THE CRUCIBLE

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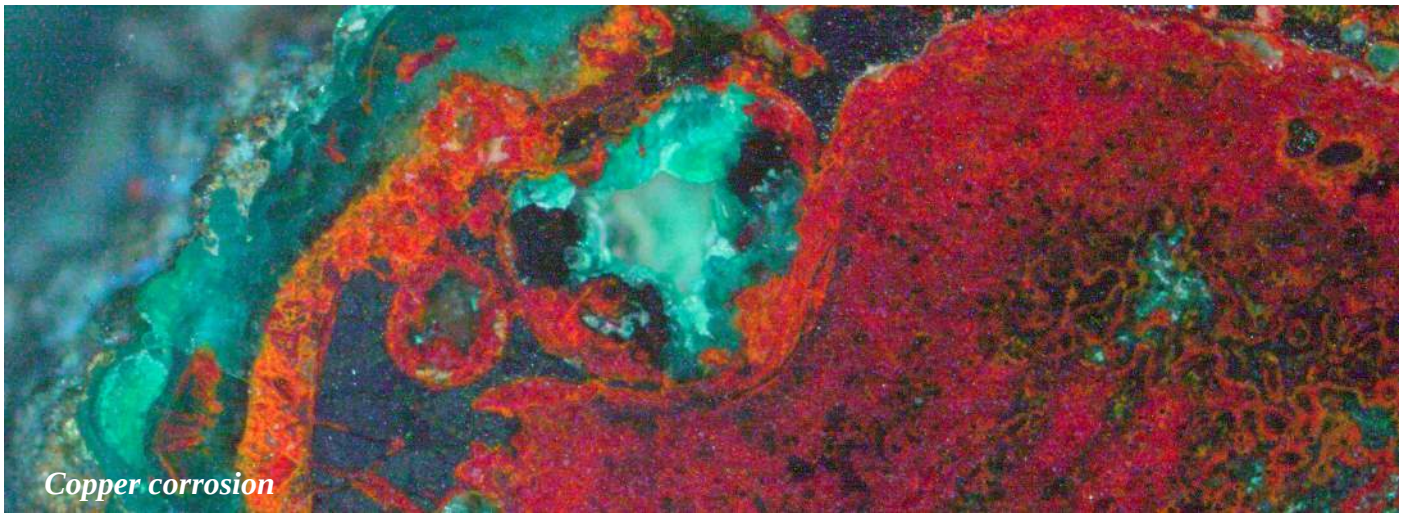

Copper corrosion

Inside The Crucible

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.

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The HISTORICAL METALLURGY Society

THE EARLIEST ZINC ARTEFACTS

Sometimes the significance of analytical data may only be realised decades after it was produced. This has certainly proved to be true for the Indian zinc coins (Figs.1 -2), which are the subject of this note. They were analysed nearly 30 years ago but their importance was only realised much later (Craddock et al 2015). Following the discovery of the zinc distillation furnaces at Zawar in the Aravalli Hills of Rajasthan (Craddock et al 1985) we were anxious to discover early South Asian artefacts made with zinc, more specifically those made of Zawar zinc. To this end we chose some pieces of bidriware, which are made from an alloy containing about 95% of zinc, and a selection of white metal coins from the British Museum's collections. These were sampled for lead isotope analysis, which was performed at Oxford by the late Noel Gale. White metal coins are quite common from all over the world but are invariably of low denomination and rather poor quality, consequently they are little studied. They are usually assumed to be of lead or pewter but surface XRF analysis showed that many of the Indian coins were of zinc. To our surprise and chagrin neither the bidri nor the coins were of Zawar zinc, indeed the lead isotope ratios showed that geologically the zinc could not have come from anywhere in Aravallis. As our interest at the time was firmly focussed on Zawar these were set aside as 'not Zawar' without too much interest in where they actually had come from. It was thought that both the bidri and the coins must have been made sometime after the mines closed in the early 19th century using imported zinc. Subsequent research on bidri production suggests that throughout the post medieval period most if not all of the bidri is likely to have been made from zinc imported from China in vessels of the Dutch and English East India Companies (Fig. 3) (Souza 1991; Craddock 2013).

Fig. 1 (left) Zinc coins from North West India, Series B, C & M Reg. 1892, 0207. 46-51. (A. Milton / BM)
Fig. 2 (right) Zinc coins from North West India, Series C, C & M Reg. 1900, 0805. 1-15. (A. Milton / BM).

The story with the coins turned out to be very different. When the scientific data relating to the whole Zawar project was being put together much more recently, interesting features became clearer. Although the coins had come from several locations from all over the North West of India and had differing trace element composition, the lead isotope ratios for all of them were remarkably similar (Fig. 4). This suggested a single source which was very unlikely if the zinc had come from a variety of 19th century imports. Discussions with the Coins and Medals Department of the British Museum concerning their origin produced another surprise. Although, at that stage their exact origin was uncertain, it could be said with some confidence that they were not modern, but almost certainly Medieval. Yet another revelation was contained in a paper by R.C. Dey (2008), a retired geologist, who in the course of his travels had collected many pieces of refractory from old mines and smelting places. These included zinc smelting retorts identical to 16th century retorts from Zawar, but found at a small settlement of Kwanu on the banks of the Tons River which divides the States of Himachal Pradesh and Uttatranchal in the far north west of India. Thus, unexpectedly, at this late stage in putting together the report on Zawar, as the earliest and only zinc producer in India, we were faced with the prospect that there was actually a second major early producer.

Fig. 3 In the Post Medieval Period most Zinc entering international trade came from China. Zinc ingots, part of a cargo on the EIC Diana, wrecked in the Malacca Straits, in 1812 enroute from China to India (BM Reg. PE 1997, 0202.1 & 2). (A. Milton / BM).

Realising the importance of these coins further numismatic research was carried out (Cribb 2014). The coins are of the same size as the base silver coinage of medieval North India. These coins, known as jitals, were in circulation from the 12th to 14th centuries AD (Tye and Tye 1995). Their designs derive from those of the Shahi kings who had ruled in Afghanistan and Pakistan from the 9th to 11th centuries AD. The zinc coins are closest to those of the last three Kangra kings who ruled in the Himachal Pradesh region, although there is no evidence in their design to link them with any state authority, and it is possible that they were unofficial or religious coin-like tokens. Unfortunately the Kangra kings have no firm dates (see Cribb 2014 for more detailed discussion on the problems of chronology),

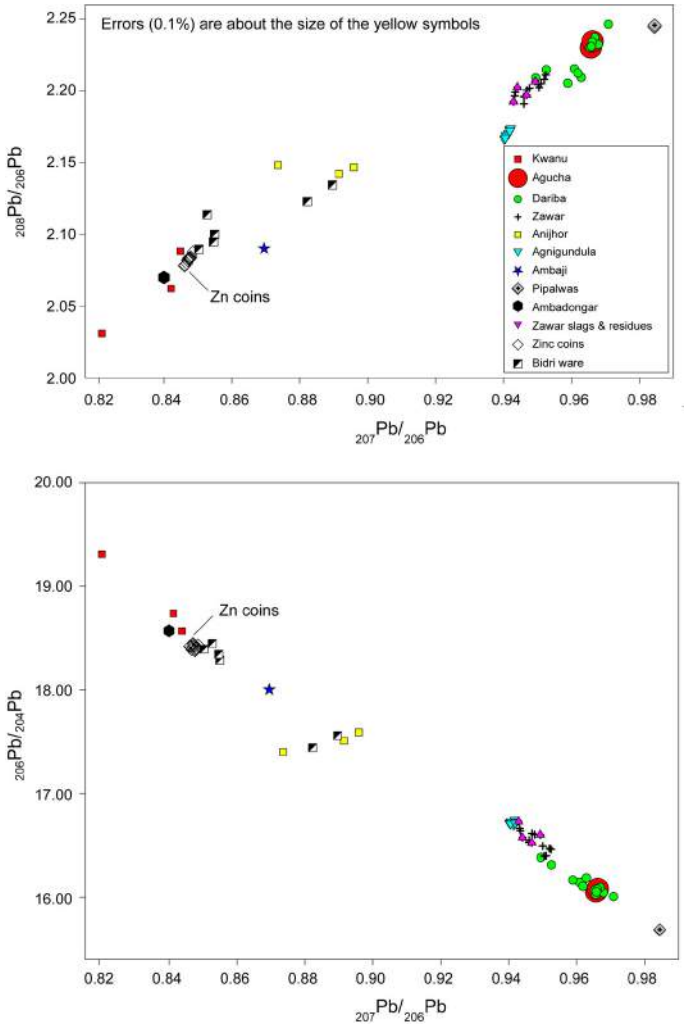

Fig. 4 Lead isotope plots of some of the principal sources of zinc, copper, lead and silver worked in the past, together with those of a selection of the zinc coins and zinc -based bidri ware. Note the Aravalli sources on the right are very different from those of the zinc coins, but some mineral samples from Kwanu are much closer, but not coincident.

but it is most likely that the later kings ruled in the 14th century AD. The zinc coins are unlikely to date from very much later as the jital-like designs would not have been readily available after the 15th century. Thus, on balance, a 14th – 16th century date is most probable for the coins.

It is still likely that the production of zinc metal on an industrial scale began first at Zawar around 1,000 years ago, with production increasing enormously between the 14th to 16th centuries before being severely and perhaps permanently disrupted by the long war with the Mughals at the end of the 16th century. After this some production was resumed through the 17th and 18th centuries, but it seems clear that most of the Indian markets had been irretrievably lost to the Chinese. Recent excavations in China have shown that zinc was being produced there by a completely different method from the early 16th century (Craddock and Zhou 2003; Zhou et al 2012). Production increased dramatically such that by the end of the century Chinese zinc transported in European vessels dominated world markets and would continue to do so until the 19th century (Fig. 3). This zinc was almost invariably alloyed with copper to form a variety of alloys from the Chinese cash to the Indian bidri. Thus these coins from the north west of India are apparently unusual in using unalloyed zinc, although some low denomination coins minted by European traders in 18th century India, locally known as bazarucos are also of zinc, but with the zinc very likely coming from China (Yih and de Kreek 1993) and others may lurk at present undetected as being 'white metal'.

Coins seem to play an important part in metallurgical innovations generally. It is perhaps significant that the earliest regular series of brass artefacts were the coins of Mitradhes VI, issued in Phrygia at the beginning of the first century BC (Burnett et al 1980), and now the earliest regular, large scale production of artefacts of zinc is again represented by coinage.

Paul Craddock
Joe Cribb
Noel Gale
Susan La Niece

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SILVER PRODUCTION IN THE SOUTHERN ANDES OF BOLIVIA DURING THE 15TH TO 17TH CENTURIES.

The great concentration of mineral deposits in the highlands of southern Bolivia and the north of Chile and Argentina, has made the region the principal producer of non-ferrous metals in the Andes. The desire to access the productive silver, copper and gold mines of the region proved one of the reasons that drove the Inca expansion from Cuzco to the south. With the arrival of the Spaniards, the exploitation of minerals in the region and especially of silver, became a central part of, and one of the principal motors, behind the colonial enterprise in the "New World"; impacting not only the destiny of the indigenous populations of the region but also of the world. As the Spanish Crown consolidated its hegemony, the incommensurable resources generated by the mines of the southern Andes, and especially those of Potosi, made possible the development of the Industrial Revolution in Europe and fomented some of the first experiments in mechanization and production chains in the mills and foundries of the region during the 15th and 17th centuries.

Fig. 1 View to the Cerro Rico mount of Potosi (Potosi, Bolivia).

Because of its importance, Andean mining practices have been the object of numerous historical studies and to a lesser extent, of archaeological investigation - principally in the Villa Imperial of Potosi. Over the last 10 years, we have researched different mining areas in the region; centre our studies in and around Potosi (Figure 1), as part of a research program aimed at understanding the technological, economic, social and symbolic aspects of silver production during the 15th to the 17th centuries. Within the framework of this program, we have studied pre-Hispanic and colonial mines (Figure 2) and metallurgical sites in important mining centres like Potosi, San Antonio

Fig. 2 Entrance of an old silver mine from the second half of the 16th century. San Felipe mount, Oruro.

Fig. 3 View of San Antonio del Nuevo Mundo mining site, called today San Antonio de Lipez.

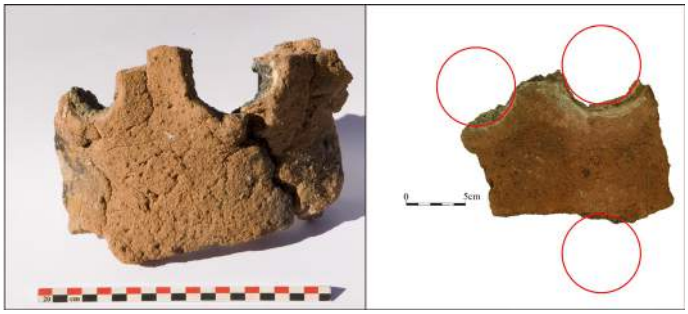


Fig 4 Fragments of huayras found in Potosi. Dated to the second half of the 17th century.

Fig. 5 Colonial reverberation furnaces, Santa Isabel. Probably from to the beginnings of the 17th century.

de Nuevo Mundo (Figure 3) and Oruro, as well as smaller less important sites in the Bolivian altiplano (like Santa Isabel, Alto Chichas and Pacajes). We have also complemented this research with a series of experiments on different models of furnaces (huayras or wind furnaces and reverberation furnaces) that were constructed from archaeological models found at sites like Potosi and Porco (Figures 4 and 5). These experiments have provided us with a better understanding of the technology of these furnaces and their operational chains.

Beyond the particularities presented in the cases studies, the articulation of archaeological data with the results of our experiments and with the information provided by historical sources, reveal a dynamic of intense exchange and transference of indigenous and European knowledge and technologies related to metallurgy during the first moments of the Colonial Period in the Andes.

Pablo Cruz

Florian Téreygeol

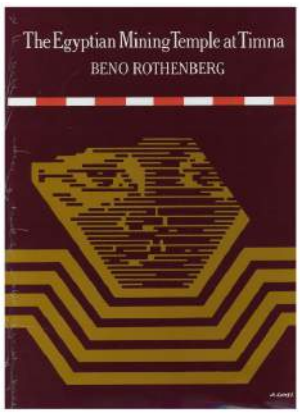
HISTORICAL METALLURGY: DIGITAL INDEX

While we keep edging closer to resolving the availability of Historical Metallurgy online, we thought some readers might like to have access to a digital database of the journal's paper titles, classified by authors, materials and period. We cannot guarantee that it is free of errors or omissions, but it should be a useful resource for researchers. If you would like a copy of it, please email Brian Read (**brian.read2@ntlworld.com**)

IAMS BOOK SALE

The Institute for Metallurgical Studies (IAMS) have a number of books by Beno Rothenberg for sale. The prices listed are suggested donations; all money made from the sale of these books will go to IAMS. Please contact **carlotta.gardner.11@ucl.ac.uk** for further information.

Ancient Mining and Metallurgy in South-west Spain - £10 +pp



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"WHAT ARE YOU UP TO?"

It often takes years from the moment a project starts until the results are reported, but it is always useful to know what other researchers are up to, even if they are only in early stages of their research. If could be news of the site you are excavating, a particularly fascinating find, a highlight of a little-known furnace or museum exhibit, or just a couple of lines on your current thinking. Whatever it is, **The Crucible** would love to know.

Please send your contributions (up to 100 words or so plus a picture) to: **thecrucible@hist-met.org**.

WEALDEN IRON RESEARCH GROUP

The 2015 edition of Wealden Iron (2nd series volume 35) begins with several new discoveries resulting from fieldwork. Bloomery sites have been found in Ticehurst, Waldron, Chiddingly and Catsfield, in East Sussex, the last of these dated to the Late Iron Age or early-Roman period. Two found in the bed of the pond of Ifield Mill, Crawley, during restoration work on the pond bay of the former forge site, were located one inside the other. Of particular interest is a bloomery discovered near Southborough, Kent, for which a single radiocarbon date of 353-231BC has been obtained. Further corroboration is anticipated. Other short items include the dendro-dating of timbers used in the construction of the pond bay for North Park Furnace, near Fernhurst, West Sussex. Their 15th century origin suggests either recycling of timbers from another structure or an earlier water-powered use of the site. In another note, analysis of calcined siderite ores associated with smelting sites around Outwood in Surrey reveals variable iron content within a small geographical area.

Longer articles include a theoretical examination of the ratio of iron to silicon in calcined ore - Ore Bloom Potential - exploring how that and other factors, such as furnace structure, could affect yields in bloomery furnaces. By the same author, a series of micrographs reveal the early formation of bloomery iron.

Protestants in the 16th-century Weald had their share of persecution during the reign of Queen Mary I, and the individuals linked with the iron industry who were accused or suffered because of their beliefs are listed and their social backgrounds discussed. The case of the ironmaster, Richard Woodman, who met his end at the stake in Lewes in 1557, has the highest profile but many others in the industry may have risked a similar fate.

The iron industry in the Weald in the late-16th century has traditionally been associated with the Walloon process, so documentary evidence of a bloomforge in the region is of particular interest, especially if possibly associated with the Yorkshire entrepreneur, Thomas Proctor. The forge in question, Marriott's Croft, on the Kent-Sussex border north of Frant, was operated by John Wybarne, but his neighbours, the Dyke family, had connections with the north Yorkshire dales area where Proctor had been active.

The list of ironworks in the Weald between 1653 and 1664 survives only in transcripts, but one forge mentioned, Kinians, has never been identified. A short article proposes that its name may associate it with George Kenyon, who worked with Ralph Hogge, and can be identified with Langley Forge, worked as a furnace by Hogge, known to have been operating in 1653.

The stormy conditions just before Christmas 2013 did much damage and not least to the pond bay at Thursley Upper Hammer pond, in Surrey, which was breached by the surge of water. Opportunity was taken to record the structure of the dam, which dated to the first decade of the 17th century, from the section that the flood exposed.

Finally, the description of the operation of a blast furnace long associated with the Sussex ironmaster, John Fuller, has been shown to have been a translation of a text by the Swedish scholar, Emmanuel Swedenborg. In a forensic article, in which Fuller's manuscript and Swedenborg's published Latin text are compared, minute details betray Fuller's debt to the Swede.

For further details of the Wealden Iron Research Group see the group's website, **www.wealdeniron.org.uk**, where one can find the group's online database of sites and people associated with the region's iron industry.

Jeremy Hodgkinson

Experimental iron smelting furnace. The WIRG conducts regular such experimental smelts and field surveys in the Wealden area.

COMITÉ POUR LA SIDÉRURGIE ANCIENNE / COMMITTEE FOR ANCIENT IRONWORKING

One of Radomír Pleiner's most significant initiatives was the creation in 1966 of the CPSA, of which he acted as Secretary for nearly 40 years. The CPSA was an international and inter-disciplinary group of scholars of early ironworking. The Communications of the CPSA, edited by Pleiner, were published twice-yearly in the journal Archeologické rozhledy with offprints being circulated to all the corresponding members. In the pre-internet age this was a vital source of information on early ironworking, with reports on conferences, current research projects and many bibliographic notices, which remain a valuable resource today.

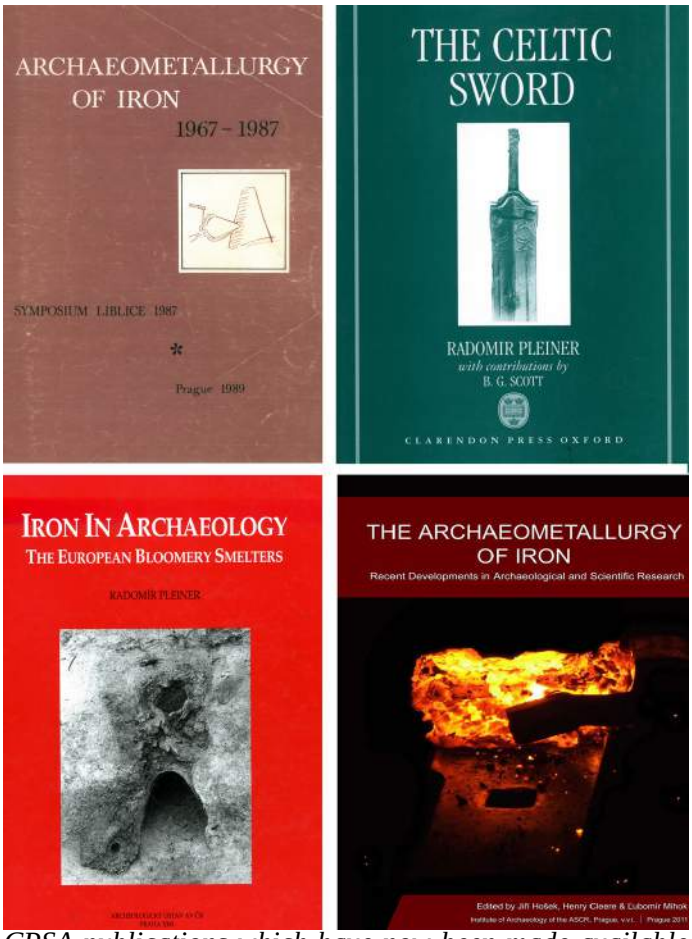
Following the death of Radomír early in 2015 (see **The Crucible** Issue 88, for his obituary) it was decided to revive the CPSA in a form more suitable for the 21st century through the pages of Academia.edu, which can be accessed via **https://independent.academia.edu/CPSA**. This site has two primary aims, firstly to act as an archive of CPSA activity and publications, secondly to act as a contact point where scholars of early ironworking and their publications can be found.

All the Communications have been uploaded to the Academia.edu site, along with several bibliographies and tributes to past members. Recent uploads include three out-of-print books, Pleiner's classic work on The Celtic Sword (1993), the first volume of his magisterial Iron in Archaeology (2000) and the recent volume The Archaeometallurgy of Iron (2011) which was presented to Pleiner on his 80th birthday.

A full list of these documents, with direct links to the Academia.edu site, is at **https://academia.edu/15249466**. Anyone can read these documents online, but to download them it is necessary to sign up to Academia. In the first six months the site has attracted over 2300 views and 513 visitors from 53 countries. The site is still being developed and it will become increasingly useful and comprehensive as more people follow the CPSA and upload their papers on ironworking. We should like to invite interested members of HMS to join in this initiative.

The other major activity of the CPSA was the series of conferences organised by its members all over Europe, of which 21 were held between 1970 and 2001. The proceedings of these conferences, almost all published, form a valuable record of the development of ironworking studies (**https://academia.edu/15249400**).

Some of the earlier volumes are now difficult to obtain and gradually they will be uploaded to the Academia.edu site. The volume of proceedings from the 1987 Liblice conference, which covers archaeometallugical work carried out during the first 20 years of the CPSA is already available and in the near future the proceedings of the second CPSA conference, at Eisenstadt in 1975, will also be uploaded.



CPSA publications which have now been made available online.

Finally, an international conference is being organised in honour of Radomír Pleiner in the 50th year of the CPSA, to be held in Prague in 2017, with the title Iron in Archaeology: Bloomery Smelters and Blacksmiths in Europe and Beyond. Final details are not yet available and will be announced in the next issue of **The Crucible**.

Peter Crew

Jiří Hošek

THE CASE OF PRE-COLUMBIAN BRONZE OBJECTS IN NORTHWESTERN ARGENTINA: METALLURGY, ARCHAEOLOGICAL CONTEXTS AND CHRONOLOGY

Pre-Columbian societies in the Andes had a rich metallurgical tradition, mainly orientated towards ceremonial practices and the development of social status. In Northwestern Argentina, in the southern Andes, there was a special development in the technical procedures and the design of the finished objects. This metallurgical tradition was based in copper and more specifically in the alloy tin bronze. The production of metallic objects gained technical and expressive sophistication in line with the growth of a complex society. The scale of production also increased over time.

Fig. 1 Aguada metal plaques made with the lost-wax casting method (left, height 9 cm; right, height 20.7 cm; Ministry of Foreign Relations Collection, Buenos Aires) (Gonzalez 2007: 36, figure 2).

Discoveries of metal objects dating to the Formative period (1000BC – AD500) are scarce. The majority of those found are made of gold and are found in the central valleys of the Catamarca province, in funerary contexts attributed to the sociocultural entities of Condorhuasi and Ciénaga. The Regional Integration period (AD500-900) saw the consolidation of tin bronze production. A series of utilitarian objects made of tin bronze were found in the Aguada contexts in the Hualfín Valley (Catamarca province), the bulk of production however, was associated with ornamental pieces such as ceremonial axe blades that depict a feline figure in a realistic art style. The most striking objects found are the plaques, which are made by the lost-wax casting technique, and are abundantly decorated with elaborate designs. The decoration is comparable to a formal sketch, the plaque depicts a man with an ornament on his head, and two felines standing on his shoulders (Fig. 1). None of the plaques have been discovered in direct association with other Aguada materials.

Fig. 2 Regional Development period objects: a. decorated circular plaque (diameter 19.5 cm; Ministry of Foreign Relations Collection, Buenos Aires) (Gonzalez 2007: 37, figure 4); b: Axes with a blade and handle forged into one piece (length 25.3 cm; Ministry of Foreign Relations Collection, Buenos Aires (Gonzalez 2007: 39, figure 8).

Tin bronze alloys prevailed during the Regional Development period (AD900-1400) whilst the use of precious metal was rare. This period saw a strong increase in the volume of metal produced and the quantity that was invested in individual objects; there was also an increase in the production of utilitarian objects. Bells, plaques, and axes were decorated profusely, combining frets with human faces or warriors in relief (Fig. 2). The Inca occupation (starting in the early 15th century) saw metallurgical production undergo a quantitative leap in the places where the technological tradition was well rooted.

Figure 3 shows the distribution map of metallurgical activity, divided by period, based on the discovery of technical ceramics used in the process of production (namely crucibles and moulds). In concordance with the spread of metallurgy in the Northwest during the pre-Hispanic periods, there is an increase in the amount of production in the late pre-Hispanic period (Regional Development and Inca periods). However, there is a lack of evidence for metal production during the Aguada period. Is this due to the burial of earlier sites or are there

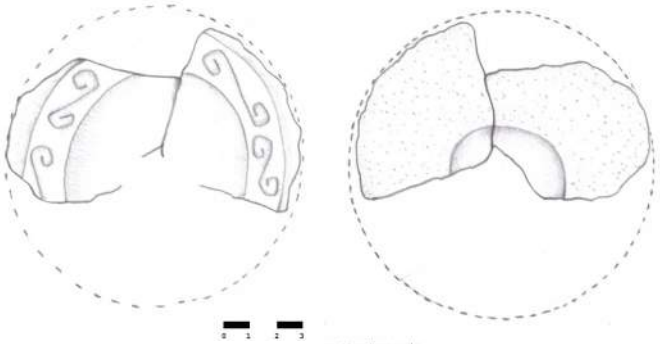


Fig. 4 Fragments of a decorated mold of a circular plaque found during an archaeological fieldwork in Rincón Chico (Catamarca province).

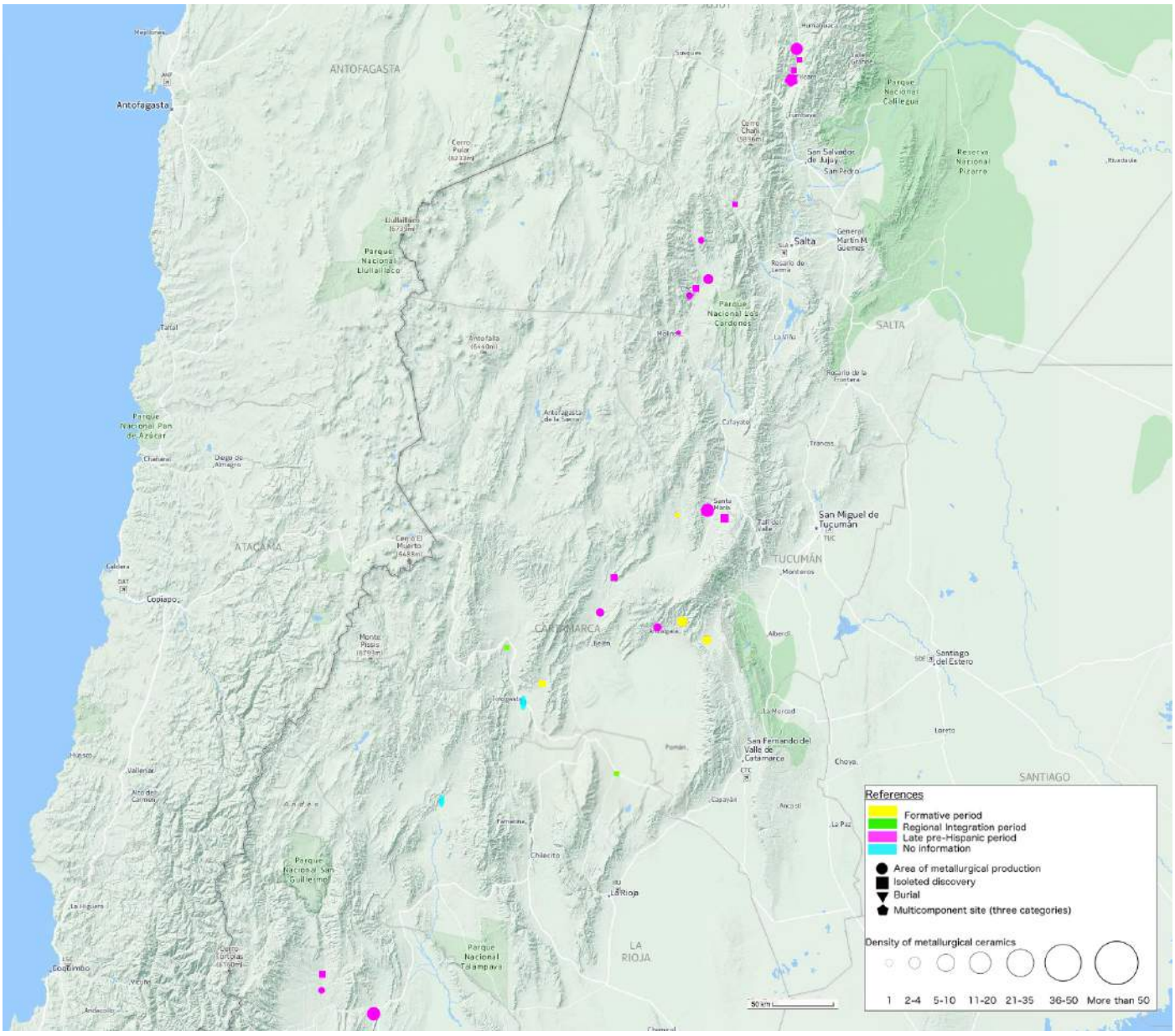


Fig. 3 Distribution of metallurgical ceramics in Northwestern Argentina according to the period, type of context and density.

other factors influencing this distribution? Similarly, many moulds of decorated objects have been found dating to the late pre-Hispanic period, but no moulds relating to the Aguada plaques have been found. This might be because lost-wax moulds survive as fragmentary pieces and are therefore difficult to assign to specific objects. The moulds that were found are not associated with contexts of the Regional Integration period, many lost-wax moulds were found in the later period contexts. It may be possible that some of the objects originally assigned to the Aguada period actually belong to the latest periods. This mystery can only be resolved through systematic fieldwork in the future.

Geraldine Gluzman

HMS WEBSITE CALL FOR PHOTOS

As part of the website development HMS is building an online archive of past HMS events. If you have any photos from any of our past conferences please send them to events@hist-met.org for inclusion on the website. There will also be a digital archive of abstract books and space for thoughts and comments about events.

DE FERRO DE ALAVA: THE IRON, THE PEASANTS AND THE MONASTERY

In the year of 1025 the powerful monastery of San Millán de la Cogolla (La Rioja, Spain) completed a kind of cadastre, which carefully registered all the villages devoted to the monastery. Although several facts remain unclear about the 'Reja de San Millán' (Pastor 2006), there is one indisputable fact: the settlements mentioned had to commit with one or more 'reja' – likely an undetermined quantity of iron –; another significant factor is that the manuscript is entitled 'de ferro de alava'.

A network of more than 307 villages – typically modest size agricultural settlements – located close to one another producing iron at least one time annually is something we currently have no physical evidence of. A joint project between the University of the Basque Country (UPV-EHU) and UCL Institute of Archaeology (Fig. 1) has been designed to investigate this.

Recent archaeological excavations (Quirós Castillo 2011) carried on the Basque Country area (North of Spain) point to the existence of a system of connected peasant communities spanning from Early to Late Medieval Period. Nonetheless, information concerning the production of iron at any stage (primary or secondary) is disappointingly scant with only one unique positive case of a smelting and smithing workshop (Azkarate Garai-Olaun et al. 2011). Paradoxically, even during the earlier period the inhabitants of the sites enjoyed relatively large amounts of iron implements – totals of 242 and 449 metal items were unearthed in the villages of Zaballa and Zornoztegi respectively –, typically household or farming based tools e.g., sickles, billhooks, scissors, knives, horseshoes, stirrups, ladles, latches and hinges, locks and keys, etc. (Fig. 2).

The metallographic examination of a first set of tools from the Early Middle Ages, mostly recovered from the village of Zaballa (Quirós Castillo 2013), revealed that these are good quality functional objects with surprisingly low levels of slag inclusions within the iron metal. Most of the artefacts consist of low carbon steel forged from piled iron, with occasional more complex composite structures of steel by secondary carburisation and, above all, the unpreceded case – to

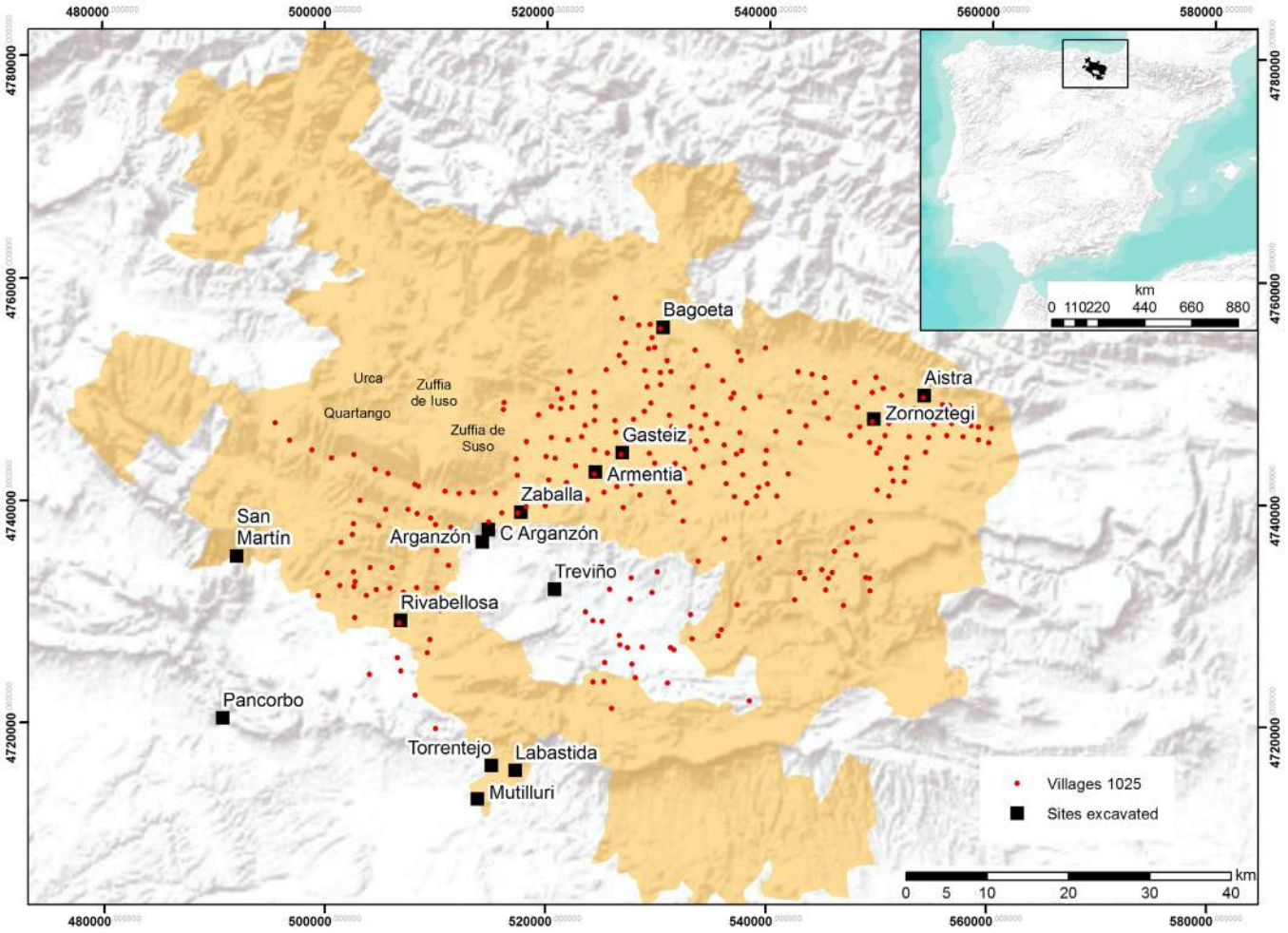


Fig. 1 Map of settlements in the territory of Álava mentioned in the manuscript "Reja de San Millan" in 1025 AD.

Fig. 2 Billhooks, sickle, arrow-head, knives and scissor excavated within the same dwelling structure in Zaballa, 8th to 10th centuries AD.

our knowledge – of a pair of scissors made by pattern-welding, documenting the first case of weaponry made by this sophisticated technique (Fig. 3). The appearance of a pair of pattern-welding scissors found on a peasant dwelling of a small village, without a church of its own, opens new perspectives concerning the use of this sophisticated and complex technique strongly related with elites and weaponry (Lang & Ager 1989). It also challenges the paradigm of medieval impoverished peasantry without access to iron tools (Le-Goff 1982).

Fig. 3 Scissors found in Zaballa dating 8th to 10th century AD and micrograph showing the complex banded structure alternating phosphoric iron and martensite.

Where all this iron was produced and manufactured is the major question to be approached by the current joint venture between the two universities. Was there a self-sufficient artery of peasant settlements intimately related with ironmaking communities, and did the monastery prefer to collect taxes in metal instead of grain or animal husbandry, which in principle was more appropriate to the villain condition of the communities?

David Larreina-Garcia

Juan Antonio Quirós-Castillo

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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**.

ZOFIA STOS-GALE

Our interviewee is a familiar name for anyone who has ventured into Bronze Age metallurgy in the last three or four decades. Born in Krakow (Poland), Zofia Stos-Gale fought her wishes to become an art historian and instead studied Nuclear Physics and Electronic Engineering, following her sister´s advice to do "something useful". A meeting with Martin Aitken in the 1970s changed her life, and since then she has devoted her career to combine materials science and archaeology. Her extensive and pioneering work with the late Noel Gale, culminating in the creation of the Isotrace Laboratory in 1988, led to the establishment of lead isotope analyses as the most common strategy used today by archaeologists to provenance metal artefacts to their geological sources. Thanks to their work, the Mediterranean arguably remains the world region where the prehistoric metals trade is best understood, and the testing ground where sampling, analytical and data processing strategies for metal provenancing have been kept under constant refining. Much of the resulting data are being made accessible in open access at the OXALID database (http://oxalid.arch.ox.ac.uk).

Much of Zofia's career developed in Oxford where, besides Martin Aitken and Noel Gale, she credits fondly the influence and advice of Colin Renfrew, Ronnie Tylecote, Ulrich Zwicker, Beno Rothenberg and Mike Tite. In the last fifteen years she has spent a spell as an advisor on EU funding at the University of Surrey, and she has most recently started a collaboration with Johan Ling of the University of Gothenburg and his colleagues on a research project concerning the sources of metals and trade in Bronze Age Scandinavia. We eagerly look forward to seeing what comes next!

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

ZOFIA STOS-GALE: Trying to get from ancient metals more information than meets the eye by applying analytical techniques developed in geology and material science. Using the scientific data to stimulate archaeologists to reconstruct the past from the point of view of the development of metallurgy as the driving force for economy and a long distance trade in prehistoric times. I taught science to archaeologists and as a scientist I learned archaeology to help to bridge the 'two cultures'.

THE CRUCIBLE: What is your most memorable professional moment?

ZOFIA STOS-GALE: There are several memories that stand out. The first amazing experience was surveying the practically undisturbed and unexcavated (in 1982) site of copper smelting on a high cliff on the Cycladic island of Kythnos, seeing there Bronze Age pottery, large copper prills amongst the slag pieces and stone hammers. The charcoal found in the slag was later dated by 14C to 2800 BC. This Ayios Yoannis site is one of several similar prehistoric industrial sites on high cliffs on the Aegean islands, but this one was the first to be securely dated and there are many Eearly Bronze Age arsenical copper artefacts from the

Aegean that have lead isotope compositions consistent with the slags from this site. Another huge surprise was when we were analysing copper oxhide ingots – all of them had very narrow range of lead isotope compositions; ingot samples from Sardinia, Cyprus, Bulgaria and the Aegean were all of the same origin! An extensive program of collecting samples of ores and slags with the help of George Maliotis allowed us by 1997 to characterise isotopically the Cypriot ores and identify the main region on this island from which copper was extracted to cast these iconic Bronze Age merchandise. And a totally unforgettable experience was handling and sampling with Cemal Pulak and Noel Gale the ingots and metal artefacts found on the Uluburun shipwreck. The metals at that time (1995-1997) were stored in the 'French Tower' of Bodrum castle, where the walls were covered with the graffiti left by the French crusaders…

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

ZOFIA STOS-GALE: There is no doubt that Noel Gale was most influential in my professional life. He was a careful, precise, hardworking and innovative scientist with a long experience in nuclear physics and geochronology. Also, for a physicist he was a very good chemist! In many ways our skills were complementary and we worked well together. I also have high regard for Mike Tite and I adored Ronnie Tylecote and his wife Elisabeth.

THE CRUCIBLE: What is your main current project?

ZOFIA STOS-GALE: In 2012 I was contacted via Facebook by Professor Johan Ling of the Archaeology Department at the University of Gothenburg in Sweden, who was searching for help in interpreting the lead isotope data on Swedish and Danish bronzes. Since then we have been working together and with a larger team, trying to solve the difficult puzzle presented by the analytical data obtained from the Scandinavian bronzes. The lead isotope and chemical data show clearly that they are not made of Scandinavian copper and that the great majority is isotopically quite different from Eastern Mediterranean copper. Some seem to be made of copper from the Alpine deposits, but some might have originated from the Iberian copper ores. And where was the tin coming from? We are collaborating with archaeologists and archaeometallurgists from Italy and Spain hoping to find out more about the Bronze Age metallurgy in south-west Europe.

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

ZOFIA STOS-GALE: We are living in a digital age, but most of the archaeometallurgical publications are still appearing in elegant hard cover books, or articles in various journals, often even without tables of analytical data, but with conclusions drawn from numbers known only to the authors. It is not possible to have a complete oversight of all research with such fragmented and poorly documented results. So, I would like to use my big grant to create a virtual archaeometallurgical laboratory based on existing labs in various countries, where in this virtual space all scientists and archaeologists will collaborate, exchange ideas and help each other to solve problems, where all new data will be recorded in an open access database, and published research and data digitalised. Such laboratory would also develop the good standards of analytical methods and interpretation of data. Teaching of scientific techniques, including archaeometallurgy should be a basic part of all courses in archaeology; my virtual laboratory could also provide such on-line courses.

Ingot sampling in Bodrum, 1995.

THE CRUCIBLE: Which publication should every HMS member read?

ZOFIA STOS-GALE: This is a difficult one… Tylecote's 'A History of Metallurgy' is not a bad start but seems a bit out of date now. The series of 'Der Anschnitt' published by the Mining Museum in Bochum has many good volumes, but there are also many other excellent series published in the last 15 years. Just looking at my bookshelves I see that there is no one book that says all. This is why we need a website devoted to archaeometallurgy!

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

ZOFIA STOS-GALE: Fascinating field, requires lot of work and understanding of two cultures, science and humanities, but not easy to find a well-paid job… so be prepared to diversify…

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

ZOFIA STOS-GALE: Science and scientific curiosity has great power to take you through the life. Studying and researching ancient metallurgy is a great 'forensic' experience. There is still a lot to discover: go for it!

ANDREA DOLFINI

I am a late comer to the exciting world of archaeometallurgy. My background is that of a traditional Italian archaeologist. In the particular incarnation favoured by the University of Milan, where I obtained my First and Master's Degrees, this meant three things: good working knowledge of the Classical texts and archaeology, lots of pottery classification and material culture studies, and mucking your hands in the field. Science played a tiny part in the curriculum, if any. I owe to my student days, however, rock-solid foundations in archaeological and research skills as well as an inordinate passion for Italian and Mediterranean prehistory.

Whilst reading archaeology, I started digging for archaeological companies. As my fieldwork commitments grew steadily over time, when I finished my studies I turned to what then seemed my natural career path. I spent a few years travelling up and down Italy, excavating an array of prehistoric, Roman, medieval, and post-medieval sites. Highlights from my 'fieldwork life' include, in no particular order, digging a Bronze Age village in the wind-swept limestone hills of Calabria and uncovering early medieval painted graves in Pavia, once the capital of the Lombard kingdom of Italy. All that glitters is not gold, though. Less enjoyable jobs involved pulling apart the mighty foundations of early modern brick buildings with a jackhammer, which had to be done without compromising on the stratigraphic method – an interesting experience, but I would not recommend it if you suffer, as I do, from back pain! Eventually my continuing interest in the research side of archaeology, which I managed to keep alive during my fieldwork years, got the upper hand and I felt the urge to move my career in that direction. This is the time when I first meddled in prehistoric copper technology.

The opportunity was provided by a PhD research project investigating the origins of metallurgy in central Italy. Being a complete outsider to the arcane world of archaeometallurgy, I worked my way into it in a most heterodox way. In a nutshell, this involved a modicum of training at Padua with Gilberto Artioli supplemented by some microscopy at Cambridge, where I was based; lots of independent reading in as diverse disciplines as ore geology, analytical chemistry, and early smelting technology to name but a few; and a good deal of talking to people, which notably included several chats with Ben Roberts (we were then the only PhD students at Cambridge working on early metallurgy) over some well-deserved pints, after long days spent in the library.

I was fortunate enough to enjoy a smooth transition from doctoral research to a full-time lectureship at Newcastle University in 2008. I have since further developed and expanded my interests in prehistoric copper technology and objects. Working with students has been an unexpected

bonus for me as they are pretty good at challenging your views and certainties but also, let's admit it, provide much-needed muscle power when it comes to pumping the bellows or to chopping down trees with replicas of Bronze Age axes! There are two research strands in which the help and collaboration of my students has been especially important: metalwork wear analysis and experimentation with prehistoric tools and weapons. I am especially fond of my ongoing Bronze Age combat project, which caused some headache to the university safety officer but gave my team the opportunity to operate, quite literally, at the cutting edge of metalwork research. And with no injuries to report so far!

I have been a member of HMS since 2006 and was invited into the council two years ago. These are exciting times for the society as, amongst other things, we are expanding our international membership and are strengthening the journal's profile. The main challenge ahead lies in repositioning the society to make it a truly international player, tapping in particular the fast-growing research and practice 'markets' of Asia and Africa. Doing so without losing our traditional membership as well as our healthy mix of academic and non-academic expertise will be a balancing act that may not be easy, but it's certainly worth attempting. It is a privilege for me to help reshape the society and I look forward to working with all members to make this happen.

IAMS SUMMER SCHOOL 2015

29th June - 10th July, London

This years annual IAMS summer school was held at UCL and Monkton Up Wimborne, Dorset. I am a visiting Japanese PhD student, currently attached to Cambridge University, and fortunately got the opportunity to attend. This summer school offered instructive seminars for students and researchers alike who wished to learn the theory and practical methods of archaeometallurgy. It was divided into two parts, the metallurgical experiment workshop in the first week, which will be the subject of this review, and lecture sessions on archaeometallurgy theory and laboratory usage in the second week.

On the first day of the seminar, Dr. Michael Charlton taught us about iron in archaeology. Discussion was made about the processes of bloomery iron production, the origins of iron in human history, the mechanisms of smelting, and the features and by-products. This information was very beneficial for students who do not have backgrounds in this field. And in addition, it gave excellent theoretical information with which to prepare for the smelting experiments the next day.

On June 30 we went to Monkton Up Wimborne, located in Cranborne Chase, Dorset and started the experiments under the direction of Jake Keen and Mike Tizzard, who are specialists in traditional iron smelting techniques. During this experiment, Prof. Marcos Martinón-Torres and Dr. Charlton were also present, and kindly answered our questions throughout the week.

The process began with the preparation of the raw materials: selecting and crushing the ore, sieving charcoal, and mixing clay for the furnace. The ore was classified into four grades depending on their quality; the high-class ore being less sandy and of a more purplish colour, while the low-grade ore was more sandy and of lower density. In the crushing step, we used metal

Students crushing and beneficiating iron ore.

Furnace number two in operation.

hammers. Due to my interests in ancient tools, I used a stone hammer picked up from a riverside in China. The roasted ore was easy to break with the stone hammer, but the unroasted ore felt much harder. The difference was quite significant, highlighting an important aspect of roasting. The ore was reduced to approximately 1cm, and then mixed with crushed charcoal before adding to the furnace.

Three furnaces were used. The first was modelled on a medieval furnace and built by Jake in advance. The furnace was dried before use, and the motor of a hoover was used as a blowing system. The second furnace was smaller, and was built during the three days we were there, using clay mixed with sand and straw. The third furnace, built into the side of a bank which had been operating for some time now, had a tall shaft that created a forced draft.

For furnace 1, traditionally, the ratio of ore and charcoal is 1:1, but we prepared 20kg ore and 16kg charcoal afor the first charge. The ratio was then changed gradually; 1:1.5 five times, 1:1 four times, 1.5:0.75 six times, and 2 kg ore was charged at the end. The operation seemed

Ore assaying experiment.

to be going well but unfortunately the result was not so successful. The particles of iron in the slag did not coalesce together, meaning a bloom did not form, possibly due to temperatures not being high enough. Neither was a bloom formed in the third furnace. However, small quantities of iron was obtained from the second furnace, although less than expected.

As well as the iron smelting, two other experiments were also run by one of the UCL students. One was to investigate the use of small crucibles for assaying the quality of the iron ores, based on techniques as described by Lee Sauder. The ore was ground and placed into crucibles with charcoal and strongly heated for 20-40 minutes. Success was mixed; occasionally small amounts of iron was obtained, with other experiments failing due to temperatures being too low, duration too short, or cracking of the crucibles. The second experiment tested a traditional South American casting method. A casting crucible with a hole in the base from which metal could flow have been found from Chile and Argentina. A similar crucible was reconstructed by UCL PhD student Maria Teresa Plaza. About ten copper coins and cut brass pipe were used for melting. However, incomplete melting meant that the metal was unable to flow out the base as hoped.

Removing the solidified slag mass from furnace 1.

These results tell us how important and difficult it is to maintain the required temperature for smelting. There is a lot of evidence of ancient iron smelting and we tend to accept it as a matter of course; but these experiments highlight the difficulties faced by early metalworkers in obtaining iron. Seeing how by-products, such as slags and blooms were created, helped me to understand the processes at work at metallurgical sites. This week made me realise the importance of experimental studies.

The IAMS summer school 2015 students and teachers.

Finally, I would like to express my sincere appreciation to all the people who arranged and led this seminar, and who helped me to write this review.

Yuriko Ara

HISTORICAL METALLURGY SOCIETY STREET FURNITURE CONFERENCE AND AGM

12-14th June 2015, Staffordshire

Nestled in the heart of Warwickshire is the home of William Shakespeare, Stratford Upon Avon, a beautiful, quaint and idyllic… and … esteemed location of the annual conference of the Historical Metallurgy Society 2015.

Meeting up with people is always a great event and any opportunity to do so is always very welcome, and this was no exception.

Paul Dobraszczyk, of University of Manchester, as the keynote speaker, kicked off the conference on the Friday evening. Paul's lecture "Social Ornament: iron on the street" was a wonderful start that imparted a context on the conference subject, "Celebrating Street Furniture".

The keynote lecture was followed up by a trip out to one of the local eateries and a few drinks to catch up with those attending.

On the Saturday morning, following the previous nights impressive thunderstorm, the lectures of the conference got started with Dr. Peter King's dissertation on 18th century iron-founding: air furnaces and coke-smelting. Peter's ability to paint a historical picture that is approachable to all in the audience was again in evidence as he gave light to the mysteries of the furnaces and their workings in the most intricate and wonderfully enticing detail.

Richard Williams followed up and continued with the theme of foundries with his lecture "The Production of Foundry Irons from 18th Century Charcoal and Coke fired Blast Furnaces". His descriptions of the workings of the foundry and its output described so much of the street furniture that we are currently aware of, yet in a contemporary context of the 17 and 18 hundreds.

In a totally different vein, Jonathan Prus described a project that will allow the easy access for all concerned to the production and administrative details of the foundries of the UK historically, in his lecture "Who made that? Access to data on foundry history".

Chris McKay asked us to look up at the tower clocks that are present in so many of our town squares. He gave us a great idea of how these clocks were made, and of course why! His lecture "Cast Iron Time" was littered with pictures of these "behemoths of time" and proved to be a very interesting and enlightening, not to mention educational presentation.

"Knock knock, what's there?" was the story of the Arundel Castle bell-pull, which had recently had a another layer

of history added to its story, with the conservation work carried out by William Hawkes, at West Dean College. This lecture demonstrated the other side of the story of our cultural heritage and what it takes to keep the objects we cherish safe and in good condition.

Ruth Rhynas Brown showed us that recycling is nothing new with her lecture "Re-using old cannon". This presentation gave an insight into the re-use of canons of all things, to make street bollards! This was an interesting insight in to a historical aspect of a perennial problem we have today, yet we seem to have had a much greater degree of ingenuity in the past.

The lunch break gave time for us to pause and reflect on the morning's proceedings before we were thrust in to another session of intrigue interest and wonderment. The hotel put on a superb lunch and we wanted for nothing as the hotels staff did all they could to provide us with a superb service and a great time.

Immediately after lunch Paul Belford was intended to have carried on the refreshment theme with his lecture "Beer, coal and light: a preliminary study of cellar access systems". However Paul was sadly unable to attend the conference, but we were fortunate enough to have Eddie Birch who is more than capable of stepping into the breach. And so Eddie, with his usual high level of ability and competence, presented Paul's paper. This work gave insight into the humble drey-drop and all it entails. Painting an interesting and realistic picture of the drey-mans job and how the street furniture beneath our feet plays an integral part in the day to day running of businesses, modern and historical.

Rachel Cubitt followed up with an interesting and enticing take on the foundries of York and surrounding area, showing us the beauty of her home towns street furniture and where it plays a part in the fabric of the city.

Eleanor Cooper, of the Oxford Preservation Trust inspired us to look a little deeper at the project being run by Oxford City Council in her lecture entitled "Oxford Preservation

Trust and Oxford City Council Victorian Railings Reinstatement". This gave an interesting insight into the work that is being done to preserve the street furniture we hold so dear, and how it might work for other councils to do the same.

"Survey of Cast Iron Lamp Posts in Clifton and Hotwells, Bristol" was next up from Maggie Shapland, of Clifton and Hotwells Improvement Society / Bristol Industrial Archaeological Society. This whistle-stop tour of the area of Bristol gave us an insight into what happens when we look up. The often-ignored lamppost was the subjects here and was bought into sharp focus by an enticing lecture full of the wonders of ironclad Bristol.

Finally finishing the day's proceedings was Andrew Naylor of Hall Conservation. His lecture "Street Level Conservation" was a catalogue of the fantastic projects he and his company have undertaken in the preservation of the street furniture around the UK. The work he and his team carry out is an exemplary showcase of the type of work we need to pursue to preserve the very fabric of the streets we enjoy today, and hope to enjoy for the future to come.

Following on from the superb dinner on the Saturday night… On the Sunday, following the lectures of the previous day, the delegates were able to take a tour of Stratford to experience exactly what we had been so enlightened about the day before. Taking in the historic lamppost collection as well as other items of interesting street furniture along the historic spine, this tour was a flexible look at the city that had so graciously hosted us and all it has to offer.

So… Wide and varied, interesting and intriguing, all of the lectures gave an insight and education alike into the workings of the streets we tread on a daily basis. Many of us will never look at the humble street furniture in the same way again, and perhaps that's the best thing that has come out of this conference: The ability to look up, to look down, to see… and really observe. But not just to see, to really understand. We have been given an insight into the form, function, and history, and in fact, the desirability of our most often encountered object based heritage. This rare opportunity to look into what we encounter every day was an inspired choice by the organisers. It was an opportunity that I personally was very grateful to be able to experience and take part in, and most sincerely hope to be able to repeat again in the future.

William Hawkes

FEEDBACK

Congratulations on another excellent issue! I was particularly interested in Alan Williams's short article on steelmaking references in Leonardo da Vinci's notebooks. The description and the hearth pictured could certainly refer to either fining or cofusion, but I'd like to point out a third possible interpretation. Leonardo could, perhaps, have witnessed the making of steel from low carbon iron by the processes we current practitioners variously refer to as Aristotle steel, Evenstad, hearth steel, or oroshigane.

Lee Sauder

References:

Sauder, L. 2013. Making steel in the 'Aristotle furnace', in Dungworth, D. and Doonan, R. (eds) *Accidental and Experimental Archaeometallurgy*, 107- 110.

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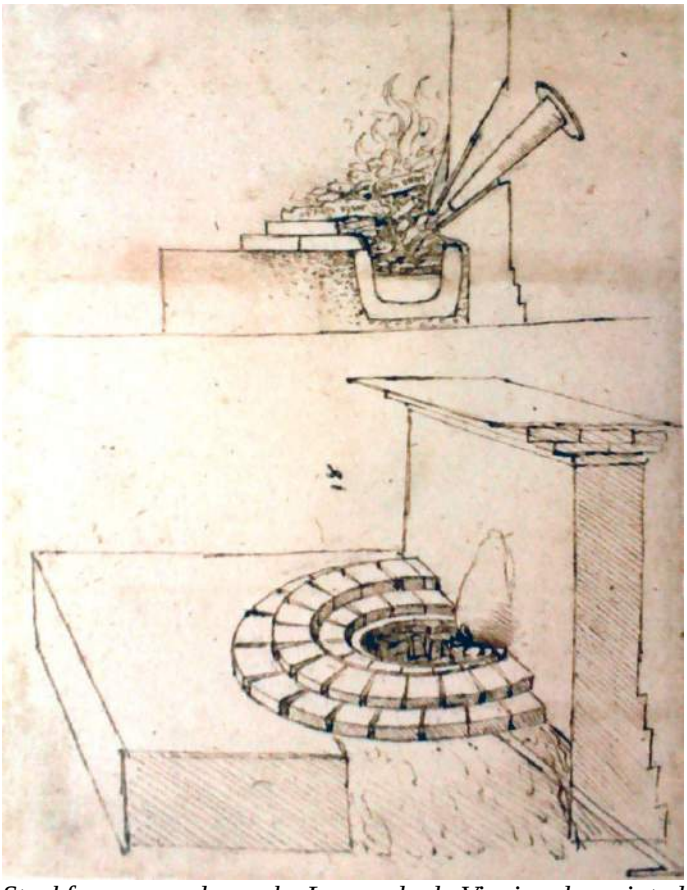
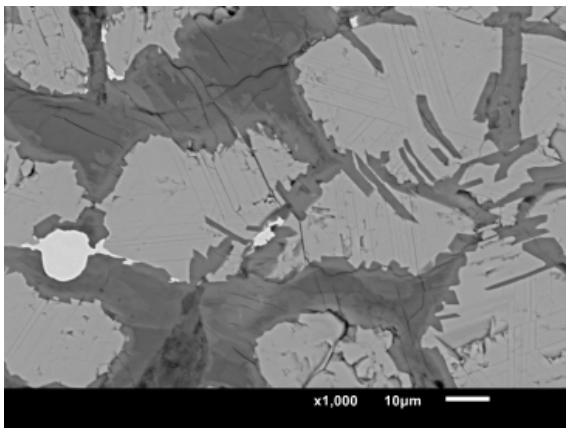


Steel furnace as drawn by Leonardo da Vinci and reprinted from Issue 89 p5, but this time correctly orientated! Thanks to the eagle eyed readers that let us know.

PETER CREW and **JACK PROCTER** write: A remarkable bloom weighing 90kg has been recognised from a water-powered ironworks in southern Cumbria. However, it appears to be entirely of cast-iron and is probably from a failed overblown smelt. The front edge of the bloom is covered in pale-grey slag packed with quartz, probably from a catastrophic failure of the furnace lining. Sub-rectangular depressions on the top surface suggest an attempt to forge the bloom when still hot. Other finds include porous tap slags, large refining slag-cakes, high quality quartz-rich firebricks and a piece of cast-iron pig. It may be some time before a convincing interpretation can be offered!

THILO REHREn writes: Iron slag without silica? Archaeological pre-blast furnace iron slag is always based on iron oxide and silica, right? Kind of bland fare, with a bit of flavour offered by some alumina, titania, manganese oxide etc. Things get much spicier though on an island off the coast of Yemen and Somalia: Socotra. Here, people were smelting iron in a system dominated by iron oxide and calcium oxide – and only a few percent of silica and alumina for added flavour. Kind of similar to what people did in EBA Wales (for copper), actually. And Roman Kythera – another island. Watch this space!



TOM BIRCH writes: I've just completed a two year post-doc in Frankfurt (Goethe University) where we analysed over one hundred antique silver coins from the Western Mediterranean (550-100 BCE). The coins were drilled and analysed for their composition (EPMA, LA-ICP-MS) and provenance (lead-isotopes). It has been enriching and challenging to learn new methods and techniques, and one of the most significant outcomes of the project has been the manufacture of new silver-alloy reference materials (MBH Analytical) for archaeology! I'm an adamant supporter of open-source software, which has formed the backbone of our data processing and analysis, and the 'code' will soon be available for others to share, scrutinise and use.

PETER KInG writes: I am trying to write up for publication detailed historical research on the British charcoal iron industry (from c. 1500) and early coke (up to c.1815). Much of the research was done in the 1990s, but I have been updating it as new resources have become available, such as British Newspaper Archive. Unfortunately I recently suffered a setback through a computer failure, meaning that I am currently working from a back ups made in July. I would be very appreciative if any brief details of unpublished archaeological, historical work or 'grey literature' reports relevant to this project that people know be passed my way. Thanks for any help. Please email: **peterkingiron@blueyonder.co.uk**

MARIAnnE MödLInGER writes: The research project 'Chemical and metallurgical aspects of arsenical bronze: the case of arsenic-loss in prehistoric metal production' funded by Marie Skłodowska-Curie Actions and carried out at the IRAMAT-CRP2 (Bordeaux) investigates out-of-equilibrium Cu-As alloys with 1-10wt.% arsenic. The project will:

- Investigate the construction of out-of-equilibrium phase diagrams of arsenical bronzes;
- Evaluate mechanical properties of arsenical bronzes;
- Quantify and evaluate the loss of arsenic during re-melting and annealing activities.

You can follow the project's activities at: **http://arsenicloss.com**

Forthcoming events

Conference, date and Location	description	Website, Email and Prices
THE SWORd - Form and Thought 19th-20th November 2015 Solingen, Germary	Two day conference to be held at the Deutsches Klingenmuseum discussing the material characteristics, decoration and symbolic value of swords, and its use as a weapon and a cutural object.	swordconference@posteo.de
Celebrating Yorkshire's Industrial Heritage 9th December 2015 Barnsley, UK	A one day workshop celebrating Yorkshire's industrial heritage inclusing discussion on the current issues that the indistrial heritage secotr are facing today.	http://heritagequay.org/events/industrialheritage/
VI national Conference on Archaeometry and 2nd Latin-American meeting of historical technologies 2nd-4th December 2015 Cordoba, Argentina	A conference on Archaeometry will be held in the Universidad Nacional de Río Cuarto, Cordoba, Argentina. It will include sessions on *"Material characterisation"*, *"Preservation and conservation"* and *"Historical technologies"*; presenting studies on mining and metallurgy.	vicongresoarqueometría@gmail.com
Conservation and Repair of Architectural and Structural Metalwork 8th-11th February 2016 Chichester, UK	Course that covers the conservation of structural metalwork, architectural features and statuary, and includes both ferrous and non-ferrous metals, with tuition from leading practitioners on a wide range of repair techniques.	http://nhig.org.uk/events/event/
Roman Archaeology Conference 16th-19th March 2016 Rome, Italy	This three day conference is the premier international conference devoted to Roman archaeology.	http://romansocietyrac.ac.uk
Finds from the Roman north and Beyond 2nd April 2016 York, Uk	Spring meeting focused on various aspects of finds from Roman sites throughout the north of UK, and an organised visit to Segedunum Roman Fort, Baths and Museum.	www.romanfindsgroup.org.uk/meetings
dTRG Conference 6th-11th May 2016 Tavistock, Devon, UK	An international conference entitled *"A Celebration of the Tinworking Landscape of Dartmoor in the European Context – Prehistory to the 20th Century"*	www.dtrg.org.uk
41st International Symposium on Archaeometry 15th-20th May 2015 Kalamata, Greece	The International Symposium on Archaeometry (ISA), is a most welcome forum to present the latest data and updates of the Archaeometry research and archaeological science, covering the full spectrum of topics, materials, techniques, time span and global applications.	http://isa2016.uop.gr/index.html
REHABEnd 24th-27th May 2016 Burgos, Spain	This mayor international conference is oriented to construction and cultural heritage management. Some interesting topics are *"Conservation of industrial heritage"* and *"Restoration of artworks and archaeological materials"*	http://www.rehabend.unican.es/index.html
Iron in Archaeology: Bloomery Smelters in Europe and Beyond 30th May - 2nd June 2017	International conference in honour of Radomír Pleiner in the 50th year of the CPSA	Further details to be announced in the next issue of **The Crucible**