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The St Fagans Experimental bloomery; the first six years

Tim Young

The experimental iron-making project at the Museum of Welsh Life, St Fagans (a branch of the National Museums and Galleries of Wales), finished its first phase of experiments in March 2004. The furnace had been built exactly six years earlier, but after some twenty five smelting experiments, the furnace was abandoned to the elements, because of the museum's plans to redevelop that part of the site. It is hoped that the project will construct a new furnace nearby within the next year, but the current hiatus allows us the opportunity to evaluate those first six years and to undertake further analytical studies.

The rationale behind the furnace experiments was simple: to try to reproduce the technology employed in smelting the haematite and goethite ores of the Bristol Channel Orefield in a Medieval-style slag-tapping bloomery. We had three main reference points in starting this process:

1. The excellent work of Peter Crew, who had so convincingly pointed the way towards an understanding of the non-tapping furnace (Crew 1991).
2. the PhD thesis of Gary Thomas (Thomas 2000), which was undertaken at the same time as the early experiments. Gary worked on the mass balance of bloomery iron smelting in the Bristol Channel area and gave us great insight into the yield and efficiency of local operations.
3. The detailed accounts (Public Records Office SP1-66) of bloomery iron smelting from Glamorgan haematite ores in 1531. These accounts showed that a bloomery could produce two 50kg blooms per day, using three men pumping the bellows at a time.

These starting points indicated that the rate of reaction must have been much faster, at least in late bloomeries, than in early non-slag tapping furnaces. Our ambitious target was to develop a technique which could produce a single 12kg bloom within a working day; rather more modest than the reproduction of a full-size Tudor

bloomery. Mass balance modelling of probable late medieval slags from the same area as the Tudor accounts shows a standardised efficiency (*sensu* Thomas & Young 1999) of 74%. In other words, 1kg of haematite ore would yield about 0.5kg of iron. We would therefore need a furnace capable of a throughput of at least 24kg of high-grade ore per smelt.



Figure 1. The St Fagans iron smelting furnace

Peter's work strongly influenced the design of the furnace. After an early realisation that we had built it too short, the furnace design stabilised on a shaft with an internal diameter of approximately 0.34m, a wall thickness of greater than 0.3m, a bed depth of approximately 1m and a depth below the blowhole of approximately 0.25m.

During the early part of the project we smelted entirely local ore, but as this became more difficult to source and as we saw the experimental campaigns were going to be long, we switched to using an imported ore (but closely matching the Glamorgan haematites in chemical composition) kindly provided by Corus, to provide a uniform feedstock.

The early experiments were surprisingly successful, with small blooms being made right from the start. Increasingly, however, we realised that what we were doing was reproducing the style of results already achieved by Peter Crew in non-slag tapping furnaces, and that we were failing to make headway on scaling-up the process: our blooms tended to be quite delicate, we could not achieve tapping of the slag and each smelt took a very long time (9-12 hours for the large charges

we wanted to be able to smelt). We clearly needed to push the reaction rates higher and so we experimented with increasing blowing rates; early experiments used double-action blacksmiths' bellows (initially a single pair, later with two pairs) in various configurations, which were later replaced by a purpose-built large single-action bellows and the final few experiments were blown with an electric blower.



Figure 2. Slag tapping at St Fagans

Attempts to measure the air-flow probably provided at best semi-quantitative results, so discussion of charcoal burn rates is probably more useful. The early experiments, producing the fragile blooms, had burn rates of 6–8kg/h. The large single action bellows raised the burn rate to 10–11kg/h, but yields of both iron and free-flowing slag were extremely disappointing at these rates. The electric blower used for the last four smelts produced a dramatic change in furnace performance: burn rates leapt to 14–16kg/h, the blooms became dense and solid, varying from 4 to 6kg from 19 to 25kg ore (i.e. a standardised efficiency of 35–40%), the furnace produced large quantities of freely flowing slag, and the overall cycle time was reduced to around 6 hours. These last few smelts seem to indicate that the high blowing rate approach championed by Sauder & Williams (2002) has great potential.

There is much still to do to complete the analysis of these experiments, in particular investigation of the iron produced in the later blooms. However, we have already learnt much about operating this style of furnace. Adjusting the operating parameters to increase the efficiency must be the main thrust of the next experimental campaign; even raising the efficiency to 50–60% would be equivalent to most Roman bloomeries in the area. The other main area of improvement is in the manipulation of the furnace base – we have too much slag solidifying within the furnace and experiments in how to manage this, including whether the tap arch needs to be blocked or open will be

on-going. In the meantime, monitoring of the collapse of the first furnace is providing new data on how such furnaces decay.



Figure 3. Forging one of the St Fagans blooms

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www.geoarch.co.uk/experimental/experimental.html

Copper from HMS Colossus

David Dungworth

Three samples of copper (a bolt, a rove and sheathing) from the famous shipwreck have been submitted for examination. Copper sheathing for the hulls of Royal Navy ships was introduced in 1761 to protect them from the teredo worm. Metallography shows that all samples are made from hot-worked (or cold-worked and annealed) copper containing small amounts of oxygen. Qualitative EDXRF analysis indicates nearly pure copper with small amounts of arsenic and lead.

Does anyone know of any references/comparative material?

Spherical Hammerscale and Experimental Blacksmithing

David Dungworth and Roger Wilkes

It has long been recognised that hammerscale comes in two different forms: flakes and spheres. The flakes are unproblematic but there has been much discussion about how and why the spheres form. The flakes (figure 1) are believed to form when the surface of a bar or iron is heated in the fire: the surface oxidises to form magnetite and this easily flakes off the iron (especially during smithing when the hot iron plastically deforms).

The spherical hammerscale is virtually identical to flake hammerscale (e.g. silvery-grey colour and magnetic) but a very different shape (figure 2). While most have associated spherical hammerscale with welding operations, some spherical hammerscale has been produced during Peter Crew's experimental iron smelting. The association of spherical hammerscale with welding has been a 'factoid' and some archaeologists have challenged us, 'can you prove that the spheres are produced by welding'.

We decided to carry out an investigation of flake and spherical hammerscale and included experimental smithing to try and recreate both types of hammerscale (we hope to report in full in *Historical Metallurgy* in due course). We cleaned a teaching smithy (West Dean college) and forged and welded both a wrought iron and a mild steel. After each operation we swept up the hammerscale produced. This showed that spherical hammerscale was associated with welding. In addition, we recorded some of the welding using a high-speed digital video camera. Figures 3–5 show stills taken from one of the films (the images have been reduced to black and white and are negative images to help clarify them here).



Figure 3. Still from high-speed digital film of welding. 0.007 seconds after the hammer struck the iron (negative image)

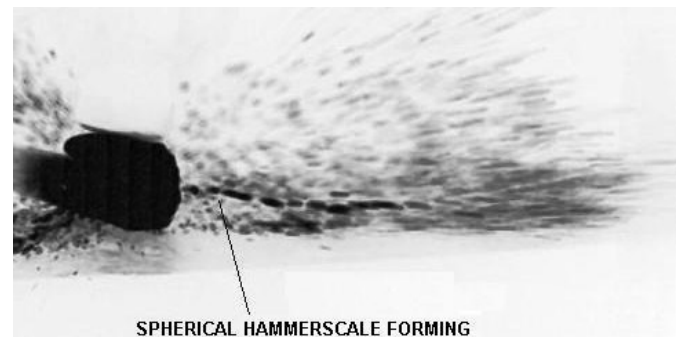


Figure 4. Still from high-speed digital film 0.012 seconds after the hammer struck (negative image)



Figure 5. Still from high-speed digital film 0.017 seconds after the hammer struck (negative image)

Figure 3 shows the bar of wrought iron bent over on itself for welding (black) with the hammer above

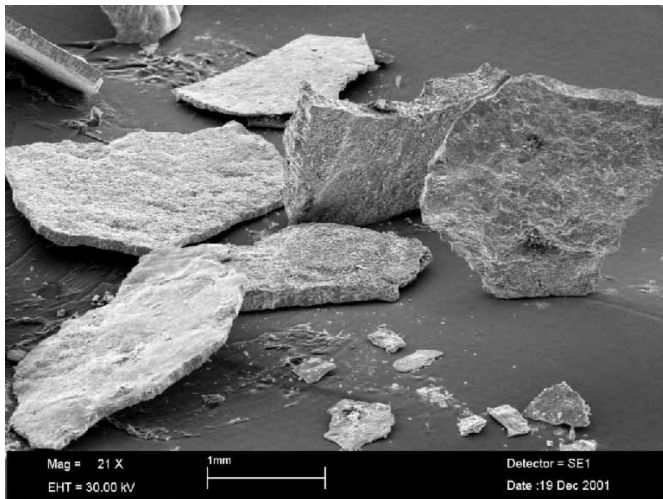


Figure 1. Flake hammerscale

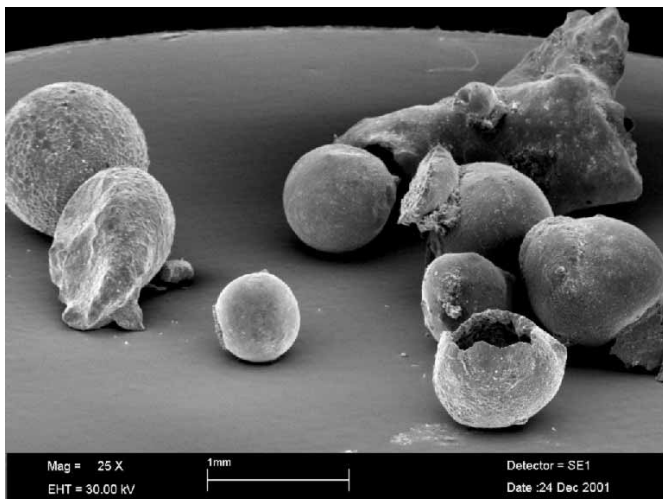


Figure 2. Spherical hammerscale

(white), 0.007 seconds after the hammer struck the iron. This shows flakes of hammerscale flying off in a wide arc and a thin stream of material (dark) coming out of the weld line. After a further 0.005 seconds (figure 4) this stream has started to turn in to a stream of separate spheres and this process is largely complete after a further 0.005 seconds the stream (figure 5).

The final publication will include photomicrographs and details of the chemical composition of spherical and flake hammerscale (both experimental and archaeological) and will explore other issues (such as the use of fluxes).

Medieval Copper Working in Carlisle, England

Frank Giecco

Recent excavations at 15 John Street, Carlisle by North Pennines Archaeology Ltd have revealed evidence for large-scale medieval copper working. During the 14th century there were several phases of large timber buildings and associated furnaces. The earliest building, defined by a timber beam slot, contained a sequence of floor surfaces and internal partitions. The primary floor surface of this building produced a silver groat of Edward the third, dating from 1351–1377, and small quantities of 13th/14th century greywares. This initial floor surface was sealed by a sequence of occupation layers (covering a period of over 100 years) which all produced mould fragments and molten droplets of copper alloy. There were a number of furnaces to the south of this building. All these furnaces had traces of slight structures that may have partially covered them and the immediate working area, the evidence for these tentative structures came in the form of post holes and short lengths of cobble foundation. Most of the furnaces had signs of being refurbished a number of times. The working areas around these furnaces were littered with smashed furnace lining and mould fragments as well as metalworking slag. Qualitative analysis of some of the copper alloy spillages suggests that they are a lead antimony bronze. Samples of metalworking debris are now with Gerry McDonnell, University of Bradford for detailed study.

Bashley Britten and Finedon Iron and Glassworks

David Dungworth

While pursuing research into the recipes used for the manufacture of post-medieval bottle glass in Britain I have come across some interesting references to the use

of blast furnace slag. One of the most interesting sources is Powell (1883) which contains the following,

Great credit is due to Mr Bashley Britten for having devised a method of utilizing in the manufacture of glass the iron slag which accumulates as refuse at the rate of nearly 8,000 tons per annum. . . . The glass manufactory at Finedon in Northamptonshire is in close contiguity to the blast furnace of the iron works; and as molten slag is run out of the furnaces it is directly conveyed to the furnace in which it is converted into glass.
(ibid 83–4)

Does anyone know anymore about Bashley Britten and Finedon?

Reference

Powell, H. J. 1883. *The Principles of Glass-Making*. London: George Bell

Smelting Experiments at Butser: A reply

David Bick

I have read with interest and a certain amusement (HMS News 58) about the trials to see whether bronze could be produced in a furnace without leaving any appreciable amount of slag, thus explaining the dearth of smelting sites in bronze Age Britain. And as far as they went, the results were very satisfactory, but really proved nothing at all. This is because the outcome merely demonstrated what any schoolchild versed in chemistry could have told them. The ores chosen (malachite or basic copper carbonate, and cassiterite or tin dioxide), contain only the metals copper and tin, plus oxygen and carbon. The latter would have been converted into carbon dioxide, leaving only the metals themselves, either as elements or as bronze alloy. But even then, unburnt charcoal would have survived to bear witness to the event.

The tests were in any event very unrepresentative because malachite is, and was, an uncommon mineral. Whatever its ultimate use, nearly all the copper ore mined at ancient sites in this country was a complex mixture of iron and copper sulphide, and usually running as a poor 8 or 10% copper. Where then would the iron go, if not to remain in some form or another as slag? This is the kind of ore that experiments must be made upon for real advances in the history of copper metallurgy.

However, slag, or the want of it, is not the only obstacle. Remains of furnaces are equally absent, and in any court of law the case for smelting would have been thrown out without more ado. Of course, an obvious answer might be that the ores were never smelted, but used for various purposes. That copper minerals were

the source of blue and green pigments is undeniable, and the ores must have come from somewhere. Yet in considering such a solution, the copper lobby is strangely reticent, as if reluctant to admit a weakness in its case. Pandora's Box is better left unopened.

The First Cementation Steel Furnace in England? Recent Excavations at Coalbrookdale

Paul Belford and Ronald A. Ross

The development of the cementation process in the late 16th and early 17th centuries allowed steel to be made cheaply and in quantity for the first time. The process is thought to have originated in Germany and the Low Countries, and spread to Britain through the efforts of Sir Basil Brooke circa 1619. Documentary research strongly suggested that Brooke's first successful steel furnace was located at the Upper Forge, in Coalbrookdale, Shropshire. Excavations from 2001 to 2004 located a furnace thought to be either Brooke's first furnace (circa 1620), or a second built before 1640. As these furnaces date approximately a century earlier than the next archaeologically tested example, Derwentcote in Northumberland and were both built within a century of the first use of the process, it was expected to shed considerable light on the development of this technology.

Excavation revealed that conversion of the building to a malthouse in the 18th century had truncated the furnace itself, leaving only about 1 metre standing. However, enough remained to discern some unique features. Later furnaces, including Derwentcote, are comprised of three structural elements. In the middle is a rectangular furnace, supported by buttresses, and surmounted by a tall round chimney. The main operational parts of the furnace (the stoke holes, firebox, cementation box(es), and ash-pit) are oriented along the long axis, and the furnace is stoked from both ends. Off each end of this are other rectangular buildings known as feasing or tenting houses. These were used for storage of raw materials and fuel, and other infrastructure activities, as well as protecting the workers loading and stoking the furnace. The feasing houses are the same width as the furnace minus the buttresses.

The Brooke Furnace was not rectangular, but was instead an oval sandstone structure, with two flattened brick-faced short sides, and at least two buttresses for support on one side. It is likely that buttresses originally existed on the other side as well. The exterior shape is reminiscent of some 17th and 18th century glass furnaces. The brick-lined ash pit, all that remained of the operational elements, ran diagonally across this

structure, and was accessed at each end by a passage that doubled back sharply. The ash pit did not run completely across the structure, but was interrupted by a wall in the middle. This may indicate that the firebox itself was split, perhaps as a load-bearing measure. Even in a small furnace, the contents of the cementation box would weigh several tons.

Unlike later examples, the Brooke Furnace appears to have been fully contained within a larger building. Contemporary walls run parallel to the flattened short sides of the furnace, leaving a gap of 0.8m on each side. This gap comprised the entrance to the ash pits, accessed by stone steps. The arrangement seems awkward, with restricted access to the stokeholes, but the arrangement would work reasonably well for a right-handed shoveler.

Excavation at the Brooke furnace will continue in the spring and early summer of 2005. Investigation will centre on the relationship of the feasing house and other infrastructure to the furnace itself, on locating and fully excavating, the other Brooke Furnace, and on further collection and analysis of waste products from the furnaces. Individuals interested in participation in either the fieldwork or the analysis are encouraged to contact the authors.

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Figure 1. Excavation in progress at Coalbrookdale

Anglo-Saxon Copper Alloy Working at Carlton Coalville, Suffolk

Eleanor Blakelock

Excavations by the Cambridge Archaeological Unit at Bloodmoor Hill, Carlton Coalville, Suffolk revealed a Roman field system and extensive 6th to 8th century Anglo-Saxon settlement remains. Crucibles and moulds from Anglo-Saxon sunken featured buildings provide evidence for copper alloy working.

The crucibles were hand-made and constructed from a clay fabric with abundant quartz inclusions, up to 2mm in size, and vegetable-temper. A layer of sand on the outside of many of the crucible fragments had become vitrified in areas. The crucibles have a wall thickness of 10–15mm and an external diameter of 100mm. The exact height of the crucible is not known but it is likely to be more than 120mm high possibly up to 160mm. The bases are rounded and more vitrified than the other crucible fragments. The overall form of the crucible appears to be a large vessel, deeper than it is wide, with a pouring lip.



Figure 1. Mould Fragment

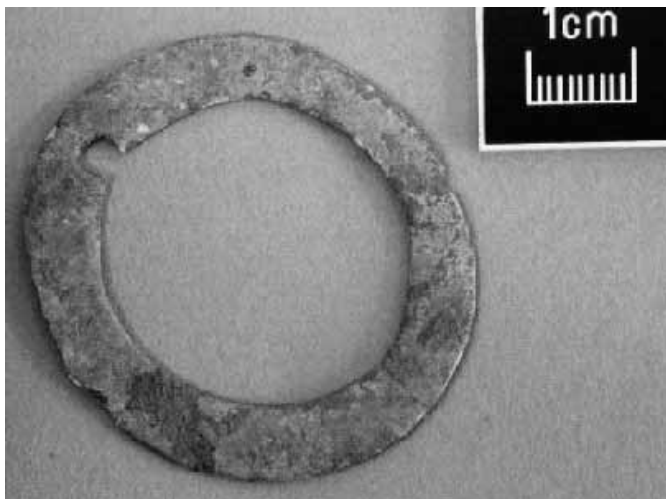


Figure 2. Penannular brooch

The moulds were created from a fabric similar to that used in the construction of the crucibles except they had fewer and smaller quartz inclusions. Two fragments of piece mould were clearly used to cast a flat curved object. Comparing with the copper alloy artefacts from the site, showed that the objects being cast were simple Anglian penannular brooches.

Roman Iron Production in Worcester

Eleanor Blakelock

An archaeological investigation carried out by Birmingham Archaeology at 14–20 The Butts, Worcester revealed a possible Roman street and many pits in which 67.9kg of ironworking waste was found. Previous excavations in Worcester have revealed that ironworking was an important activity in Roman Worcester. The ironworking waste at the Butts was recovered from secondary deposits; there was no evidence for furnaces, but some areas of the site were heavily truncated. Most of the slag assemblage consisted of smelting slag (e.g. tap slag) with small amounts of undiagnostic slag, vitrified lining, metallic iron fragments (including a possible bloom fragment) and ore. There was no evidence of iron smithing.

Samples of slag, metal and ore were examined and analysed (optical microscope, SEM-EDS, hardness, XRD, etc). The smelting slags from the site have low concentrations of phosphorus, intermediate amounts of lime, magnesia, potash and alumina which is typical for slags from the Gloucester, Worcester and Somerset area. The XRD analysis of the ore showed that it is goethite with some haematite. Tim Young has identified the ore as stalactitic and likely to come from the Forest of Dean.

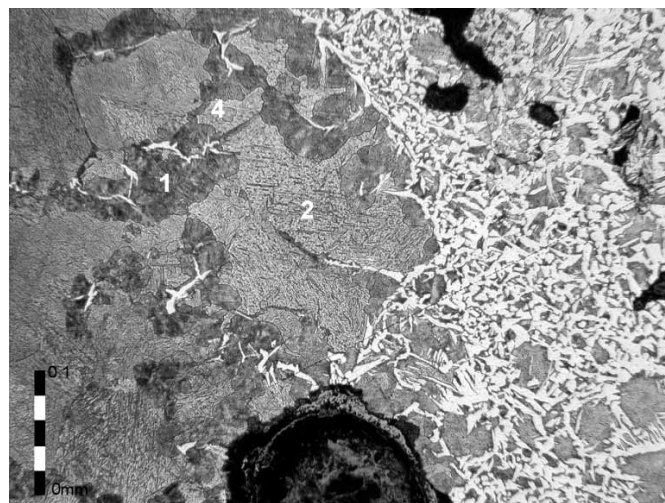


Figure 1. Photomicrograph of the possible bloom fragment

The bloom fragment weighs 520g and is 100mm by 60mm and 60mm thick. The microstructure was heterogeneous and included the phases pearlite, bainite and martensite and Widmanstätten ferrite (VHN 154–193). The proportions of these phases and the results of the hardness tests together indicate that the fragment is steel with a carbon content varying from about 0.3–0.8%. The bloom fragment had also cooled unevenly; the presence of martensite in the central region indicating rapid cooling whereas the Widmanstätten microstructure of an adjacent region suggested slow cooling. When the bloom fragment was analysed using the SEM the amount of phosphorus present throughout the sample was below the detection limit.

Seventeenth Century Vessel Casting at South Petherton, Somerset

Eleanor Blakelock

Following the publication of Butler & Green (2003) there has been an increase in interest in cauldron casting. Most of the cauldrons and skillets in the exhibition have now been acquired by Somerset County Museum. A high proportion of the vessels in the collection were produced by two families (the Sturtons and the Fathers) in south Somerset. Steve Minnet of Somerset Museums Service asked locals to look out for any fragments of mould or copper alloy casting waste in their gardens. One family in South Petherton reported finding moulds and documentary research suggests that their house lies on the site of the Sturton foundry. They allowed the County Archaeologist (Bob Croft) to excavate a substantial part of the front garden. The excavation revealed a series of pits, back-filled with large quantities of ceramic moulds. The mould fragments have been carefully cleaned and some makers marks have been revealed.



Figure 1. Skillet handle mould fragment (reversed image to show the inscription as it would appear on the casting)

Figure 1 shows a reversed image of part of the mould for a skillet handle. The letters which survive are **ETSX** and closely match known skillets ('THIS BE GOOD WARE TS') produced by Thomas Sturton. Figure 2 shows a reversed image of part of a cauldron mould. This has a ligatured **WM** incised into the mould (this is the mark of William Sturton).

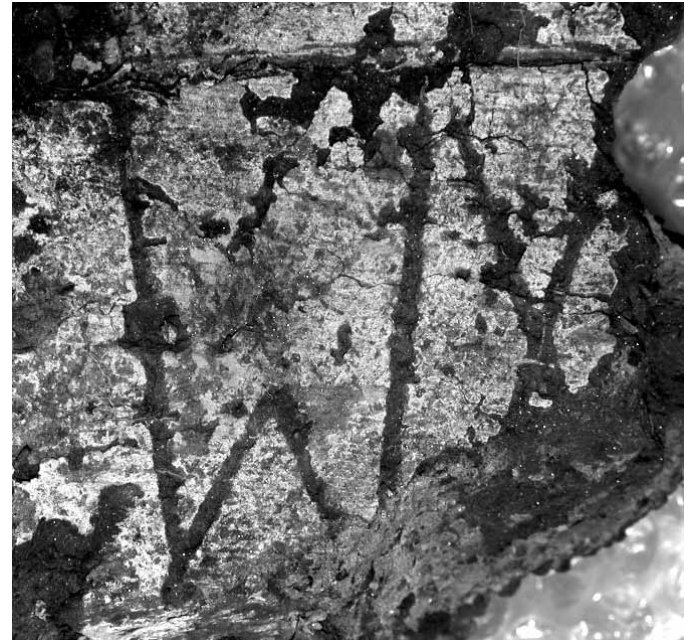


Figure 2. Cauldron mould fragment (reversed image)

Analysis of copper alloy spillages from the site confirms the use of a leaded antimony bronze (cf. Dungworth & Nicholas 2004). There are still some unanswered questions about the origins of this metal. It has been suggested that this metal is a waste material from the liquation of argentiferous copper obtained by smelting *fahlerz* type ores. Analysis of the casting debris shows that this alloy frequently contains up to 2wt% nickel and 15wt% tin but these elements are virtually unknown in *fahlerz* types ores (Ixer & Patrick 2003).

References

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Archaeometallurgy in Sardinia

Paul Craddock

The Associazione Italiana di Metallurgia, the Associazione per l'Università del Sulcis Iglesiente and the Università degli Studi di Cagliari held a meeting at Cagliari on 10th and 11th of September to launch *Archaeo Metallurgy in Sardinia*, (Sanna *et al.* 2004). This constitutes a major multi-authored study dealing with all aspects of prehistoric metallurgy on Sardinia.

The meeting itself had two main themes, one was on the metal sources and the abundance of copper and bronze metal found in the Bronze Age Nuragic settlements, and the other theme was to place the Bronze Age metallurgy of Sardinia within the context of its neighbours and beyond, Iberia (S. Rovira Lorens), France (M. Pernot), Central Europe (E. Pernicka), and Cyprus (V. Kassianidou), with more general archaeological and metallurgical overviews from J. Muhly and R. Maddin.

On the second day the meeting went to the Parco Geominerario centred on the town of Iglesias in the south eastern corner of the island. The topics were new data on archaeometallurgy in Sardinia (C. Atzeni, R. Valera and F. Lo Schiavo), new analyses and studies on ingots in Sicily (A. Giunilia-Mair and F. Lo Schiavo) and in the Alps (N. Trampu-Orel and A. Jockenhövel). The mines of this region produced mainly argentiferous lead together with some copper in the recent past. The mines are of considerable antiquity although without certain evidence of ancient exploitation. Visits were made underground at the Galleria Villamarina mine and to the Porto Flavia mine where an adit cuts through the sea cliff which enabled ore to be discharged directly into the ships below. The mines were in operation until quite recently, and together with other Sardinian mines are being restored as a series of mining museums.

The Bronze Age metallurgy of Sardinia has attracted the interest of scholars and especially archaeometallurgists for many years, the cause of this international interest being two-fold. The enormous numbers of Nuraghi, the Bronze Age cyclopean stone towers, and their associated settlements are a constant reminder of the prehistoric past, together with the great quantities of copper and bronze metal, in the form of ingots and artefacts that have been found. Such quantities of metal betoken a large scale mining and smelting industry with intriguing international connections. In particular, from the 19th century onwards, large numbers of the distinctive oxhide ingots have been found, either complete or more usually fragmentary, and their number increases with almost every Nuraghe excavated or hoard of metal discovered. The oxhide ingots are also metallurgically distinctive, the copper is often highly oxidised, leading some metallurgists to speculate that some form of processing had taken place

after the metal was smelted (as suggested by Cyril Stanley Smith, p. 265, Figs. 18.1 & 2 in discussion on Merkel 1986). Quite early on it was recognised that the Sardinian ingots were similar to those found in the Minoan and Mycenaean settlements in the eastern Mediterranean. Thus it was assumed that the ingots were evidence of a Mycenaean interest in Sardinia with copper being shipped back to the east, and more recently this interest was confirmed by the discovery of Mycenaean pottery, etc on the island.

The application of lead isotope analysis since the 1990s has changed that scenario rather dramatically. Several hundred samples of Sardinian Bronze Age copper and bronzes have now been analysed by various groups, notably by the Gales at Oxford (Stos-Gale 2000). These show that whilst the artefacts and bun ingots are of local metal, apparently all of the copper of the oxhide ingots emanates from one source on Cyprus, the Apliki/Skouriotisa mines in the north-west of the island. Not only is this a complete reversal of the assumed direction of the trade, but there is another mystery. Having apparently brought the very considerable quantities of metal to Sardinia, such that fragments of oxhide ingots appear in many of the hoards of general metalwork, it was not used; none of the Sardinian artefacts seem to contain the Cypriot copper.

To an archaeometallurgist it is noticeable that attention seems to have drifted away from the extractive metallurgy and consideration of the possible influence that processing might have on the lead isotope figures. Many years ago when Tylecote *et al.* wrote their 1983 paper on Sardinian metallurgy, which together with Lo Schiavo *et al.* (1990), remains the best introduction to the subject, all aspects from the ore in the ground to the finished bronzes were considered equally. Since then there seems to have been little progress on the location and investigation of mines or smelting places. However, production debris in the form of scatters or even heaps of slag should exist. This is because the relatively high iron content of the local bronzes strongly suggests that true slag-forming smelting processes were already taking place on Sardinia. It is perhaps also significant that slag-forming processes were not yet used in the remainder of the western Mediterranean, which itself suggests a special interest and influence in Sardinia from the east (Craddock 1986).

Since the publication of the first lead isotope efforts have concentrated on geological sampling of the metalliferous deposits on the island and the on the metal ingots artefacts, but it is at least conceivable that the explanation for the surprising results lies in the process metallurgy between ore and metal. A not impossible scenario was suggested to the meeting. Some of the copper ores of Sardinia, notably those at Funtana Raminosa, are argentiferous (Tylecote *et al.* 1983: Table 2), and some of

the Nuragic bronzes have high silver contents, up to 6.5% in the metal analysed by Begemann *et al.* (2001) and by Atzeni (2004: 65). Given that the putative entrepreneurs from the Eastern Mediterranean were very interested in silver, it is unlikely that they could have failed to notice this. The removal of silver from copper is quite easy by the process of liquation (Percy 1880: 303–56).

In the Post Medieval European process lead was alloyed with copper in the ratio of about 11 to 3, whereupon the silver transferred to the lead, and cast into large cakes. These were heated to red heat but below the melting point of copper, for some hours and the majority of the argentiferous lead drained from the copper. The copper cakes still retained much lead more of which was removed as lead oxide by prolonged roasting during which much of the copper also oxidised, and which then had to be refined to remove the last of the lead and copper oxide. In the Japanese version of the process, recorded by J.H. Godfrey in the late 19th century (Percy 1880: 340–3) three parts of the argentiferous copper was alloyed with one part lead and fragments of this alloy worked on a hearth at red heat for some hours until almost all the now argentiferous lead had been squeezed out. Thus the products were argentiferous lead, from which the silver could be extracted by cupellation, and rather oxidised copper, recalling C.S. Smith's prescient comments on the state of the oxhide ingots. If this process had been used then both the resulting silver and copper would now have the lead isotope signature, not of the original lead accompanying the copper in the ground, but of the lead used in the liquation process. It might be argued that there is no evidence for the liquation process at this early date, but as it is so simple it leaves little distinctive debris, unlike the rather more sophisticated process of cupellation, which is characterised by the presence of litharge and is thus dated back to the fourth millennium BC in the Near East, and second millennium BC in Iberia (Hunt Ortiz 2003: 346–7). Having discovered significant silver in the copper, the Mycenaean would naturally have wished to keep the knowledge to themselves and carry out the process within their own depots using their own materials, including the lead. This is not as improbable as it might at first seem. The lead is recyclable to some extent by resmelting the litharge. It also recalls the old legend recounted by the Greek writer Timaeus in the 4th century BC of the Phoenician sailors going to the west and producing so much silver that they could replace their lead anchor stocks with silver, surely a literary way of saying that they took lead to produce the silver.

All of the silver and much of the copper would have been sent back to the east, and some of the copper would have entered into local trade, but cast in the distinctive oxhide ingot form so that the traders would be able to recognise that it had been de-silvered.

There are major problems with this scenario. Cyprus is reputed never to have had any workable lead deposits, although the mines which have the lead isotope ratios that match those of the oxhide ingots are now huge open cast pits, making it difficult to know what other minor deposits might originally have been present. Another problem is that the overall lead content of the oxhide copper ingots is almost always low and the distinctive lead isotope composition is found not just in the Sardinian ingots but in the majority of the ingots that have been found all over the Mediterranean and beyond.

The explanation may lie in the complexity of the metals trade in the Mediterranean in the Bronze Age and indeed the whole liquation hypothesis was put forward not as the unassailable explanation, but rather to demonstrate that the lead isotope ratios could be radically changed during the process metallurgy, and are not solely dependent on the ore sources.

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Copper Processing in Central America: Excavations and Finds at El Coyote, Honduras

Aaron Shugar

The excavation of El Coyote was directed by Pat Urban and Ed Schortman (Kenyon College). El Coyote, with 340 surface-visible structures, was a regional center during the Late Classic (AD 600-850), Terminal Classic (AD 850-1000), and Early Postclassic (AD 1000-1300). Unlike most of their counterparts throughout western Honduras and the neighboring Maya lowlands, El Coyote's rulers flourished during the Terminal Classic and Early Postclassic. While other magnates suffered losses of power and increasing marginalization within interregional exchange networks, El Coyote's paramount lords continued to attract adherents to their capital, raised sizable constructions, including a ballcourt, and acquired relatively large quantities of goods from afar. In contrast, residents of the Naco valley 9km to the northeast acquired only two blades of this obsidian at the same time. How were El Coyote's rulers able to survive the perils of the Classic/Postclassic transition? One possibility is that they somehow managed to control a resource highly valued by the leaders of other Mesoamerican societies at this time, a resource that gave them access to goods, such as Plumbate pottery and Pachuca obsidian, with which they could attract and hold clients. One strong possibility is that these magnates learned how to convert plentiful local supplies of raw copper into artifacts and/or ingots for export to distant locales.

Test excavations at El Coyote directed by Urban and Schortman in 2002 turned up copper-bearing slag from the southeast margins of the center. More intensive study on this area in 2004 yielded a complete copper production center. The finds are spectacular and the evidence is astounding with clear indications of a full copper processing center existing on the site. There are different areas associated with the different production processes. At the moment we have uncovered an ore processing area where copper ore was crushed in preparation for smelting, a complete *in situ* copper smelting furnace with a built up platform, slagging pit, and walls made of adobe bricks. Four slag heaps have also been identified. Likely the most outstanding find is what we are calling a 'water table' that was used to crush copper slag under a constant water flow to remove entrapped copper from the slag for remelting and casting (figure 1). The find is in amazing condition and nothing of the sort has been found in all of Mesoamerica. Additional metallurgical debris is scattered over 1400m² on the SE margins of the site. Initial studies of the slag substantiated the theory that it

derives from the byproducts of copper processing pursued on a fairly large scale.



Figure 1. Recently excavated 'water table' used for crushing and sorting slag to remove and wash the copper (note the small depression in the front rock caused by excessive pounding).

As yet, these activities remain undated. Though the possibility that they pertain to the Historic era can not be ruled out, it is at least equally likely that copper processing here is of pre-Columbian vintage. Specifically, the recovery of Early Postclassic diagnostic pottery from excavations in the workshop tentatively suggest that at least part of the atelier was in use during this period and its output may have underwritten the locally unusual persistence of elite power at El Coyote. There is a known high quality copper ore mine in the hills within 8km of the site. Currently, full technical studies are being performed on the archaeometallurgical remains by Aaron Shugar (Lehigh University and Smithsonian Center for Materials Research and Education) to gain a better understanding of the activities that took place. Further more detailed excavations are planned for the area in the upcoming field seasons.

Iron & Steel Town – An Industrial History of Rotherham

Anthony P. Munford. 2003

159 pages. Sutton Publishing Ltd. (Stroud)

Paperback. £12.99. ISBN 0-7509-3037-3

Until recently Rotherham had been a major centre for the production of both iron and steel for over 200 years but a comprehensive history of this industry has never received any attention, unlike that of the neighbouring steel industry in Sheffield. This gap in the record has now been filled successfully by the present book.

The origins of the iron industry in Rotherham can be traced back over two thousand years and the book opens with a brief mention of evidence for Roman iron working at Templeborough. However, it is not until the 12th century AD that more substantial evidence appears and there follows a discontinuous record of various iron smelting activities into the 17th century, when attempts to make steel first appear. It is only towards the end of that century when a more significant development occurred, with the appearance of the Walker family, first as nail-makers but advancing through four generations to become the major producer of iron and steel in the area. In the early 19th century their business passed into other hands and by that time a new iron and steel operation was established on the outskirts of Rotherham. This would eventually become the Park Gate Iron & Steel Co. which continued to exist until the re-nationalisation of the steel industry in 1967. At that time the Park Gate interests were merged with those of Steel, Peech and Tozer. The latter company traced its origins to rolling mills established in the 1830s and it continued to exist, as part of The United Steel Co., in 1965 replacing its existing open hearth furnaces to become the largest electric steel making operation in Europe. Subsequent re-nationalisation, re-privatisation and, finally, the establishment of Corus ultimately led to the demise of these operations, the old electric melting shop eventually re-emerging as the Magna Science Centre at Templeborough.

The story of the steel industry takes up the first two thirds of the book, the last third describing the fortunes of other Rotherham companies involved in the metal trades, including brass founding and the manufacture of products for the railway industry. The history of the manufacture of glass products, another major industry in Rotherham, is also included here.

The whole book is based on a wealth of information from contemporary documents, illustrations and maps and provides a comprehensive description of the iron and steel industry in Rotherham at a reasonable cost.

Tim Smith

A Photographic History of Sheffield Steel

Geoffrey Howse. 2001.

125 pages. Sutton Publishing Ltd. (Stroud)

Hardback. £14.99. ISBN 0-7509-2856-5

The scope of this collection of photographs (taken mainly from the archives of the Kelham Island Museum, Sheffield) is described in a short introductory chapter as being chosen “to give an insight into the steel and cutlery industries ...[of Sheffield]” and it does this admirably. Although much of the same ground was covered in an earlier book by Ken Barraclough (*Sheffield Steel*, 1976) there is surprisingly little overlap in the photographs chosen. The sections cover “The Growth of Steel”, “Crucible Steel”, “The Development of the Steel Industry”, “Staybrite Steel”, “The Cutlery Industry” and “A Tour Through the Works”. This last section includes more personal and social aspects of the industry, rather than concentrating solely on the processes and the products. Pictures of award presentations, fire-fighting teams and the opening of a new shower block are all present, as well as Gracie Fields, rather incongruously, standing on a piano during a wartime concert. The section on Staybrite steel, dealing with the production of stainless steel by Firth Vickers is perhaps the least satisfactory, relying considerably on advertising shots proclaiming the uses of their Staybrite products. This section does have the merit of including a record of the last stainless sheets being rolled at this site in 1966, albeit by a workman whose dress code would terrify any modern safety inspector.

Information in some captions is very limited but the only error noted is for one of the oft reproduced engravings from the 19th century, showing Sheffield basking in shafts of sunlight under the arc of a rainbow, said to be the view in 1930. The mistaken date receives greater emphasis in a later aerial photograph, taken from a similar direction in the early 20th century, when the whole area is immersed in smog.

Tim Smith

Word Heritage Site bid for the Cornwall and West Devon Mining Landscape

Culture Secretary Tessa Jowell has announced that the Cornwall and West Devon Mining Landscape has been chosen as the UK’s 2005 nomination for World Heritage Site status. Over the last 4,000 years, Cornwall and west Devon have supplied much of the western world’s tin and copper and the area was the biggest producer of tin and copper in the world during the 18th and 19th centuries. As such it contributed substantially

to Britain's industrial revolution and influenced mining technology and industrialisation throughout the world.

Deborah Boden, World Heritage Site co-ordinator, said that the achievement of World Heritage Site status would bring international recognition of the heritage value of the Cornwall and West Devon Mining Landscape, and the wider social and cultural achievements of the people engaged in the industry. The distinctive and technologically advanced method of deep mining developed in the region was transported around the world and still endures, both in Cornwall and west Devon and in places as far away as Australia, South America and South Africa.

The nomination will be assessed by expert advisers to the World Heritage Committee over the next twelve months and final decisions will be made by the World Heritage Committee at its annual meeting in the summer of 2006.

For further details see the web site
www.cornish-mining.org.uk

Annual Conference, Middleham, 9–11 September, 2005

Peter Cloughton

A booking form for the annual conference is enclosed with this newsletter — additional copies can be obtained from

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www.exeter.ac.uk/~pfclaugh/mhinf/hmsbook.rtf

The conference provides an opportunity to discuss advances in the study of early metallurgy in lead and silver. The venue is in lower Wensleydale, on the edge of the Yorkshire Dales, an area rich in the history and archaeology of mining, the processing of lead ores and iron working.

Contributions are requested on all aspects of mining and the metallurgy of lead and silver, particularly prior to 1700, from any part of the world. The Society will consider publishing selected papers. Offers of papers should be sent to Dr Peter Cloughton, address as above, accompanied by a short abstract.

History Committee

Eddie Birch

The application for a grant from 'Awards for All' to get the HMS archive into useable order has been accepted. This will allow us to make the archive much more useful as a source of the Society's own history. It will also mean that in future documents presented to HMS will be much more accessible. Christopher Williams, a professional archivist, started work at the beginning of January.

Ruggero Ranieri has resigned from the History Committee as he is returning to Italy. Ruggero was an invaluable member of the committee, and it was largely due to his lead that the decision was taken to get the archive into shape. We wish him all the best.

Early Rolling Mills for Non-ferrous Metals: an appeal

Tonny Beentjes is interested in the early use of rolling mills for processing non-ferrous metals. If you know of any references covering the period before 1760 contact him at West Dean College, West Dean, Chichester, West Sussex, PO18 0QZ.

While submissions to the Newsletter are welcome at any time, if you want to have something in a specific issue of the newsletter then it needs to be with me by the following deadlines.

1st March, 1st July 1st November
Contributions can be sent in any format (hand-written, typed, email, floppy disk, CD-ROM, etc).

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