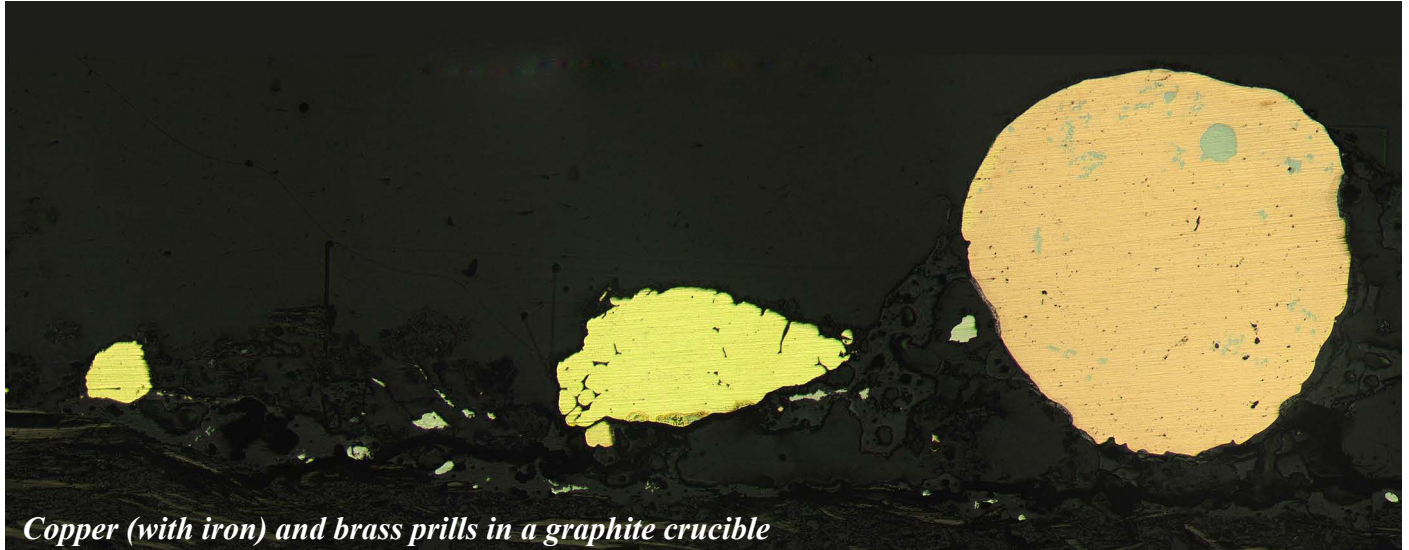


THE CRUCIBLE

Historical Metallurgy Society News

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Copper (with iron) and brass prills in a graphite crucible

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Submissions

*Submissions to **The Crucible** are welcome at any time, but deadlines for each issue are 1st March, 1st July and 1st November every year. Contributions can be sent in any format, but we prefer digital if possible.*

The Crucible

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The **HISTORICAL
METALLURGY**
Society

The recent 2016 Annual General Meeting saw some significant changes to the membership classes of HMS, as previewed in the last edition of *The Crucible*. As with so much of the recent 'behind-the-scenes' activity, this is focused on the need to establish *Historical Metallurgy* online. It became clear during discussions with potential digital publishing partners that we needed to streamline our rather over-complex membership structure and lay the basis for a sustainable financial model for the medium term future. Accordingly, the first part of that process, the changes that affect personal members, will be introduced for 2017.

From 2017 there will be just two classes of subscription-paying personal members: concessionary and ordinary. There will be no distinction between UK-based and overseas members within those classes. Concessionary members will include both bona-fide students and members of state-pensionable age. The small number of existing family members will continue to receive the benefits of the society as they do at present, but there will be no new members admitted to that group. The present reduced-rate subscription for IOM3 members will also disappear, but will be replaced by new activities and benefits. The precise form of these IOM3 benefits have yet to be determined and this remains a task for the MPP Committee; Ellie Blakelock would welcome suggestions from members for alternative models through which the relationship between HMS and IOM3 might be strengthened.

Accompanying the introduction of the new classes will be a rise in the subscription rates for individual members (the first for well over a decade!) to £35 pa for ordinary members and to £20 pa for concessionary members from 2017. Our deliberations with potential publishing partners had drawn attention to the unsustainability of current rates and although we had hoped to delay a rise in subscriptions until after the introduction of an online presence for *Historical Metallurgy*, they suggested that changes to our financial model were a necessary precursor to that development. In particular, our institutional members' rate had remained the same as the standard individual subscription and was far behind a viable market rate for such a product. The institutional rate is therefore being raised to £140 pa for 2017. It is likely that further changes to the status and fee structure for institutions will be required when the digital presence is brought to fruition over the next few years. In contrast, it is intended that the new individual rates will be maintained for a considerable period.

My note in the last edition of *The Crucible* also mentioned some of the changes being made to the production of *Historical Metallurgy*. Not all the organisational changes have yet been made, so full reporting of the introduction of the editorial board and a defined level of service to authors

will be made in the autumn edition.

I have now received reports of the arrival of the reprinted copies of HM v47/2 and v48 on several continents, so I hope that all members have now received their copies. Could any members for whom these are still missing please contact me? All members are reminded to of the need to keep the Membership Secretary informed of any changes of both postal and email addresses.

Finally, I would like to thank for their service to the society those members (Eddie Birch, Andrew Naylor and Sarah Paynter) who ended spells on Council at the recent AGM. We now warmly welcome Lorna Anguilano and Peter Northover onto Council.

Tim Young

HMS RESEARCH IN PROGRESS

MEETINGS ABROAD

Since 2008 the Historical Metallurgy Society has successfully been organising Research in Progress meetings. These have become an increasingly popular meeting with contributors coming from far and wide, and from a variety of different walks of life. There is deliberately no theme which means that any new or ongoing research can be presented, be it the results from archaeological sites, scientific analysis, historical research or a new interpretations of existing data. The audience is made up of interested parties and the atmosphere is friendly, so they are a great place for a student's first outing.

This format has been such a success that it could easily be taken, adapted and run by other groups in other countries. The meetings are often run by students mostly using university facilities and are therefore cheap to run, and not labour intensive. If anyone is interested in using the Research in Progress format feel free to get in touch and I can provide you with any guidance, support and example forms that you may like (Eleanor.blakelock@blueyonder.co.uk). HMS will gladly advertise the event on our website and we may also be able to provide funding for a prize for the Best Student Research.

The date and venue for the next meeting has been agreed. It will be held on Tuesday the 29th of November in the Department of Metallurgy and Materials, University of Birmingham. More details are available on the website. I look forward to seeing you there.

Eleanor Blakelock

ANCIENT IRON METALS TRACING BY IRON ISOTOPES ANALYSIS

The development of precise and accurate analytical techniques over the last few decades has allowed us to expand the range of methods for ancient metal tracing. Elemental and isotopic analyses are now widely used for this purpose. Generally, isotopic methods were employed for non-ferrous metal tracing in the past (e.g. Klein et al. 2009), while elemental analyses were used for ferrous metal tracing (e.g. Coustures et al. 2003). Both methods, however, show limitations. For example, overlaps of isotopic or elemental composition can occur between objects of different provenance. Moreover, elemental analyses performed on slag inclusions contained in the metal may require an important sampling of archaeological artefacts. These limitations underline the need to develop new methods for provenancing as a complement to the existing ones (Baron et al. 2011).

For the first time, we used Fe isotopes as a new tool for ancient iron metal tracing. Isotopic ratios $^{57}\text{Fe}/^{54}\text{Fe}$ and $^{56}\text{Fe}/^{54}\text{Fe}$ were quantified using a plasma source mass spectrometer after sample dissolution and Fe purification (Poitrasson & Freyrier 2005). We first developed this approach by analysing materials from two archaeological experiments on iron ore reduction performed in the Montagne Noire massif (SW of France), which was a major region of iron production during the Roman period. Ore, slag and metal samples were analysed in order to estimate the possible influence of the bloomery process on Fe isotope composition. This approach was subsequently evaluated through the analysis of archaeological iron bars from Les Saintes-Maries-de-la-Mer Roman shipwrecks (SE of France) whose provenances have already been studied by elemental analyses (Baron et al. 2011). In

addition, some materials coming from a different region of iron production (Bassar region, Togo) were analysed to investigate the inter-regional variability of Fe isotope compositions.

Our results show that the Fe isotope composition of metal and slag reflects that of their corresponding ore (Fig. 1a). We noted a slight isotopic heterogeneity in non-refined metal which may be due to the difficulty in homogenizing the iron bloom during the bloomery process. However, the purification and smithing steps allow us to assess the isotopic homogenization of the metal. Thus, we can conclude that the chaîne opératoire of iron production does not induce significant Fe isotope fractionation.

Trace element analyses performed on iron bars from Les Saintes-Maries-de-la-Mer led to establish two groups with different provenances: a first group of bars coming from the Montagne Noire, and a second group with bars of other provenance (Baron et al. 2011). Our results show that the Fe isotope composition of the bars from the first group is similar to that of archaeological ore from la Montagne Noire, which validate their provenance assumption (Fig.1b). However, the isotopic composition of several bars from the second group corresponds to that of the Montagne Noire. This underlines the possible overlaps in Fe isotope compositions between materials from different regions.

Finally, the comparison of the Fe isotope composition of materials from the Montagne Noire and that of iron objects from Togo demonstrates that these two distinct regions of iron production can be easily distinguished by their isotopic signature (Fig. 1c). The results obtained so far

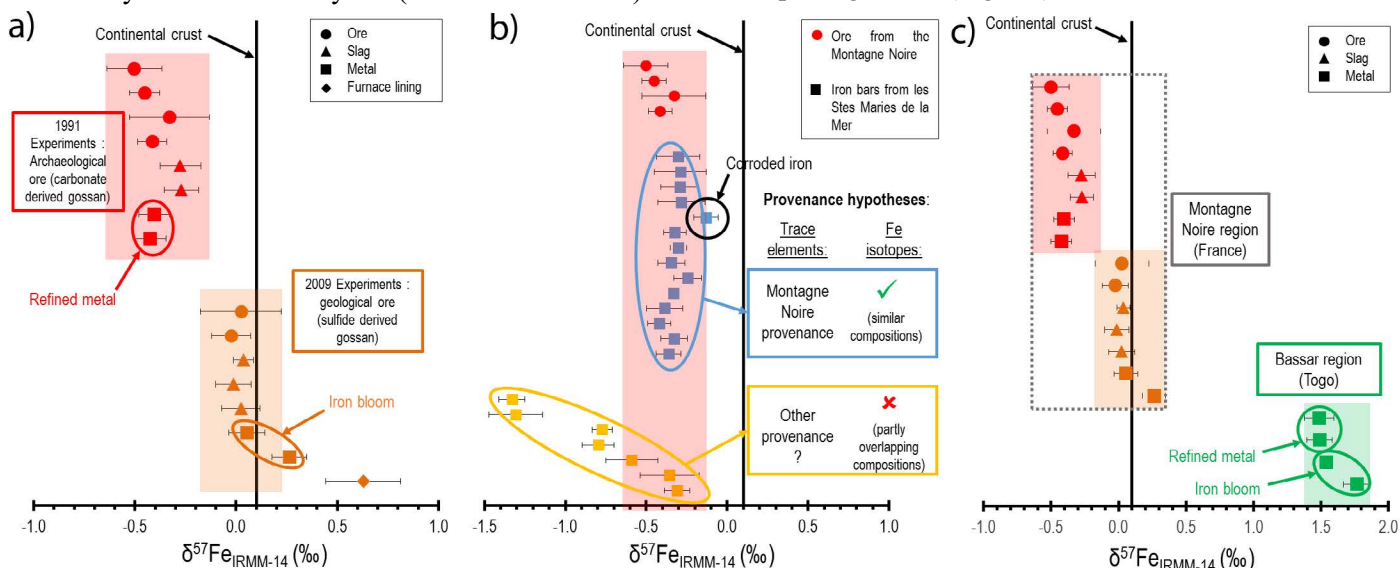


Fig. 1 Fe isotope composition of materials from a) experiments performed in Montagne Noire massif, b) Les-Saintes-Maries-de-la-Mer Roman shipwrecks and archaeological ores from the Montagne Noire massif, c) Montagne Noire and from the Bassar region (Togo).

suggest that Fe isotopes are an effective tracer for ancient iron metals which offer many perspectives for future provenance studies.

This work was presented as a poster communication in the 41st International Symposium on Archaeometry (15-21 May, Kalamata, Greece) and received the best student poster award of the Historical Metallurgy Society. We sincerely thank the Historical Metallurgy Society for this prize. We also thank the Federal University of Toulouse and the Region Midi-Pyrénées for funding this study.

Jean Milot
Franck Poitrasson
Sandrine Baron
Marie-Pierre Coustures
Caroline Robion-Brunner

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MEETING OF HISTORIANS IN LATIN AMERICAN MINING

The 13th Meeting of Historians in Latin American Mining (MHLM) titled "Interdisciplinary dialogues and challenges around past and present Latin American mining" will be held from the 4th to 7th April, in Buenos Aires, Argentina. The Organizing institution is the Ethnohistory Section of the Institute of Anthropology from the University of Buenos Aires. This meeting aims to gather various disciplinary approaches and issues related to mining. Presentations are expected to consider technological and organizational dimensions of mining but also the religious-symbolic, spatial, economic and political aspects linked to these activities. For more information visit <http://www.13reunionmineria.wordpress.com>

THE STAFFORDSHIRE HOARD

The Staffordshire Hoard was discovered in 2009, north of Birmingham, in England. It is the largest ever single find of Anglo-Saxon gold (c. 5 kg) and silver (c. 1 kg) metalwork. The majority of the assemblage consists of war equipment; however there are no weapon blades. The objects range in date from the mid/late 6th century to the mid/late 7th century, giving the find a terminus post quem date of c. 675. The Staffordshire Hoard is owned by Birmingham City Council and Stoke-on-Trent City Council on behalf of the nation, and cared for by Birmingham Museums Trust and the Potteries Museum & Art Gallery, Stoke-on-Trent.

For the last few years a large English Heritage (now Historic England) funded research and analysis project has been carried out managed by Barbican Research Associates (Cool 2015). This has reached the end of the analysis phase of the project. Analysis of the gold, silver and copper alloys in the Hoard have been carried out at the British Museum, Birmingham Museum and Art Gallery and Birmingham University.



Gold objects of the Staffordshire Hoard.

The largest quantitative survey of Anglo-Saxon gold, to date, revealed no reliable relationship between the fineness of alloy used and object date, although the low copper content is consistent with the use of recycled coinage as a source of gold. However, over 100 components on the objects appear to be deliberately depleted in silver at their surface which, it has been argued, was the result of a deliberate and probably widespread Anglo-Saxon

workshop practice. Previously unrecognised, this involved the depletion gilding of sheet gold appears to have been used to create contrast between decorative components, as well as to potentially enhance the colour of the gold. The results from the initial pilot study currently available online on *Archaeometry* (Blakelock In press) and another article with the full results from the survey has been accepted in the *Journal of Archaeological Science* (Blakelock et al. In press).



The author working on the Staffordshire Hoard.

In addition to the analysis of the gold from the Hoard, the silver and copper alloys were also examined. The silver analysis revealed no clear workshop groups based on the composition, however there was a distinctive group formed from several helmet components and a collection of unusual niello mounts. Qualitative surface XRF analysis of the copper alloys suggested that unlike other Early Saxon assemblages there was not a range of alloys used, suggesting that the Hoard copper alloys may not have been heavily recycled.

This is just a taste of the new data that has been produced by the project. In the near future the analytical reports will be made available on the *Archaeological Data Service* to be used alongside the final Staffordshire Hoard publication. More details about the project can be found on the Barbican website <http://www.barbicanra.co.uk/staffordshire-hoard.html>.

Eleanor Blakelock

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GOLD AND SILVER IN SAN PEDRO DE ATACAMA, NORTHERN CHILE

Both for the general public and for us archaeologists, the discovery of gold artefacts is full of excitement and it has a special taste... we consider them as treasure, they mean richness and power. This conception is mainly based on our occidental culture, where these items get a lot of attention because they are sources of wealth, being therefore, highly valued. However, something that amazes me about American cultures is how they continually defy those concepts. For example, recent research on Musica goldwork from Colombia suggest that the process of making specific gold offerings called tunjos, can be equally or more important than the resulting gold artefact itself (Martín-Torres and Uribe-Villegas 2015). Similarly, the Nahuange communities from north Colombia were intentionally treating their gold ornaments to make them pink, instead of keeping them golden (Sáenz Samper & Martín-Torres 2016). These two examples show that gold had multiple and variable values: sometimes, the value of a gold object may be closely related to their manufacture and the materials involved in it; or the perfect appearance is not the one we expect it to be. In other words, we should never take any specific meaning for granted.

In this research I am working with gold and silver found in the oasis of San Pedro de Atacama, a small locality in northern Chile (Fig. 1). San Pedro is located between the



Fig. 1 Map of the South Central Andes showing San Pedro de Atacama and Tiwanaku.

Atacama Desert, one of the driest deserts in the world, and the Andes mountains. Initially, it may appear an inconvenient location for a settlement, but actually its position is strategic because it linked a series of exchange routes that connected the Bolivian highlands, southern Puna and northwest Argentina, with the valleys of the Pacific Coast. It became therefore, an important political, religious and economic centre, especially during the Middle Period (AD 400-900), when the South Central Andes was integrated under the influence of the Tiwanaku culture that developed in the circum-Titicaca area (Berenguer 1998; Korpisaari 2006).

During this period, large quantities of foreign items and exotic raw materials appear in the cemeteries of San Pedro; and amongst them a series of gold and silver grave goods. The quantity of these, nearly 200, items concentrated in one locality is striking for the period. In general, gold finds are not very common in the South Central Andes; and when they are found, they are usually grave goods or offerings associated to specific individuals (Bennett 1936; Money 1991; Korpisaari 2006; 2011; Tarragó et al. 2010). Therefore, the presence of several cemeteries in San Pedro with a number of individuals bearing gold (and silver) objects is very special and different from contemporary contexts.

In addition, it has been traditionally assumed that most of gold and silver items found in San Pedro were imported from Tiwanaku, however nobody has actually analysed and characterised the total collection in order to assess this idea and identify potential different traditions. My research aims to fill this gap, and study the assemblage of gold and silver grave goods from a technological perspective, with the purpose of better understand the objects that comprise it and to identify technological groups that could inform us about the regional interactions taking place during the Middle Period. In this report, I would like to present briefly some of the findings and discuss them.

As mentioned, nearly 200 gold and silver objects are stored in the Museum R.P. Gustavo Le Paige in San Pedro de Atacama. They comprise ritual cups, headbands, headdresses, bracelets, pectorals, beads, bells, pendants and rings, distributed in eight cemeteries. The chemical composition of 180 artefacts was obtained by XRF, using a handheld instrument, and the manufacture techniques were recorded using a digital microscope.

In terms of composition, the copper levels in gold are low within the assemblage, with less than 6% except in four cases with copper levels above 10% (Fig. 2). The levels of gold and silver however, are very variable ranging from 3.5-73% silver and 26-97% gold; whilst 13 objects were made of pure silver. Analyses on native gold from the South Central Andes have detected deposits with different silver

levels, some of them containing up to 5.7%, 10-14%, 21%, 26% and 30%; but none of them had silver levels beyond 30%. Therefore, based on silver levels, the assemblage can be divided in two main groups: those containing up to 30% silver, suggesting the use of native gold; and those above 30% silver, levels not found in deposits of the region so far, which implies the artificial alloying of gold and silver.

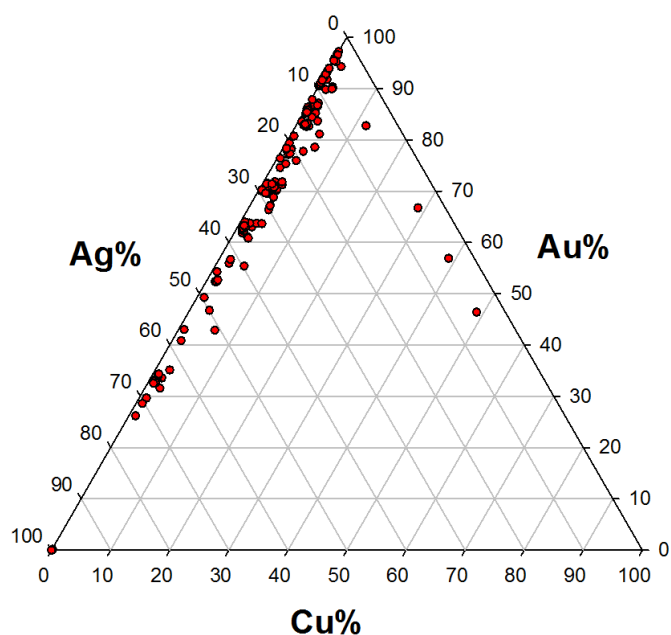


Fig. 2 Ternary diagram showing the gold, silver and copper content of 180 objects analysed from San Pedro de Atacama.

Gold technology of the South Central Andes has its own characteristics: almost all objects were hammered, annealed and sometimes were decorated using techniques such as embossing, chasing and chiselling; soldering was rare. The materials from San Pedro are not an exception, and all of them are hammered and annealed sheets, but the quality of the work is very varied. Some objects were carefully made showing polished surfaces, even cuts, polished edges and treated perforations (either flattened or cleaned from the remaining burrs). Whereas other objects show rudimentary manufacturing traits such as uneven cuts, edges worn by use and unpolished surfaces.

The characterisation of these materials is work in progress, but overall the chemical composition and manufacture styles are diverse suggesting that objects made of different styles are converging in San Pedro. Currently there is no metallurgical evidence to propose that gold or silver metallurgy is taking place in San Pedro (e.g. smelting, alloying), supporting the idea of imported items arriving to the area.

However, I have found a series of objects of different qualities and elemental composition with a series of cuts and alterations. These are basically objects that were

re-shaped, modified or cut into pieces using mainly mechanical means: punching, cutting and folding. These modifications are always rough, leaving visible and unpolished cuts; showing in many cases no attempts to match the quality of the original items (Fig. 3). Noteworthy is the apparent shortage of solutions involving melting the metal and making a fully new artefact in those cases, which may suggest a lack of knowledge of (or interest in) those metallurgical processes.

Based on all the above, I suspect that people in San Pedro were not necessarily melting gold or silver to produce their ornaments, but they have access to finished artefacts that were locally modified according their taste or needs. In this case, cutting and punching were the main working techniques, requiring tools such as chisels, needles and burins, already available in San Pedro and extensively used in other industries such as bone and wooden sculpture.

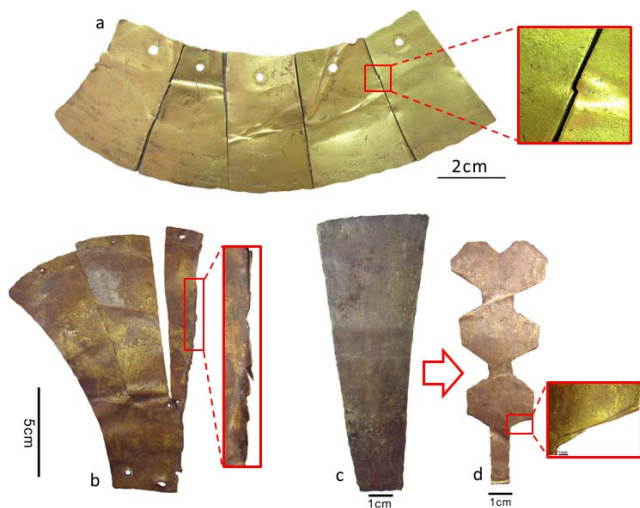


Fig. 3 Images of some objects that were cut into pieces (a), modified (b) or re-shaped (c-d) in San Pedro.

What surprises me about this local metalwork, focused on re-shaping and cutting finished objects, is the lack of attention to detail. Some of the modifications are really coarse and visible; and despite of this, people used them and were buried with them. Therefore, it looks like the final quality of the objects was not always important. Likewise, some objects are cut in a half, suggesting that using only sections of larger artefacts was not a problem either (Figure 3b). This behavior can give us a hint about the meaning of precious metals for the people from San Pedro, because it looks like for certain people it was important to be buried with gold or silver, regardless of the craftsmanship of the objects. Additionally, a few artefacts were completely or partially re-shaped, usually adding more complexity to the shape (Figure 3c-d); whereas others artefacts were multiplied by cutting it into several parts (Figure 3a). Perhaps in these cases, people were adding extra value to

the objects, creating their own designs or modifying the their use (for example cutting bands used as bracelets or headbands, and turning them into pendants attached on clothes).

For now these are only suggestions. This research is still on its early stage and I still need to process more data; but going back to my initial thoughts, to understand the value of gold and silver in San Pedro, it is important to consider them not only as exotic imported items, but how they were treated and locally re-signified. It is clear that as metal, gold and silver were important; if not, how can we explain the large amounts of precious metal offerings deposited in the cemeteries? But looking at the way it was worked in San Pedro it is possible that gold and silver were not necessarily treated more special than other raw materials, such as bone, wood or minerals.

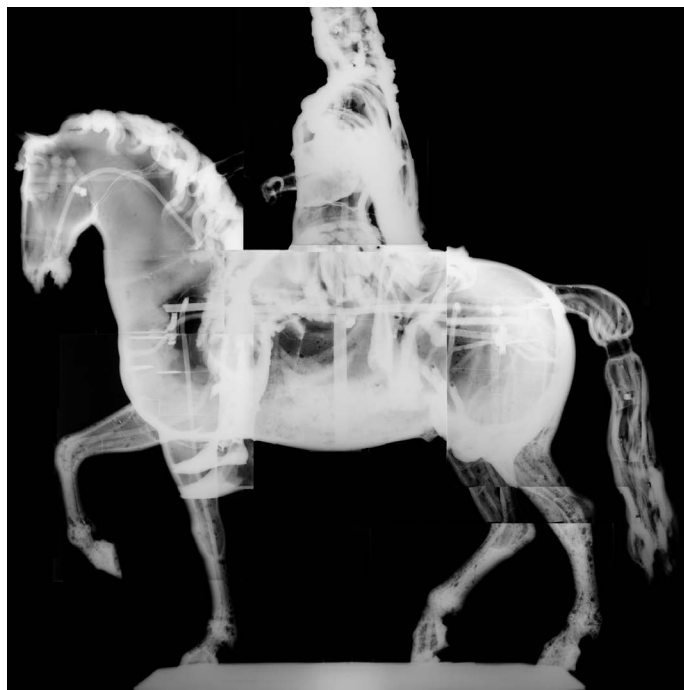
María Teresa Plaza

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CAST:ING

COPPER ALLOY SCULPTURE TECHNIQUES
AND HISTORY: INTERNATIONAL
INTERDISCIPLINARY GROUP (2015-2019)



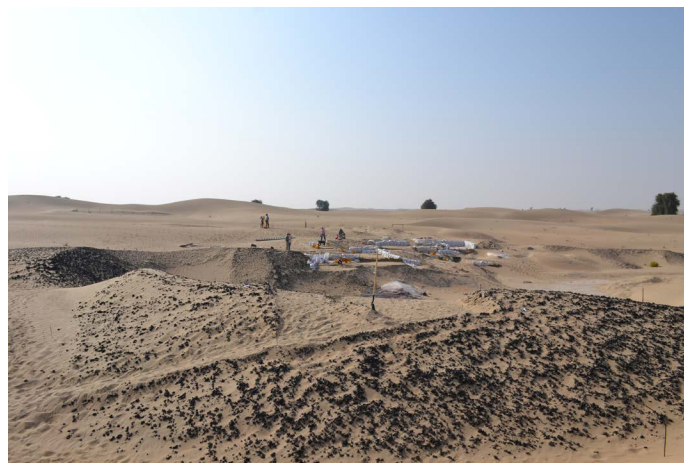
X-ray montage of Louis XIV bronze sculpture.

An international, interdisciplinary team of Archaeometallurgists, conservators, curators, historians, archaeologists, and craftsmen are collaborating on the online publication *Guidelines for Best Practices in the Technical Study of Bronze Sculpture*. This well-illustrated aid to the interpretation of technical evidence is for a varied audience and will also feature a multilingual vocabulary and an extensive bibliography. The project aims to facilitate advances in the understanding of bronze sculpture – from questions related to the production of specific works to those concerning the complex development, significance and transmission of bronze-making worldwide. Follow the CAST:ING project as it takes shape at www.cast-ing.org (currently under construction).

David Bourgarit

INVESTIGATING AN ENIGMATIC IRON AGE METALLURGICAL SITE IN SOUTHEASTERN ARABIA

Saruq al-Hadid, located in the eastern extension of the Rub al-Khali dune fields in the Emirate of Dubai (U.A.E.), is among the most intriguing prehistoric sites in Arabia. The site was discovered in 2002 by his Highness Sheikh Mohammad bin Rashid al Maktoum, ruler of Dubai, as it stood out from the neighbouring dunes due to its dense surface concentration of black slag. Excavations in subsequent years have brought to light not only abundant copper smelting and refining waste, but also unprecedented numbers of beautifully worked artefacts of copper alloy, iron, gold, stone, shell, bone, wood and pottery, with a peak of activity dating to the local early Iron Age (c. 1200-600 BC). Aside from the obvious question of why a smelting site was established in the desert more than 80 km from the nearest ore sources, the co-occurrence of the metal production waste with the diverse range of other artefacts, including apparently cultic remains bearing prominent snake imagery, offer a challenging puzzle for the archaeologist.



Saruq al-Hadid looking to the south towards the SHARP season 2 excavation area.

In October 2014, the University New England, Australia, commenced the Saruq al-Hadid Archaeological Research Project (SHARP) in collaboration with Dubai Municipality. SHARP incorporates fieldwork and post-excavation recording and analysis of the thousands of artefacts found at Saruq al-Hadid, aimed at providing a better understand the nature of human activities at the site.

A major interest for SHARP was to establish the chronology of metallurgical activities at the site. This is complicated by the site's heavily deflated stratigraphy, with most of the metallurgical slag and many artefacts artificially concentrated together by wind erosion into a deflation pavement that caps the dunes. Efforts to tease out a relative stratigraphic relationship and chronology through closely-

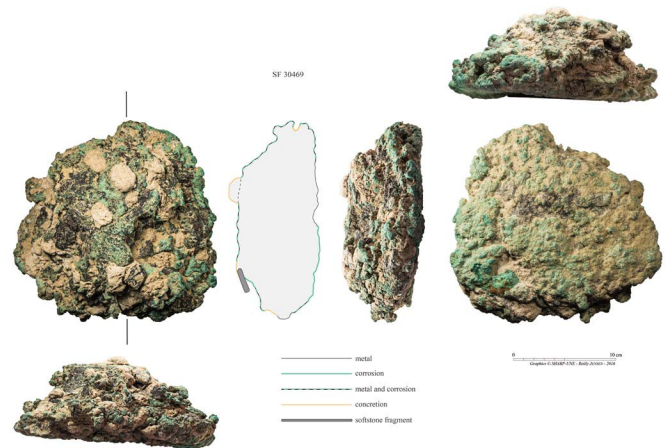
controlled excavation are therefore very challenging. We have been able to partially overcome this problem through direct absolute dating – the C14 dating of rare charcoal inclusions in the slags and the TL dating of technical ceramics with adhering slag – alongside some insights from slag typology from better dated sites elsewhere in SE Arabia. Although results are still very preliminary, it seems that copper smelting began at Saruq al-Hadid at least by the early Iron Age, c. 900 cal BC, and may have extended from that time through the early centuries BC/AD and into the early Islamic period in the 9th/10th centuries AD. The slags themselves attest to the smelting of sulphidic copper ores, a technology first seen in SE Arabia in the early Iron Age and mastered by the early Islamic period, and the abundant fragments of semi-processed raw copper lumps and copper ingots known from the site are unsurprisingly rich in copper sulphide inclusions.

In contrast to the apparent long chronology of smelting at the site, most of the excavated metal artefacts can be typologically dated to the early Iron Age, a conclusion supported by numerous C14 dates. Preliminary pXRF analyses of this large assemblage of arrowheads, blades, axes, vessels, bangles and other items, including numerous small copper-alloy snakes, provide evidence for the use of almost pure copper, as well as tin-bronze and possibly zinc-containing alloys. Initial lead isotope analyses confirm, in broad terms, a shared SE Arabian provenance for copper artefacts, copper production debris and copper slag, but there are outliers in these analyses and the finer details have still to be established.

Another fundamentally important aspect of the early Iron Age layers at Saruq al-Hadid is the presence of hundreds of kilograms of iron fragments, some of which are part of broken artefacts (mainly blades) while others are semi-finished products, such as rod fragments, that could have been further worked on site. Iron is otherwise rarely reported in Iron Age SE Arabia – in fact, the region was once described as having “an Iron Age without iron”. A SHARP PhD student, Ivan Stepanov, is studying this material and has identified, through the presence of pseudomorphic structures preserved in the otherwise totally corroded artefacts, a mix of uncarburised and heterogeneously carburized metal. His work is now focusing on the relatively well-preserved slag stringers remaining in these artefacts as one avenue to investigate provenance for this unprecedented collection – with typological studies of the large iron blade handles indicating an influence from the Luristan region of Iran and highlighting a possible source region.

These archaeometallurgical studies are only in their preliminary phase, and are part of a broader research effort by SHARP that includes excavation to better characterise

the site’s long occupation sequence. This began as early as the Bronze Age, with deposits characterized by the residues of hunting, cooking and feasting and a near absence of metallic remains. Analyses of the huge numbers of animal bones from these layers, by the SHARP PhD



A raw copper ‘ingot’ from Saruq al-Hadid excavated during season 2.

student James Roberts, highlight the attractiveness of the location for seasonal hunting and the grazing and watering of domestic animal herds. Likewise, archaeobotanical studies of charcoal, plant macro-remains and wood by Dr Claire Newton (Université du Québec à Rimouski) highlight the range of vegetation the site supported in the past, the presence of desert trees and shrubs that may have been crucial sources of fuel for Iron Age (and later) pyrometallurgical activities, and the changing site environment. Surprisingly, the site has also produced preserved wooden artefact fragments that have been C14 dated to the early Iron Age. These tend not to be made of local desert species, but were imported to the site from neighbouring oases, from further afield in the Oman Mountains, or, in the case of exotic species, possibly from as far away as the Eastern Mediterranean.

Together, our preliminary analyses are beginning to offer insights into human activities at Saruq al-Hadid. However, we are still a long way from understanding the ritual aspect of the site, which saw thousands of precious artefacts apparently abandoned to the desert sands three millennia ago. Further SHARP analytical studies will hopefully provide more answers in the near future and reveal some of the puzzles Saruq al-Hadid is still holding.

*Lloyd Weeks
Kristina A. Franke
Charlotte M. Cable*

ROYAL CITY OF MEROE



The Royal City of Meroe, situated in the Republic of Sudan c. 150 km north of Khartoum, was the second capital of the Kingdom of Kush from c. 300 BC for approximately 600 years. The spectacular monumental architecture of this UNESCO World Heritage Site includes the remains of pyramids, palaces and temples, while ancient pyro-technologies are evidenced by the remains of large slag heaps and the ground littered with pottery and fired bricks. Working in collaboration with the National Corporation for Antiquities and Museums in Sudan (NCAM), UCL Qatar's Industrial Kush project has undertaken eight extensive field seasons at Meroe and the neighbouring Meroitic site of Hamadab since 2012. Recently the multinational, interdisciplinary team has achieved a number of milestones in the project's overall research aims.



Fig. 1 The iron production workshop found on the south mound of the Royal City at the completion of the excavations. Furnace base to the right of the photograph.

Through a combination of gradiometry and resistivity surveys across much of the Royal City, the team successfully identified a Meroitic iron production workshop (Fig. 1). This workshop, only the third to be found at Meroe, was excavated to allow for geochemical sampling on a 25 cm grid. The samples collected are now undergoing analysis at the University of Brighton's School of Environment and Technology under the direction of Dr Chris Carey. Although in its early stages, magnetic susceptibility and ICP-MS analysis seem to indicate that in addition to smelting and smithing iron in the workshops, people were perhaps also working other metals in these spaces.

The footprint of the archaeological workshop was recently



Fig. 2 The iron smelting festival (photograph: Thomas Scheibner).

used to recreate a Meroitic iron smelting workshop within which a series of experimental smelts were carried out to deepen understandings of the ancient technological practices. As well as being a scientific investigation, the events were held as a festival and over 800 people came to learn about the iron producers of Kush (Fig. 2). A film documenting the process was produced in Arabic and English and this will soon be made freely available online. The experiments have provided possible explanations for certain design features in the workshop such as the central pit and raised bellows platform, and have greatly assisted in the interpretation of the archaeometallurgical remains. Samples collected during the experiments are being scientifically compared to the archaeometallurgical debris.

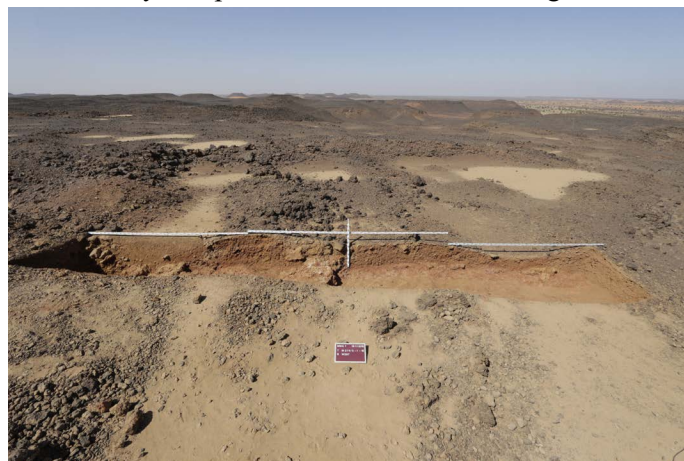


Fig. 3 Excavations at the mining area located c. 9km to the east of the Royal City.

During the experimental activities the team confirmed the location and extent of the ancient iron mines of Meroe, c. 9 km to the east of the Royal City (Fig. 3). The ore extracted from this location was identified as oolitic ironstone present as irregularly distributed bands in the upper geological horizon of only certain hilltop plateaux. The mining area is particularly lacking in material culture (indicating that those working at the mines made use of gourds, goatskin bags and baskets), although high resolution transect

surveys located occasional iron slag, suggesting ore was tested before being extracted in large quantities and taken to Meroe.

To date, excavations have been carried out at eight slag heaps across the area, with the most ambitious being those conducted at the Apedemak Temple. Here, a 25 m trench revealed a 3 m deep slag heap stratigraphy (Fig. 4-5), as well as insights into the evolution of the industrial landscape at Meroe and how the industrial remains were incorporated into the religious expressions of the capital. The slag heap on which the temple was constructed seems to have been surrounded by a retaining wall and the top truncated to form a flat surface. Around the heap beyond the retaining wall other structures were constructed, possibly chapels associated with the temple. The symbolic relationship between the Apedemak Temple (Apedemak being the Meroitic god of war and fertility), and the iron production technologies is under consideration, and excavations at the temple will continue in autumn 2016.



Fig. 4 The 3 m deep, 10 m long section in the slag heap at the Apedemak Temple. Retaining wall to the right, temple wall to the left with the remnants of an old trench visible, presumably excavated by John Garstang in the early twentieth century.

A five year wood species identification programme funded by the British Institute in Eastern Africa and carried out by Dr. Barbara Eichhorn of the University of Frankfurt is nearing completion. To date over 1000 samples of charcoal from well-stratified slag deposits spanning the sites and over one thousand years of iron production have been species identified to reveal the most selective use of charcoal in Africa. The smelters were privileging almost exclusively only a single type of wood, the highly calorific and structurally stable *Acacia Nilotica*, for their iron production. Environmental impacts, resource management and trade are all issues which are being considered in relation to these results.

Throughout the course of the excavations samples of

archaeometallurgical and associated remains have been collected for laboratory analysis which is ongoing and is already producing interesting results. Evolution of technological practices and how these relate to the story of the Kingdom of Kush are major avenues of inquiry currently being explored by the team. The 97 radiocarbon dates so far generated from the documented stratigraphy of the slag heaps has allowed for the construction of a new radiocarbon chronology for the iron production of Meroe. Stratigraphic modelling of the dates currently indicates that iron production could have been occurring at Meroe as far back as the 7th - 8th century BC at the very beginnings of the Kingdom of Kush, and continued for over a millennium into the Medieval Christian period up to 1,300 years later. However, the very early dates require further investigation which will form a major part of the autumn 2016 season.



Fig. 5 Aerial photograph of excavations underway at the Apedemak.

In addition to the archaeological research, the team continues to train Sudanese students, most recently running a dedicated field school attended by one archaeology student from each of the five archaeology departments in Sudan. For five weeks the students took part in lectures, classroom based activities and practical training, and joined the specialist teams to take part in all of the activities being undertaken. The students also played an invaluable role in the ambitious community engagement strategies of the project which have seen numerous community meetings, film screenings, festivals and other educational activities throughout the Meroe region, in Khartoum and at the Sudanese Cultural Centre in Doha.

This year will see a number of publications on the project, which will hopefully continue for years to come.

Jane Humphris



MARIA FILOMENA GUERRA

Maria Filomena Guerra, born in Lisbon, holds one Portuguese doctoral degree in Nuclear Physics and one French doctoral degree in Material Sciences. Senior Lecturer at the New University of Lisbon from 1981 to 1990 and Professor of Physics from 1990 to 1993, she also held a research grant from the Calouste Gulbenkian Foundation. She joined in 1993 the French National Centre for Scientific Research (CNRS) where she is now Director of Research in Chemistry. Affiliated to the Centre of Research and Restoration of the Museums of France (C2RMF) from 2001 to 2014, she is since 2014 affiliated to the CNRS / University Panthéon-Sorbonne research unit “Archaeology of the Americas” (UMR 8096).

THE CRUCIBLE: Can you summarise your career in a couple of sentences?

MARIA FILOMENA GUERRA: I am a nuclear physicist. I always aimed to contribute to the understanding of precious metals through the development of non-invasive analytical methods and protocols.

When I started my research on metalwork, based on the gained experience on nuclear and atomic methods of analysis and on theoretical physics, my projects chiefly focused on the origin and circulation of gold and silver. It was a challenge to try to validate suggestions on historic economy by increasing the number of trace elements measured, lowering the detection limits, to enhancing the calculation methods, etc. The challenge was in fact to be as close as possible to the limits of the analytical techniques. With time, my interests changed and improved: instead of searching information only on the materials that were exploited and used in the past, the craftsman behind the object became very important. The understanding of the manufacturing techniques became another significant theme of

research, and several techniques of exam gradually entered in my analytical protocols.

My research projects have been covering two main regions: the Mediterranean basin and the Andean area. I was allowed to see and study thousands of gold and silver objects kept in museums of many different countries. I could enter in many safe rooms and I could discuss with many scholars. I have been a very privileged researcher.

Because recently I realised that the surface of the silver and of the gold objects became more altered, my interests progressed and nowadays my research projects also focus on the corrosion of silver and of gold alloys. This new field of research brought new challenges and the opportunity to acquire new skills throughout the use of optical and analytical chemistry techniques.

THE CRUCIBLE: What is your most memorable professional moment?

MARIA FILOMENA GUERRA: It is difficult to choose one moment, there are so many and so different, but it is quite memorable the two weeks I spent in Oxford with Peter Northover, about 20 years ago, working on copper-base Celtic coins. I generally analyse directly the gold and silver objects, but for those coins I had to polish for hours samples for metallographic examination. It was hard work, but this experience made me apprehend the importance of microstructure.

A very different moment happened in 2011. The centenary commemorations of the University of Lisbon, where I gained my Physics degree, included one cycle of 100 lessons given by 100 selected alumni. In spite of being in France since 1993, I

was selected among countless alumni to give one lesson on my research.

THE CRUCIBLE: Who has been your most influential colleague, and why?

MARIA FILOMENA GUERRA: I was fortunate to meet many people, like M. J. Aitken and R. F. Tylecote, and I always could count on the support of Mike Tite. But I must say that the most influential colleague on my research has definitively been Pieter Meyers who is also a nuclear physicist, and worked at the research laboratories of the Los Angeles County Museum and of the Metropolitan Museum of Art and published fundamental work on Sassanian and Byzantine silver and Chinese metalwork. He always trusted my capacities. The many fruitful discussions that I could have with him oriented my career. He has indeed been a major influence on the evolution of my research interests.

THE CRUCIBLE: What is your main current project?

MARIA FILOMENA GUERRA: I have several projects currently running, but I should emphasize two of them. The first focuses on the anthropomorphic and zoomorphic figurines made from gold and from silver alloys that were part of the Inca capacocha ceremonies and served as offerings to huacas. The research project on the typological and technological evolution of the figurines during the Inca period and after the conquest has been running for four years with the collaboration of several museums and research laboratories in Europe and in Peru. One workshop was dedicated last September to this study. Entitled “Gold of the Incas. Andean metallurgy in the 15th – 16th centuries”, this workshop was organised in Paris by Paz Núñez-Regueiro (Curator of the Americas, musée du quai Branly) and myself - the proceedings should appear in print by the end of 2016.

The second project focuses on early 20th century René Lalique’s jewellery, characterised by a profusion of colour and brightness obtained using gold and silver alloys combined with plique-à-jour enamels, stones and other materials, and specific surface treatments. This project supported by the Calouste Gulbenkian Foundation in Lisbon (this foundation had financially supported my two Portuguese doctoral diplomas) wishes to characterise the fabrication techniques and the atmospheric corrosion of their collection of over eighty items created by Lalique between 1899 and 1927.

THE CRUCIBLE: What multi-million project would you like to develop?

MARIA FILOMENA GUERRA: I recently headed a 3-years research project between France (CNRS) and UK (IoA-UCL) on Egyptian gold jewellery that provided much data on objects kept in the Louvre Museum and in several UK museums: the Petrie Museum of Egyptian Archaeology (UCL), the National Museum Scotland, the Garstang Museum of Archaeology at Liverpool University, the Manchester Museum, and the British Museum. The data obtained, which resulted from the work of

many researchers from the cited institutions, should appear in print by the end of 2016 with all the contributions.

I could afterwards compare the objects produced in Egypt around 1500 BC with Mycenaean objects from the Greek collections that I analysed several years ago. The range of colours is higher for Egyptian workshops that extensively used casting and soldering. It would be interesting to enlarge this project to the Egyptian collections and to the bordering regions, particularly Cyprus, Turkey and the Middle East.

THE CRUCIBLE: Which publication should every HMS member read?

MARIA FILOMENA GUERRA: It is difficult to choose one publication, but I learned a lot from ancient publications, especially those by Herbert Maryon and by Paul Rivet. I would suggest “*Archaeology and metallurgy*” by H. Maryon (1941), part 1 is dedicated to welding and soldering and part 2 to the metallurgy of gold and platinum in Pre-Columbian Ecuador, and “*La métallurgie en Amérique précolombienne*” by P. Rivet and H. Arsandaux (1946).

THE CRUCIBLE: Have you got any advice for young students interested in archaeological and historical metallurgy?

MARIA FILOMENA GUERRA: It is impossible to be an expert on every technique or on every methodology that can be applied to research on archaeological and historical metallurgy, but they must be aware that an object is a whole and contains information on man’s skills, workshop traditions, availability of raw materials, recycling, abandonment, burial, etc. It is so necessary to acquire enough knowledge on these different aspects in order to, throughout the discussion with colleagues, have a good understanding of the object and of the people who had fabricate it. In fact they should keep open-minded, and critical towards their own opinions, protocols, and data.

THE CRUCIBLE: I would like to tell every reader of *The Crucible* that...

MARIA FILOMENA GUERRA: My view is the view of a physicist: for example a phenomenon can be modeled and parameters can be calculated. This view is different from the view of a chemist, a restorer, an archaeologist, a metallurgist, a goldsmith, etc. It is so essential to successfully complete a project to discuss with qualified researchers and craftsperson who have knowledge of the different areas of research concerned by archaeological and historical metallurgy, listen to their opinions and learn from their experience.

FUTURE INTERVIEWS

*Who would you like us to interview for the next issue of **The Crucible**?*

Would you like any additional question added to our standard list?

Please let us know at thecrucible@hist-met.org.

JONATHAN PRIUS

My childhood belonged to the 1950's and science was shiny and wonderful. I still think it is. I wanted to put on the white coat and work at that bench. That ambition lasted right up until I discovered the unspeakable tedium of working in an industrial laboratory. So I studied history.

The first time I saw a bloomery was in the Matopos National Park in newly-independent Zimbabwe. At that time it was complete: about 600 mm. in height, conical and revetted with two large slabs of the local granite. My duties then included the implementation of a new African history syllabus and it seemed like a good idea to see if smelting would work as an outdoor activity for teenagers. The mud-pie aspect of furnace-building was an unqualified success, but just working from elderly reference texts, the complexity and subtlety of the craft skills involved had escaped me. As Lee Sauder says "if you haven't got the product you haven't got the process..." Looking back, almost everything about that reconstruction was wrong, except the shape of the furnace.

It was almost twenty years before I picked up the bloomery thread again. In the meantime I'd changed career, finding something I was good at, done a science degree with the Open University, completed a (part-time) PhD with Cranfield ("technology transfer") and an MBA also with the OU. It's well known that MBA stands for Monstrous Bullshit Award but you must not underestimate the value of that commodity. Offices all over have Ricky Gervais-like characters ("The Office") who revere managementspeak. By then I was heading up a company with 120 employees and I needed all the help I could get.

The Wealden Iron Research Group restored some balance to my life. WIRG member Tim Smith (until recently an HMS Council member) introduced me to HMS. It was several years before I attended an HMS event but when I went it was good. They may have forgotten but I remember that Vanessa Castagnino, Eddie Birch, Tim Young, Peter Crew and a number of others were made sure that a new face was not left sitting alone in a corner. And if you share our interests, a weekend with HMS members can hardly fail to work. You plug into a wonderful network of helpful people who know things that you can't find on Wikipedia. I joined HMS Council in 2014.

It would be a gross oversimplification to say that some event(s) in my life were pivotal, but getting a job in which I could thrive was important. Two sets of intellectual tools were given me by the OU: probability theory and statistical testing altered my outlook a lot. Dimensional analysis and a thorough understanding of SI units are also profoundly useful. These happy things came to me in my mid-thirties. Which brings me to the things I've got horrendously wrong. Not enough space to list them, but I wouldn't go



Jonathan Prius with an experimental iron smelting furnace.

back and alter them even if I could. I value my mistakes and try not to repeat them too often!

There are also influences that are pervasive. My business career affects what I have brought to historical metallurgy. As the leader of a growing business I experienced major difficulties with the control of information and addressed this using databases, locally based from about 1993 then web-based from about 2004. From an early stage I found that a Darwinian design paradigm works well with this technology. Tweak it until it does what you need it to do! Time will tell, but I think the work I did designing the WIRG database (wirgdata.org) will prove to have more lasting value than any research that I have been involved in. wirgdata.org is worth a visit by anyone interested in the use of large datasets or with an interest in prosopography as a method in historical studies. As the Wealden Iron tag suggests, [wirgdata](http://wirgdata.org) focusses on a particular area. But the method has general applicability. It does need someone to drive it though, [wirgdata](http://wirgdata.org) is driven forward relentlessly by another former HMS Council member, Jeremy Hodgkinson.

My new research question: what can we learn about bloomery processes from the electrical properties of slag?

AMINA CHATWIN

We are sad to report that Amina Chatwin died earlier this year. She was a long-serving member of HMS Council and will be remembered by many as the editor of HMS News, our original newsletter. A full obituary will appear in the next issue of [The Crucible](#)."

41ST INTERNATIONAL SYMPOSIUM ON ARCHAEOMETRY

15th-21st June 2016, Kalamata, Greece

The conference welcomed over 500 participants from a wide range of fields within archaeometry. The conference had a number of different sessions that covered materials such as stone, plaster, pigments, glass and metal; Remote sensing and geophysical prospection; Bioarchaeology; Archaeo-chronometry; and a themed session titled ‘The beginning of the Bronze Age in Eastern Mediterranean’. There was also a healthy debate on the future of Archaeometry in Anthropocene studies, the UCL archaeological science section live tweeted the debate; more information can be found on their twitter page @UCLArchSci.

The archaeometallurgy session was divided between four oral presentation sessions and one poster session. With over 120 abstract submissions from 35 countries this session covered a wide range topics from the inception of metallurgy to metal-bearing cultures including mining, primary smelting and manufacturing techniques of copper, bronze, iron, gold, and silver worldwide.

The first of the four metals sessions focused on the inception of metallurgy, but failed to fully meet expectations with presentations of only preliminary results on two well-known case studies: the provenance of artefacts from the Royal tombs of Ur (Salzmann et al.) and on revisiting the Çatalhöyük metallurgy (Radivojevic et al.). Nonetheless, the last paper of the session presented a compelling diachronic approach of the entire Mycenaean Bronze Age through the metallurgical remains analysed from the major centre of Kastro Palaia (Asderaki-Tzoumerkioti et al.).

Although not strictly focussed on metallurgical remains, but on ceramic petrology, the themed session, ‘The beginning of the Bronze Age in the Eastern Mediterranean’, introduced an insight into the transitional stages from Late Neolithic/Chalcolithic and Early Bronze Ages in the Aegean world. It addressed technological change and the emergences of material cultures that ultimately precipitated the major social changes of the Eastern Mediterranean Bronze Age establishing the foundations of the Greek Bronze Age.

The second metals session presented four papers on copper alloys from various time periods and locations. The first talk discussed bronze alloy production, by characterising the composition of the objects excavated from the cemetery of Baba Jillan, in Western Iraq during the Iron Age (Oudbashi and Hasanpour). The second was on the circulation of copper in Late Bronze Age Italy and looked at the analysis of ingots from the Friuli Venezia Giulia hoard (Canovaro et al.), the aim of this research was to assess the ore source, using Pb isotope analysis, and technical process employed. The third paper was given by the chair of the session, Yu Liu, and looked at the casting technology of bronze wares in the central plains of China in late Shang Dynasty. The final paper of the session presented the analysis of archaeometallurgical material from a rescue excavation of an Archaic workshop in Thasos, Greece. The analysis undertaken by N.C.S.R.

‘Demokritos’ identified that the workshop was primarily used for bloomery smelting and iron smithing with some limited evidence of copper alloy production.

The morning of the last day of the conference was dedicated to metals and metallurgical ceramics. Maria Filomena Guerra gave an excellent keynote presentation introducing her extensive work on gold objects with a focus on the major analytical challenges of gold analysis. This was followed by two talks on iron: the technology of iron craft production in Turkey (Eekelers et al.) and the second on the role of iron in lead and silver smelting (Liu et al), a complex topic presented in a clear and insightful way. A very interesting talk on niello was given by Viktoria Mozgai who presented her analysis on the niello inlays on Pannonian artworks; posing a few questions about the intentionality of the copper content in niello on silver-based artefacts. This session was concluded by Thomas Birch, who presented the investigation of three slag heaps in Meroe, which enabled the understanding of smelting practices and the technological choices involved in the organisation of iron production in Sudan over 1,000 years.

The second session started with copper metallurgy in pre-Columbian Mexico (Maldonado and Tropper) and Colombia (Martinon-Torres and Saenz-Samper). Martinon-Torres’ talk was an intriguing presentation on how a careful study of surface treatments can give important indications on the social choices made by people in the past. Travelling west, the last part of the session started with the analysis of copper based artefacts and slags in Dubai (Franke et al.) and secondly, a technological and archaeological description of the wipe-tinning method used in Iran (Mortazavi). Azama et al. presented their interesting results from the compositional analyses of the Vendôme column in Paris; this investigation identified different bronze compositions, stages of the casting process, and corrosion products. Isotopic analyses for the study of the provenance of silver in Russia (Saprykina) concluded the session.

There was a large poster session dedicated to metals, with 82 posters in total, which covered an extensive range of topics and materials. The HMS prize for best student poster went to Jean Milot for his work on ‘Ancient metals tracing by iron isotope analysis’. Regretfully, the poster sessions were too short to allow enough time for the authors of the posters to view others in their individual sessions.

Overall this conference was a great success – both academically and socially. It was pleasing to observe that most presentations were not only investigating technological features, but were prompted by the investigation of the social role and impact of metallurgy. However, the oral papers of the metals session could have benefited from the presentation of more innovative work from less well-known case studies to broaden our understanding of the exciting new research taking place globally; a lot of which was presented in the poster sessions!

Carlotta Gardner, David Larreina & Agnese Benzonelli

FORTHCOMING EVENTS

Conference, Date and Location	Description	Website, Email and Prices
Archaeometallurgy Course 7 th - 12 th August 2016 Sedgeford, Norfolk, UK	This course is primarily a practical course. There will be a guided experimental project to construct an actual working furnace. Participants will be preparing ores, and fuel, assisting in building a furnace and will also be involved in running the furnace itself. It is an ideal opportunity to learn about the principals and techniques of archaeometallurgy and also participate in a live project.	http://www.sharp.org.uk/courses/Archaeometallurgy.html
8th World Archaeological Congress 28 th August - 2 nd September 2016 Kyoto, Japan	In addition to the usual range of archaeological theory papers, this year's WAC has two sessions which may be of particular interest to our readership: "Social Archaeometallurgy: The Role of Metal Within and Between Societies" and "Craft Production in State Economies".	http://wac8.org/
22nd Annual Meeting of the EAA 31 st August - 4 th September 2016 Vilnius, Lithuania	As always, the European Association of Archaeologists Conference is slated to include many topic relevant to our readers. Covering a much more diverse range than our typical conferences, sessions of interest include: " <i>Methods of metal detecting survey in archaeology</i> ", " <i>Iron making techniques and social change in the medieval and early modern Europe</i> ", " <i>Fueling crafts and industries in medieval and post-medieval Europe</i> ", and " <i>Tradition, Innovation and Networks – Metal Working Around the Baltic Sea from the Bronze Age to the Middle Ages</i> ".	http://eaavilnius2016.lt/
HMS Research in Progress 29 th November 2016 Birmingham, UK	This meeting is aimed at a wide variety of contributors, from historical and archaeological metallurgists to excavators, historians and economists. If you are working, or have just finished working, on a project related to archaeological or historical metallurgy, we would like to hear from you. We are particularly interested in bringing together contract and public sector archaeologists with academic researchers, and in fostering links between the different disciplines studying metallurgy and related activities. Whether you are a student, a researcher, an interested non-specialist, or a professional excavator, we invite you to meet others working in this field and present your research to an interested community.	http://hist-met.org/meetings/2016-research-in-progress-meeting.html
13th Meeting of Historians in Latin American Mining (MHLM) 4 th - 7 th April 2017 Buenos Aires, Argentina	This meeting aims to gather various disciplinary approaches and problematics related to mining. Presentations are expected to consider technological and organizational dimensions of mining but also the religious-symbolic, spatial, economic and political aspects linked to these activities. Topics will include: " <i>work systems and mining technologies</i> ", " <i>mining landscapes: impact of the activity, construction of mining landscapes and territories</i> ", " <i>Circulation of Resources, people and technical knowledges related to mining. Means of transmission of technical know-how</i> ", " <i>Resistance and tensions towards mining projects</i> ", " <i>Mining symbolic dimension</i> ", " <i>Mining agents: workers, small, medium and large-scale entrepreneur, authorities, etc.</i> ", " <i>Mining politics and legislation</i> ", and " <i>methodology</i> ".	http://www.13reunionmineria.wordpress.com
International Early Engines Conference 11 th - 13 th May 2017 Elsecar, South Yorkshire, UK	Including visits and presentations, the inaugural International Early Engines Conference will provide a forum for presentation and discussion of new research into heat engines prior to 1812.	https://www.earlyengines.org/
Iron in Archaeology: Bloomery Smelters in Europe and Beyond 30 th May - 2 nd June 2017 Prague, Czech Republic	International conference in honour of the late Radomír Pleiner and to commemorate the 50 th anniversary of the founding of the Comité Pour la Sidérurgie Ancienne (CPSA).	http://www.arup.cas.cz/iaa2017/index.html
9th International Conference on the Beginnings of the Use of Metals and Alloys (BUMA IX) 16 th - 19 th October 2017 Busan, Korea	The main theme at the Busan Conference is " <i>Cultural Interaction and the Use of Metals</i> ". The Conference will provide a forum for discussion on the effects of metals on the culture and history with a special focus on Asian materials. Comparative studies and case studies on ancient and traditional metallurgy from other regions can illuminate the interactions between the Far East and the West through South Asia as well as Eurasia.	http://eng.kim.or.kr/Board/board.asp?b_code=3231&Action=content&GotoPage=1&B_CATE=BBS11

