weights (Fig 4; Table 1). The five double sprues indicate that two or more objects were being cast in a single mould. The different reservoir shapes might be related to the types of objects being cast or represent the preferences or habits of specific craftworkers. There is, however, no correlation between sprue shape, channel shape, and alloy composition.

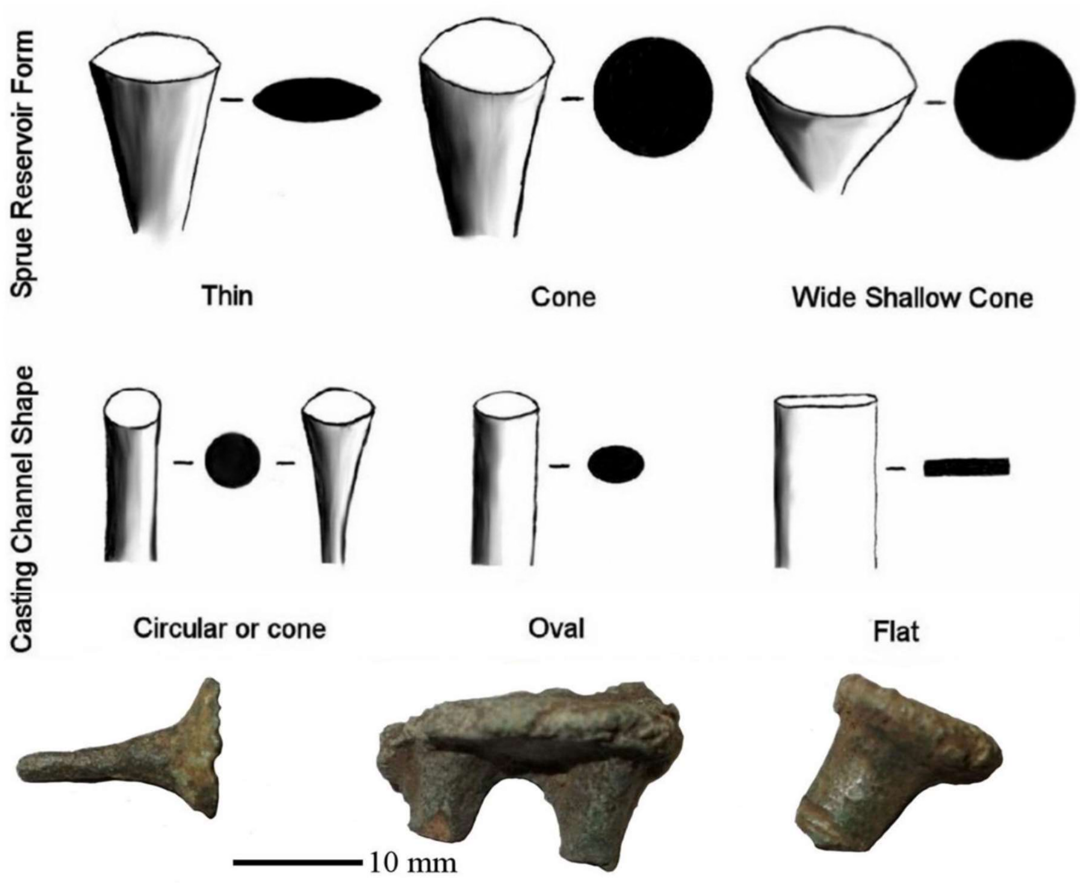

Figure 4 - Typology of the sprues from Rendlesham with examples from the site. Bottom row, left to right: RLM 0130267 (shallow cone form with circular channel); RLM 013 0642 (double cone form with oval channel); and RLM 013 0668 (thin form with flat channel). Photographs Copyright Eleanor Blakelock/Suffolk County Council Archaeological Service; illustrations Copyright Eleanor Blakelock

Table 1 - Numbers of sprues based on their channel or reservoir shape using the typology in Figure 4.

		Reservoir shape		
		Thin	**Cone**	**Wide shallow cone**
Channel shape	Circular or cone	15	10	3
	Oval	3	3	1
	Flat	3	–	–

Examination of the ends of the channels as preserved suggests that the majority of the sprues represent failed castings: rather than filling the mould, the metal stopped flowing and the surface tension of the metal formed a rounded end (Fig 5). This often happens during experimental casting if the channel is too thin to allow the metal into the mould, or if the metal has cooled down too much before pouring, or when charcoal has entered the mould. Sprues from a successful casting show a clear break or cut in the channel or other marks indicating that they have been cut from the cast object. There is no correlation between the copper-alloy composition and sprues from failed or successful castings.

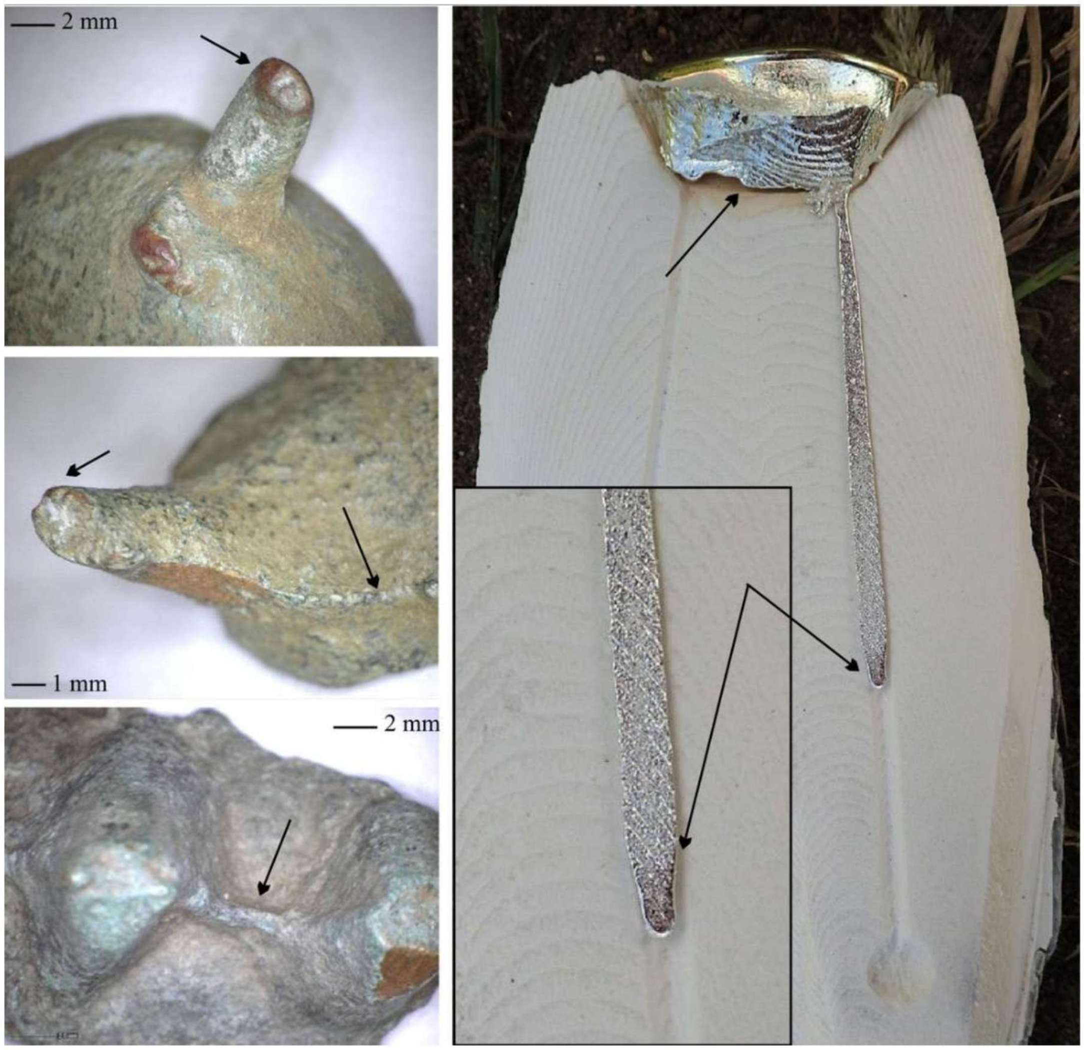

Figure 5 - Photomicrographs showing sprue ends from Rendlesham (left) compared to a modern failed casting experiment with flashing and a rounded end due to surface tension of the metal (right). Top left: EKE 022 1143showing rounded end from failed casting. Middle left: RLM 013 0570 showing cut end from successful casting and flashing. Bottom left: RLM 013 0642 showing flashing. Right: results of a failed experimental session, showing the resulting rounded end of the metal within the cuttlefish mould (c 80 mm wide). Object photographs Copyright Eleanor Blakelock/Suffolk County Council Archaeological Service; experimental photograph Copyright Eleanor Blakelock.

Flashing, the metal that has flow into the seam between mould parts, is indicative of piece mould technology, and was observed on 13 sprues, both single and double (Fig 5). Two sprues also had clear lips of metal which form when molten metal overflows the reservoir and drips over the edge of the mould (Fig 6). This indicates the thickness of the mould element: in these cases 20 mm (RLM 036 1144) and 15 mm (RLM 013 0662), suggesting a clay mould material with good technical qualities, particularly thermal shock.

This is slightly thicker than contemporary mould fragments from Bloodmoor Hill, Carlton Colville, which were 10–15 mm thick.[23]

The failed castings and unfinished objects have similar evidence for casting technology. A number of buckle loops appear to have been successful castings but still had flashing, particularly on the inside of the loop (RLM 059 1122 and RLM 043 1061; Fig 7). None had a tongue, suggesting that they had not been completely finished and were awaiting further filing and polishing before the other components (tongue and plate) were added. The two unfinished bag-catches had flashing on all edges — so much in one case that it might have been considered more trouble than it was worth to remove the excess metal, and the casting intended for recycling (RLM 014 1055; Fig 2). The Style II mount has flashing on all edges, and dress pins have both flashing and, in some cases, incomplete shafts. In one case (RLM 013 0730) the metalworker attempted to recover the badly-cast pin by hammering the shaft to extend its length but the presence of flashing indicates that it was left unfinished.

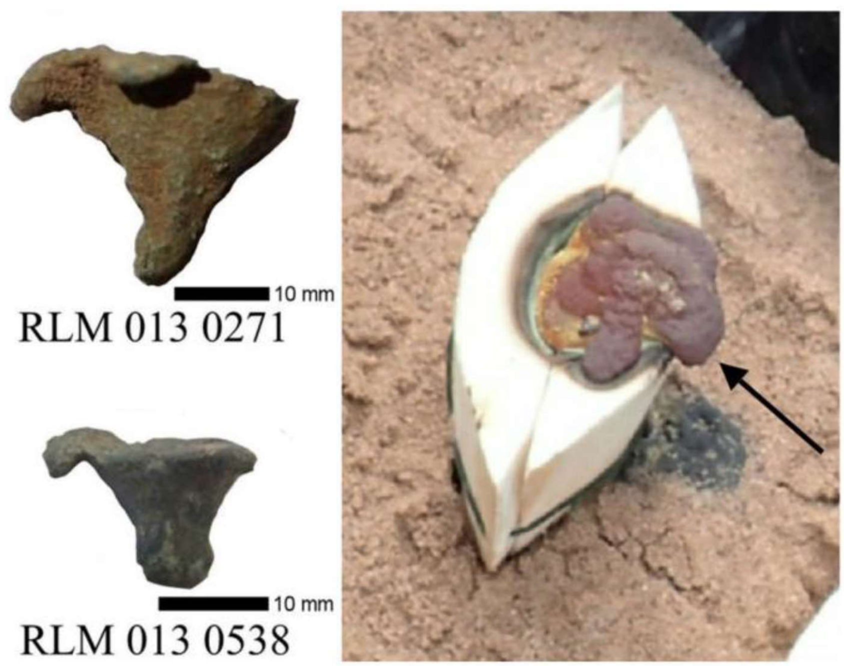

Figure 6 - Sprues with spills of metal over the edge (left), and an example from experimental casting sessions (right). Photographs Copyright Eleanor Blakelock/Suffolk County Council Archaeological Service; illustrations Copyright Eleanor Blakelock.

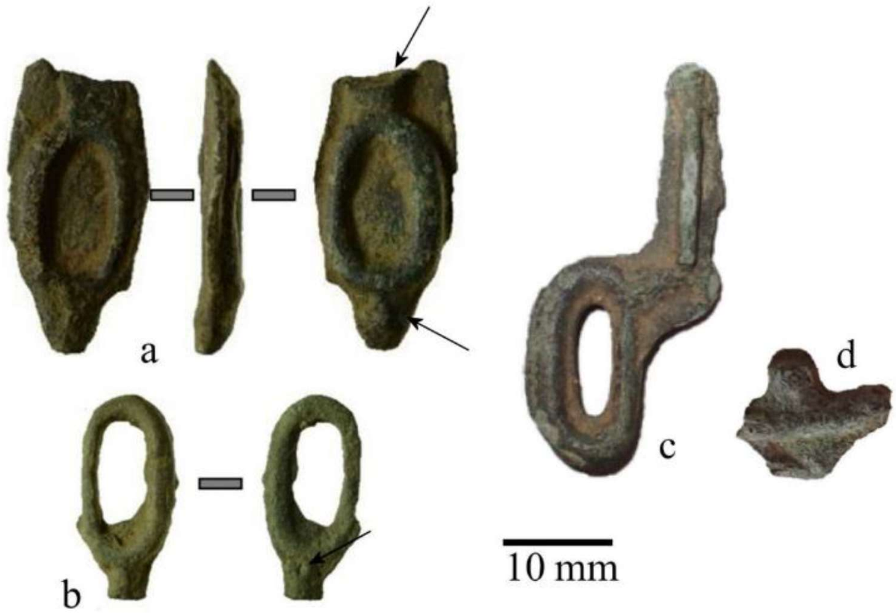

Figure 7 - Failed casts of buckle loops: (a) With channels still visible confirming they were cast in a chain (RLM 0130949). (b) Channels attached, with arrow showing the perpendicular rod present on the channel (RLM 0130950). (c) Cast from Hoxne (HXN 051 10C940), with dual casting. (d) Casting waste fragment which might indicate similar practices at Rendlesham (RLM 013 0274). Photographs Copyright Eleanor Blakelock/Suffolk County Council Archaeological Service.

Figure 8 - Misaligned pin heads and shafts of RLM 013 0196 (top) and RLM 013 0540 (bottom). Photographs Copyright of Eleanor Blakelock/Suffolk County Council Archaeological Service; illustrations Copyright Eleanor Blakelock

Two pins (RLM 013 0196, RLM 013 0540; Fig 8) were most likely discarded as the shafts and heads were misaligned by at least 1 mm, which would have been very difficult to rectify using finishing techniques. The two pins had different compositions, indicating that this problem occurred on two different pours. This may suggest that the moulds used did not have a method of accurately keying in the two halves or that it was not always effective, failing on more than one occasion.

Two of the unfinished buckle loops (RLM 013 0103, RLM 013 0949) have distinctive protrusions that suggest they were cast in a chain. Two more (RLM 036 1194, RLM 013 0950) have a flat channel with a perpendicular protrusion, perhaps part of the mould alignment system. Both these buckles had a channel visible on only one side, similar in size and thickness to the sprues with oval channels. There is evidence from bag-catch RLM 014

1055, both for the removal of the sprue and removal from another channel suggesting that it, like the buckles, was cast in a chain. An unfinished buckle from Hoxne is still attached to the channel (Fig 7). In this case, the channel intersects the loop from one side, rather than the top, and was most likely diverted into two mirror-image loops. There is no sign of a channel at the base to support multiple chained loops. A small copper-alloy fragment (RLM 013 0274) with a very similar 'T' shape suggests that this mould type may also have been used at Rendlesham.

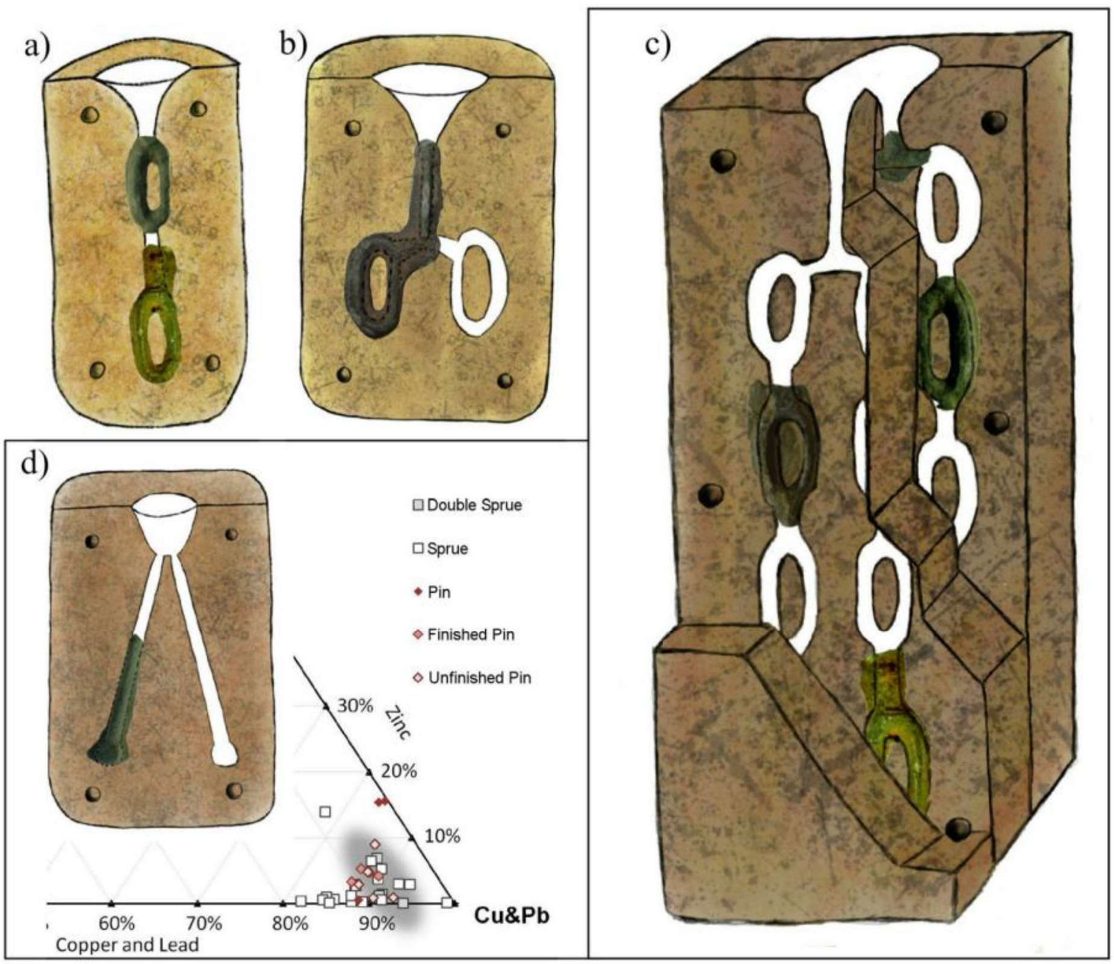

Figure 9 - Proposed piece-mould reconstructions based on the evidence from Rendlesham. (a) Based on the evidence on from Rendlesham. (a) Based on the evidence on the failed buckles. (b) Incorporates the evidence of the T-shaped piece and Hoxne example. (c) Shows how the T-junction casting waste from Rendlesham might, with the double sprues and other evidence, indicates a more complex mould for casting multiple chains. (d) Shows a mould used to cast multiple pins with a ternary diagram plotting tin, zinc and combined copper and lead showing the unfinished pins against single and double sprues. # Eleanor Blakelock.

These distinctive features allow us to identify the casting methods used. The presence of flashing on the sprues, discarded castings and unfinished objects indicate the use of piece moulds, and this is further supported by misaligned castings which can only occur when using them. Some moulds were used to cast multiple objects in chains or series, or perhaps a combination of both (Fig 9). The double sprues may indicate the casting of more than one dress pin at a time, and this finds some support in the similar alloy compositions of double sprues and unfinished pins (Fig 9). Another possibility, however, is that the double sprues were used to form multiple layers of castings similar to the more complex moulds known from Helgö (Sweden), or even the later medieval multi-layered buckle moulds from the London Guildhall.[24]

The use of clay piece-moulds for casting the majority of small copper-alloy objects in this period is well attested,[25] but the metalworking waste at Rendlesham shows that these moulds were often complex, with multiple objects being cast at a time. The use of piece moulds offered the advantage that the model could be reused,[26] and occasionally the mould itself may have survived well enough to reuse, especially if there was no fine decoration. There is little evidence for lost wax moulds in 5th- to 9th-century England and there is no evidence from Rendlesham to support the suggestion that some objects were cast using wax models which were removed by melting.[27]

ALLOY CHOICES

Early medieval copper alloys vary with the proportions of tin, lead and zinc in the metal. There are several different compositional classifications, all based on proportional thresholds for the different alloying elements,[28] but for this study we have adopted Justine Bayley's classification and nomenclature (Table 2).[29] This uses thresholds which broadly correspond with discernible changes in the composition or other material properties of the resulting alloys and might therefore indicate conscious selection.

Table 2 - Table detailing the nomenclature for the common alloys of the period.

Alloy	Tin	Zinc	Lead
Copper			
Leaded copper			>8%
Tin bronze	>3%		
Tin bronze (leaded)	>3%		4–8%
Leaded tin bronze	>3%		>8%
Brass		>8%	
Brass (leaded)		>8%	4–8%
Leaded brass		>8%	>8%
Gunmetal	>3%	>8%	
Gunmetal (leaded)	>3%	>8%	4–8%
Leaded gunmetal	>3%	>8%	>8%

A wide range of copper alloys was in use in 5th- to 11th-century England including bronzes, gunmetals and brasses, many of which were leaded.[30] There is clear evidence that bronzes and gunmetals predominated in the 5th to 7th centuries, a product of the recycling of scrap bronze and brass that can be traced back to the metal economy of late Roman period Britain in the 4th century.[31] Unlike tin or lead, its low boiling point means that some of the zinc in brass is lost through evaporation each time the metal is melted. A progressive reduction in the number of brass objects and of zinc content in the remaining brasses therefore indicates a reduction in the supplies of new metal.[32] By contrast, from the 7th and 8th centuries there was an increase in purer bronzes and brasses, and fewer gunmetal objects, suggesting new sources of metal.[33]

Compositional analysis of the alloys used by metalworkers at Rendlesham allows some insights into aspects of craft knowledge and practice. The metalworking assemblage of sprues, waste metal and failed castings mostly consisted of bronze (17) or leaded bronzes (27) with a few gunmetals (three) and coppers (three). There was no evidence for pure brass within the metalworking assemblage, and many of the bronzes had small quantities of zinc present suggesting recycling (Fig 10). This is very similar to the wider assemblage of contemporary metal objects from Rendlesham which are also mainly bronzes, leaded bronzes and gunmetals, and consistent with the wider picture of metal supply in 5th- to 7th-century England (below).

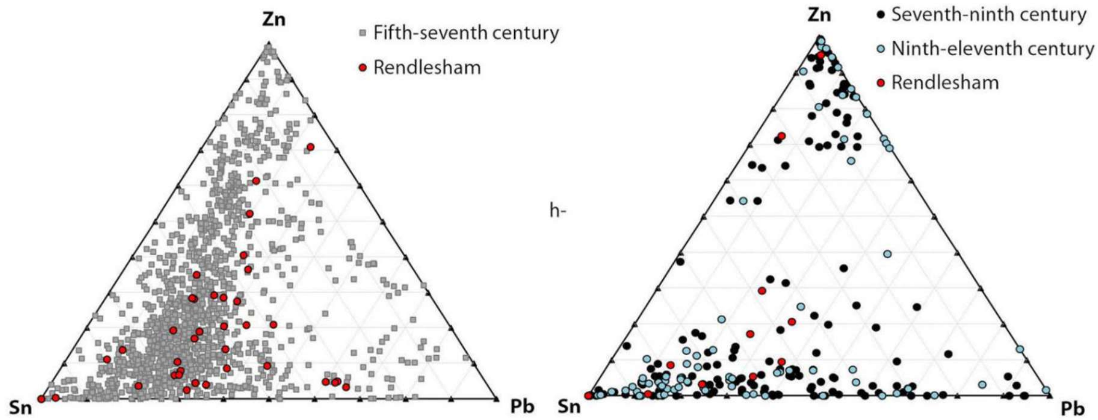

Figure 10 - Ternary Zn-Sn-Pb diagrams comparing the objects from Rendlesham alloys present in 5th to 7th century assemblages, and those dated to the 7th to 9th and 9th to 11th centuries. Copyright Eleanor Blakelock.

The alloys used for different components of the buckles (loop, tongue and plate) are broadly similar in composition, mostly consisting of bronzes with some gunmetals, but there is generally less lead in the tongues and plates than in the loops. Lead is often added to copper alloys when casting because it helps the metal flow in the mould but is detrimental to metal that is being worked, making it more brittle. This small difference may therefore represent the conscious avoidance of high-leaded alloys for the thin sheet metal of the buckle plates and the wire and rod from which the tongues were cut to be worked. In addition, when the components of individual buckles are plotted it is clear that each component has a different composition, perhaps confirming some differences in alloy choice — although it is also possible that these differences simply reflect the combination of object parts that were cast in different batches using the complex moulds described above.

Comparison of pins and buckles from Rendlesham with similar examples analysed in other studies shows similarities in alloy choice. The vast majority of pins and buckle components are tin-bronze or gunmetal but two pins, and two buckle loops and a buckle tongue, are brass; a single bag-catch is also brass. One of the pins was a disc-headed Ross type L, a form known to have been manufactured at Rendlesham in the later 6th or 7th centuries, the other a polyhedral-headed pin of Ross type LXX.ii, datable to the late 7th to 9th centuries; the buckles and bag-catch are also types known to have been manufactured at Rendlesham in the later 6th or 7th century. The polyhedral-headed pin post-dates the main period of copper-alloy manufacture at Rendlesham and so may have been manufactured elsewhere. The disc-headed pin, buckle elements and bag catch may all have been made at Rendlesham but there is no evidence for brassworking in the metalworking waste. It is possible that these few items represent a reintroduction of brassworking at some point in the later 6th or 7th centuries but all had significant quantities of tin in the alloy, something not usually associated with fresh brass and therefore brassworking. Rather, the alloy composition suggests the recycling and mixing of bronzes and brass to make gunmetals.

TECHNIQUES AND SEQUENCE OF MANUFACTURE

Examining finished objects of the same types as failed castings and unfinished items, and which are likely to have been made at Rendlesham, has provided information on the range of manufacturing techniques and the sequences of production.

As well as casting the loops, buckle manufacture involved copper forging the buckle plates, forming a wire and then using tongs or pliers to loop it around the buckle loop to make the tongue, drilling or punching holes, and filing and polishing. Punched and incised decoration generally appears to have been added at a late stage. Both the loop and tongue of RLM 036 1120 were decorated with the same punch, and had the tongue been punched before it was wrapped into place the decoration would have distorted. The engraved decoration on the buckle plate of the same piece, however, was probably done before the plate was fixed to the loop. Many buckle tongues have a ridge at the same place, probably an imprint of the tongs caused by the force required to bend the tongue around the loop. This feature is not always present, however, and so might represent the idiosyncratic technical gesture of a specific maker or workshop.[34]

Bag-catches were cast without holes, which were subsequently drilled. Where a burr survives on finished examples, it is on the underside, suggesting that holes were drilled from the front: in many cases the burr on the back — which would have impeded the swivelling of the catch in use — had been removed during cleaning and finishing. Many objects had fine striations where a file had been used to remove flashing and other casting defects; others had few striations which probably indicates finer polishing of the object. Moulded decoration on pins, such as deep grooves at the neck, were probably cast-in and touched up by filing. In some cases (RLM 036 1055, RLM013 0601) the cast form of a pin with facetted sides appears to have been touched up by filing.

From these observations it is possible to construct a sequence of manufacture for the small buckles made at Rendlesham (Fig 11). First, the buckle loop was cast and then finished by removing the sprue and any flashing. The buckle plate was made of sheet metal, flattened by repeated hammering. The tongue was formed from a piece of wire, most likely hammered into shape, and wrapped around the loop with no solder needed to join the ends. The sheet of the plate — perhaps already engraved — was wrapped around the loop and the entire buckle filed and polished to remove any tool marks. Finally, any punched decoration and further incised decoration would be added, and this may sometimes have been done after the buckle plate was attached to its belt or strap.

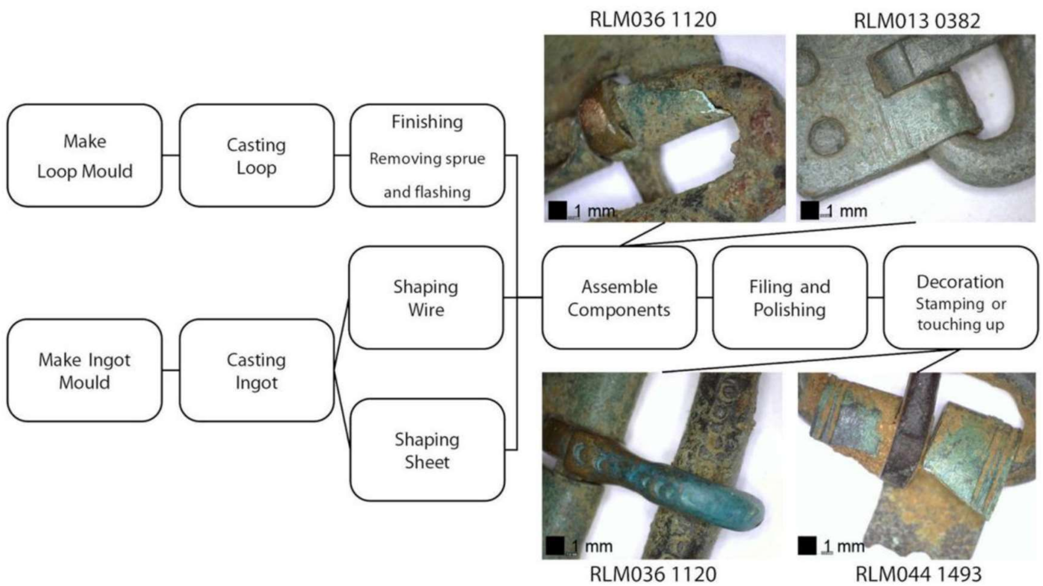

Figure 11 - Sequence of construction of copper-alloy buckles from Rendlesham. Photographs Copyright Eleanor Blakelock/Suffolk. County Council Archaeological Service; illustration # Eleanor Blakelock.

The production of a small simple item thus involved the manufacture and integration of several components, a range of metalworking techniques, and choices about alloys, all of which have implications for the organisation and infrastructure of production which are explored further below. Characterising craft practice in this way for a range of manufactured items from known production sites potentially offers a powerful tool for understanding the scale, organisation and contexts of production. Taken with other traits, such as alloy choice, it might even allow the identification of practices specific to region or area, or even to specific craftworkers or groups of craftworkers. However, because this is the first time that such a detailed sequence of manufacture has been proposed for copper-alloy objects in early medieval England, we are not able at this stage to offer any comparative analysis.

METAL SUPPLY AND THE METAL ECONOMY

Compositional analysis of the failed castings, sprues, unfinished items and items likely to have been made at Rendlesham reveals the alloys and metal sources used by craftspeople there in the late 6th and 7th centuries. Compositional analysis of the wider 5th- to 8th-century assemblage of copper-alloy artefacts, predominantly items likely to have been made in south-eastern Suffolk but including regional and interregional imports, provides insights into the wider metal economy.

The range of alloys at Rendlesham conforms to the broader pattern for early medieval England (Fig 10), with a high proportion of bronze (71%) and gunmetals (7%) among the 5th- to 7th-century objects against c 82% leaded or unleaded bronzes and 10% gunmetals in the comparative dataset. The scarcity of brasses, with the few brass objects identified dating to the 7th century or later, is also typical of the national picture. The average zinc content of the brasses at Rendlesham is around 14–16%. Previous research has suggested that new brass entering the metal economy from the 7th century had between 11–13% zinc.[35] The data from Rendlesham may therefore suggest that brasses had a higher zinc content than previously thought. There is nothing in the Rendlesham data or the wider comparative datasets to indicate significant regional or workshop differences in alloy compositions, suggesting that metalsmiths were drawing on the same wide interregional flows of recycled metal.

Forty-eight objects from Rendlesham were chosen for lead isotope analysis to examine the possible copper- and lead-ore sources. In Europe, ore deposits containing copper and lead are mostly between 50 and 600 million years (my) old.[36] The age of the ores is reflected in their lead isotope compositions (Fig 12) which can be used to assess the possible geographic origins of metals. However, it is clear that lead had been added deliberately to the alloy in the majority of the objects sampled, masking the natural lead signature present in and used to provenance copper ores. The isotope signature therefore derives predominantly from the lead in the alloy rather than the copper source. None of the Rendlesham alloys had an isotopic signature consistent with lead-ore sources in the British

Isles. Geologically younger sources in continental Europe are indicated (Fig 12), with the isotopic signatures indicating the remelting of metals from the Harz mountains in Germany, the Massif Central in France, and possibly north-western Spain.[37] Three objects — a bag-catch (RLM 044 1474); a Ross type L pin (RLM 013 0112); and a gunmetal sprue (RLM 013 0649) — that contain consistently high zinc (13.8–15.9%) represent even younger lead ores such as are found in the northern Aegean.

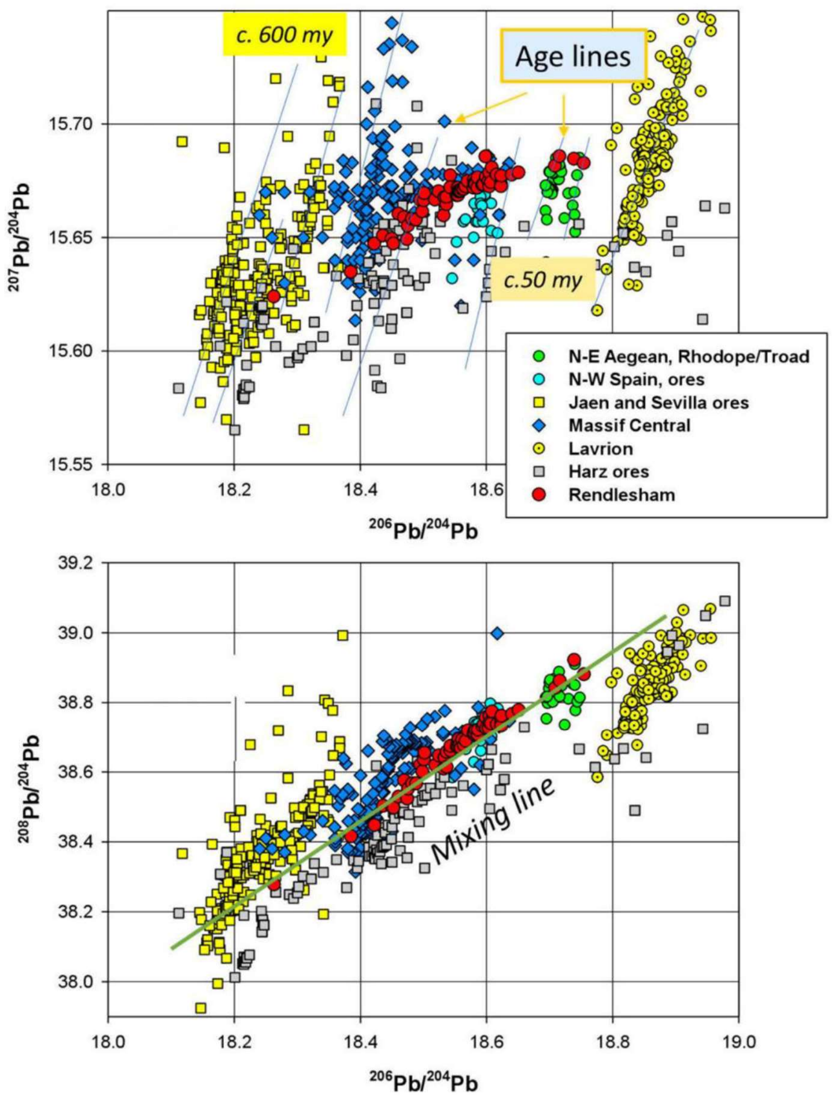

Figure 12 - Comparison of the Rendlesham lead isotope ratios with those of ores from continental Europe. The main group falls on the mixing line of ores from Germany and France; the four high zinc metals are fully consistent with the ores from the north-eastern Aegean; the copper prill trapped within a piece of slag [RLM043 1139] is also consistent with ores from the mining region of Jaen and Seville in southern Spain. # Zofia Stos-Gale.

There are very few isotope studies of material later than the Bronze Age, and no isotope studies of early medieval objects for comparison. However, the composition and lead isotope ratios from Rendlesham show similarities with the few studies of late Roman period alloys. Isotopic analysis of 2nd- to 5th-century AD bronzes from the settlement at Jakuszowice in Poland also had an isotopic signature consistent with ores from the Massif Central.[38] Overall, this is consistent with the exploitation of the same metal sources over many centuries and widespread continuous recycling.

SCALE AND ORGANISATION OF PRODUCTION

Evidence indicative of metalworking, including undiagnostic scrap and melt, has been recovered across the full area of early medieval activity, with heavier concentrations of finds in the two main areas of settlement. The distribution of datable and more strongly indicative material is similar but more tightly focused on the promontory and the settlement to the north and east. The similarity of the two distributions strongly indicates that most of the sprues, melt and undiagnostic debris derive from the same activity as the more diagnostic material of the late 6th and 7th centuries. Smithing in copper alloy, gold, and silver, and the production of both status and lower-value items, was clearly undertaken in both of the main settlement areas during the later 6th and 7th centuries. There is, however, a particularly strong concentration of sprues, unfinished items or discarded castings, and jewellery components in precious metal on the promontory c 100 m south of the probable great hall, and this probably marks the physical location of a workplace associated with the elite establishment. It is entirely possible, especially if some or all of the craftworkers were itinerant or tied to an itinerant elite household, that the spatial distribution of metalworking evidence represents successive working episodes at different locations within the settlement complex by the same group of craftworkers (Fig 13).

There is no excavated evidence for physical workshop space but the range of techniques exhibited in the Rendlesham material — precious metal as well as copper alloys — implies two working environments. An enclosed hearth would be needed to allow metalworkers to observe the subtle changes in colour to determine the temperature essential for processes such as casting, soldering, heat-treating, gilding, and applying niello.[39] Detailed work such as shaping, finishing, stamping, and beading wire would have required as much natural light as possible and may have been carried out in the open air.[40]

The spatial distributions suggest that working in copper alloy and precious metals was taking place side-by-side, indicating a group of craftworkers who between them handled the full range of materials and manufactured items. This would require a range of skills and skill levels and in turn implies workshop groupings with a master crafter or crafters aided by assistants or apprentices with different levels of skill and experience. It is possible to envisage master crafters working on complex precious metal items, some of which included lapidary elements, while others handled simpler items in lower cost materials. It is important to recognise the extent to which their activities were embedded within networks of supply and other complementary craft skills. In addition to the raw materials of metal, garnet, and glass, mercury — obtainable only through long-distance exchange networks — was needed for gilding and charcoal for all high-temperature work.[41] Similarly, the production of fittings for swords, belts, and bags or satchels presupposes skills in weapon smithing and in wood and leather working, and degrees of co-operation between specialists in different crafts.

Figure 13 - The Rendlesham survey area showing the distribution of all material related to non-ferrous metalworking (left), and the distribution of material firmly indicative of late 6th- and 7th-century metalworking (right). Illustration by Stuart Brookes.

The sprues are an unusual aspect of the Rendlesham assemblage. Sprues do not appear to have been recovered from excavated early medieval settlements in England with other evidence for non-ferrous metalworking,[42] but are present in the metal-detected assemblages from Coddenham and Hoxne. This raises the question of whether the presence of sprues in these assemblages is a collection bias or genuinely represents something specific to copper-alloy metalworking at high-status sites of this date.

At Rendlesham, Coddenham and Hoxne, the sprues were recovered from the ploughsoil. If lost or discarded on the old ground surface, and not subsequently incoporated in the fills of cut features, then they would not be recovered on excavations where the old ground surface had been lost or the ploughsoil removed by machine without detecting or sieving. Copper-alloy sprues are in fact often found and reported to the Portable Antiquities Scheme but are undatable without associations and are frequently recorded as Bronze Age.[43] It seems highly likely that a proportion of these, as well as undiagnostic scrap and melt recovered by metal detecting, derives from early medieval copper-alloy working, especially as examples of discarded castings are now being reported.[44]

The sprues from Rendlesham contain 242 g of metal, enough to make 201 bag-catches or the loops, pins, and plates for 161 buckles. Normally, one would expect sprues like these to have been added to the crucible for the next round of casting, removing them from the archaeological record. One possibility is that the these were from failed castings and that the craftworkers, suspicious of the metal, decided not to recycle them. However, there are no significant differences in composition between the sprues with rounded ends that clearly failed and those that were cut from castings, nor between the sprues and the other metalworking waste and finished objects. Either way, the apparent lack of concern to recycle sprues would suggest that the workshop had a good supply of metal. Even allowing for retrieval bias, the recovery of sprues from Rendlesham, Coddenham and Hoxne may reflect the metal wealth of these places.

There is evidence from Rendlesham both for fine metalworking for elite patrons and for the manufacture on a considerable scale of low-value utilitarian items. The latter might be components of more complex items but their production in mutliple batches, and the numbers of finished items in the overall metalwork assemblage, implies manufacture for a wider population than that of a single elite household or even the wider settlement complex. We have suggested that workshop groupings — in the sense of a master crafter and assistants — undertook the full range of work. If so, and if attached to a peripatetic elite household, this would afford elite patrons access to their skills at all times, and a local population access when the household was in residence. Material from Hoxne and Coddenham suggests a similar metalworking and production range, and there is evidence from Coddenham for the contemporary manufacture of a range of low-value copper-alloy items similar enough to those from Rendlesham to suggest close links or even the possibility that some of the same crafters worked at both places.[45] This would be consistent with crafters attached to peripatetic elite households but would not exclude the idea of metalworkers working at or from elite centres also serving the wider rural population. The higher-skilled and master crafters who would have executed fine work for elite patrons may have travelled more, with the less skilled who dealt with more routine work spending more time at any one place and its hinterland. The economic and social pull of these central places would give them preferential access to raw materials and commodities, and favour the co-location of complementary craft skills. Some centralisation of craft production at such places, serving a wider rural population, should not therefore be surprising.

SUMMARY AND CONCLUSIONS

There is clear evidence for copper-alloy metalworking at Rendlesham in the later 6th and 7th centuries, undertaken by a group or groups of craftworkers who also worked with precious metals and who served both elite patrons and a wider population. It is likely that some of these were attached to the peripatetic household of a regional elite.

In the absence of crucibles and moulds, we have shown that detailed information about the casting technology can be derived from close examination of distinctive features on sprues, failed castings and unfinished objects. Technical examination of both the finished and unfinished objects has then allowed us to characterise the subsequent sequence of manufacture. The use of piece moulds has been confirmed and it has been possible to determine the thickness of the mould material. The moulds used for buckles, bag-catches and pins allowed multiple objects to be cast in batches. This makes best use of the clay mould material, and the piece moulds may have been reused. The implication of this for the scale of manufacture supports the view of some centralisation of craft production.

Compositional analysis suggests some alloy choices, with the metalworker matching the working properties of the metal to different components, but does not allow the identification of regional or workshop-specific alloys or alloy groupings. The range of alloys at Rendlesham is characteristic of widespread and long-term recycling, with no evidence for the introduction of fresh brasses before the 7th century. The lead isotope study has shown that the lead in the copper alloys is likely to have been derived from continental Europe rather than Britain, again consistent with long-term recycling of copper alloys from the 4th century or earlier.

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