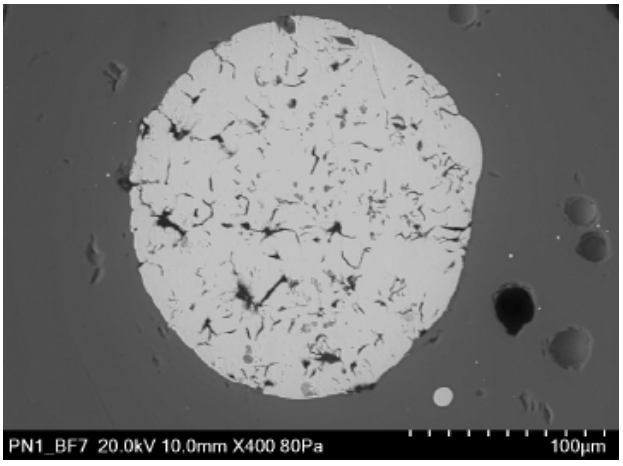
# THE CRUCIBLE

Historical Metallurgy Society News
Issue 101 Summer 2019




## Inside The Crucible



The HISTORICAL METALLURGY Society

## FROM THE CHAIRMAN

A few weeks ago, at the Archaeometallurgy in Europe Conference in the lovely Miskolc, Hungary, I overheard two attendants trying to find the word for 'copper' in Italian. Turns out it is 'rame' from aeramen derived from aes, aeris which can be either copper or bronze and is probably related to aus-, 'to shine'. This is rather unexpected as the word for copper in all other Western European languages, including Basque, is derived from the Latin cyprium aes (copper from Cyprus, Cu) (see below).

'Gold', 'silver' and 'tin' have reached the English language via the Germanic root. 'Gold', perhaps unsurprisingly, shares a root (ghel-) meaning 'to shine' with the word 'yellow (and 'green', it seems). The origins of the words 'silver' and 'tin' are unknown. 'Gold' in the Romanic languages (aurum, Au) probably also derives from aus- ('to shine'). Silver, in the Romanic languages (argentum, Ag), has a root with a similar meaning: arg-, also 'to shine, white'. The Spanish word for silver is an abbreviation of plata d'argento, 'plate of silver'. In Basque, the word for two of these 'shiny metals', copper and gold, are Romanic in origin, while that for silver is Germanic. Tin, then, in the Romanic languages, is related to Stannum (Sn) and possibly has a Gaulish Celtic origin.

'Iron' as well as 'lead', probably reached the English language via the Celtic languages (respectively isarnon and luaide). The root of the word for iron (eis-) means strong, powerful or even holy. The origin of the word 'lead' is unknown as are the roots of the same word in the Romanic languages (plumbum, Pb) and that for iron (ferrum, Fe). It is interesting to see that these last two metals, with probable Celtic origins in the English language, are the only two which have purely native forms in Basque.

The English word 'ore' is related to 'earth' and initially referred to iron-containing ore only, while this time it is the Romanic languages which have probably derived the word for ore ('minera') from the Celtic. In English, of course, this is preserved as 'mine, mining, mineral'. The word for ore in the Scandinavian languages derived from mele-, to crush, grind (see 'mill').

What I liked most is that speakers of nearly every European language (Icelandic and Czech are exceptions) use the same term for the word that binds us all in the Society. And the root of the word 'metal' is Greek 'metallon' (mine or quarry) which is possibly derived from 'metallan', and translates as 'I search after', or 'explore'. What a beautiful word to have in the name of our Society…

*Paul Rondelez*

| | ***Ore*** | ***Metal*** | ***Au*** | ***Ag*** | ***Cu*** | ***Fe*** | ***Pb*** | ***Sn*** |
|---|---|---|---|---|---|---|---|---|
| ***English*** | Ore | Metal | Gold | Silver | Copper | Iron | Lead | Tin |
| ***Dutch*** | Erts | Metaal | Goud | Zilver | Koper | Ijzer | Lood | Tin |
| ***German*** | Erz | Metal | Gold | Silber | Kupfer | Eisen | Blei | Zinn |
| ***Danish*** | Malm | Metal | Guld | Sølv | Kobber | Jern | Bly | Tin |
| ***Swedish*** | Malm | Metall | Guld | Silver | Koppar | Järn | Bly | Tenn |
| ***Basque*** | Mea | Metal | Urre | Zillara | Kobrea | Burdin | Berun | Eztainu |
| ***Gaelic*** | Méine | Miotal | Ór | Airgead | Copar | Iarainn | Luaidhe | Stán |
| ***French*** | Minerai | Metal | Or | Argent | Cuivre | Fer | Plomb | Étain |
| ***Italian*** | Minerale | Metallo | Oro | Argento | Rame | Ferro | Piombo | Stagno |
| ***Spanish*** | Mineral | Metal | Oro | Plata | Cobre | Hierro | Plomo | Estaño |

## 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. Images should be sent as high resolution jpeg or tiff files.

For consistency, we tend to use contributor's names without affiliations and email contacts. Anyone wishing to contact a contributor not known to them is welcome to forward a message in the first instance to the editors who will facilitate the contact.

***The Crucible***
thecrucible@hist-met.org
c/o Lorna Anguilano
Experimental Techniques Centre
Brunel University
Kingston Lane
Uxbridge UB8 3PH
United Kingdom



**FUTURE COVER IMAGES**

*Do you have any intresting pictures that you like to share with the community on the front of* ***The Crucible****?*

*Please send them to us at* **thecrucible@hist-met.org**

**FUTURE INTERVIEWS**

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

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

## Finding the right word

One of the resources being assembled by the Historical Metallurgy Society for its website is a specialised glossary for archaeometallurgy and historical metallurgy. It will encompass traditional usages, craft and trade terms and current metallurgical vocabulary. To keep it manageable it will exclude mining and geological terms except when relevant to metallurgical processes, such as ore types. On the other hand it will bring history into at least the twentieth century with, for example, aluminium alloys. Within these boundaries the scope is enormous, from the blast furnace to the parting of gold, from old names for alloys to terms to describe microstructures. The glossary is initially based on English words with words from other languages included when they are regularly used in English language publications (for example cire perdue)

A lot has already been achieved and members of the Archives and Collections Committee are continuing its development. Now we invite readers of *The Crucible* to contribute by sending in words they think important, useful, or interesting, with definitions if you wish, but we can supply those. For ferrous metallurgy send your suggestions to Brian Gilmour (brian.gilmour@arch.ox.ac.uk) and for non-ferrous and precious metals to Peter Northover (pn253@exeter.ac.uk).

The Archives and Collections Committee (ACC) has openings for two new committee members and the current secretary is stepping down. If you would like to become involved in our activities, or contribute some of your own, please contact Vanessa Cheel ACCchair@hist-met.org. See ***The Crucible*** Issue 100 page 4 for a short outline of ACC.

**FRONT COVER IMAGES:**

**Top:** *Kindibo furnaces (©DSCPM/MCAT), page 7*

**Middle left:** *Cast iron prill in blast furnace slag, page 13*

**Bottom left**: *Iron Smelting in the Chengdu Plain, China, page 14*

# A REVIEW OF THE LIFE OF PROFESSOR ROBERT MADDIN (1918-2019)

*Professor Maddin at the 50th celebration anniversary of the Laboratory for Research on the Structure of Matter*

Professor Robert (Bob) Maddin, a major figure in the landscape of metallurgy and of archaeometallurgy died after a short illness on 3rd March 2019 at the age of 100. The news took a while to circulate: it came to me in a mailing from the Bronze Age Studies Group and had originated from Fulvia lo Schiavo, an old friend of Bob's and much involved in the prehistoric metallurgy of Italy, especially Sardinia. This in itself is a sample of Bob's widespread network and involvement in archaeometallurgy.

This is not the place to make a detailed resumé of Bob's life; in fact he did this himself in 2008 in an interview for the Centre for Oral History of the Science History Institute in the USA which is freely available (go to https://oh.sciencehistory.org/oral-histories/maddin-robert for details on how to obtain the .pdf).

Bob's father had migrated from Vilnius to the USA in 1905 and settled in Hartford, CT, where he established a plumbing business. Bob was born on 20th October 1918 and Hartford was his home until he went to University. He graduated from high school in 1936 and lived in New York for a few months where he took some classes in English literature at Brooklyn College but was not at all sure that was what he wanted to do. He then took an extended gap year, travelling mainly in the USA and Mexico, including working in a copper mine in Arizona. This gave him the spur he needed and in 1940 he enrolled at Purdue University for a degree in metallurgical engineering. By working without a break he completed the course in under three years. He went from university to the war serving for three years in the USAAF, first as a communications officer in Liberia and then in India and China. In 1994 at one of the BUMA meetings, he discovered that he and another major figure in archaeometallurgy, Prof. Ko Tsun, had been in the same town in china at the same time in 1944, but had not encountered each other.

After mustering out of the service Bob started a PhD at Yale with research in the deformation of α brass, completing his degree in 1948, followed by one year's post-doctoral research. Meanwhile he had married Odell Steinberg in 1945. After Yale Bob moved to Johns Hopkins University in Baltimore, MD, as an assistant professor of mechanical engineering which is where the small metallurgy group was located. While at Johns Hopkins Bob received an invitation to exchange with Robert W. Cahn at Birmingham University, Bob's first connection with the UK. While in Birmingham he met Alan Cottrell who was a major scientific influence for him and they did some work together on point defects. Back in the USA Bob was approached to become a Professor at the University of Pennsylvania, an invitation he accepted.

The processes by which he became head of department in Metallurgy and the setting up the Laboratory for Research in the Structure of Matter are rather complicated and are best read in Bob's own words in his Centre for Oral History interview. It is clear that he had a strong drive to a highly interdisciplinary way of working and endeavoured to break down inter-departmental barriers. He was also founding editor of *Materials Science and Engineering*, a journal explicitly intended to connect materials science and engineering. In my own doctoral research in stress corrosion and fracture mechanics it was one of the most useful and intelligent journals.

Around 1972,influenced by the work of Cyril Smith and of Roger Moorey from the Ashmolean Museum he became increasingly interested in the history and archaeology of metallurgy.

When he retired from the University of Pennsylvania he and Odell moved to Mashpee on Cape Cod and he became a Professor of Anthropology at Harvard and an Honorary

Curator at the Peabody Museum. He travelled widely, to Oxford, where he was a Fellow at Wolfson College, to the Middle East and, especially to China. It was a meeting with Prof. Ko in 1979 which lead to the establishment of the successful conference series "The Beginning of the Use of Metals and Alloys", of which the 10th takes place in Bangkok next year. He edited the proceedings of the 2nd meeting and it is a classic among conference proceedings (and is still available). For much of his travelling Odell went too but it is reported that she did draw the line at visiting a site in Egypt when the only transport was a camel.

During this time I and my wife had the good fortune to stay with Bob and Odell at Mashpee and they were generous hosts. Bob had a small metallographic lab in his basement (which is something I have eventually emulated) and it was very satisfying to talk across the whole range of metallurgy. I was also pleased to be able to contribute to the *Festschruft* for his 80th birthday, *Metallurgica Antiqua*.

Eventually Bob and Odell moved to Arlington, VA, because of the warmer weather. Odell died in 2002 but Bob maintained an active interest in archaeometallurgy as evidenced by occasional e-mail enquiries, and having an extensive LinkedIn network.

Bob is survived by two children, four grandchildren and five great-grandchildren. With so many achievements to record it is difficult to give a rounded idea of Bob's nature. Here is a paragraph from a memorial written by one of Bob's daughters in tribute :

"Dad was renowned for his acerbic wit, his worldwide travels, his fabulous memory, and his incisive mind. His daughters, Leslie, born in New Haven in 1946, and Jill, born in Baltimore in 1949, could regale with stories of growing up with Dad: lighting the kitchen table on fire or putting one or the other of us on top of the refrigerator to make a point, testing our scientific capacity by having us guess the contents of our birthday packages, his love for fast sports cars (a decided advantage to his daughters who were delighted to drive his cars when Dad was traveling, which was often), waking us up early on weekend mornings with his blasting of classical music or to play tennis with him, or our many travels as a family across the United States and in Europe. He was one of the few metallurgists, outside the government, to be chosen to receive samples of the "moon rocks" to study in his laboratory at Penn."

*Peter Northover*

## Joan Day FSA. 1928 - 2019

It is with sadness that I have to report the death of Joan Day FSA on 29 April 2019 at the age of 91. Joan was a tour de force in the field of Industrial Archaeology whose research was linked with such people as Sir Neil Cossons, the former director of the Science Museum and chairman of English Heritage, Professor Angus Buchannan, the Emeritus Professor of the History of Technology at Bath University and Professor R.F. Tylecote. Professor of Archaeometallurgy at University College London. Although having no technical or academic training, Joan's work was of the highest order and very well respected in her field. Her most lasting work is her book, 'Bristol Brass – The History of the Industry', published in 1973, which remains the definitive work on the subject. As a consequence of this work, Joan was elected as a Fellow of the Society of Antiquities in 1975. Joan also worked closely with Professor Tylecote, co-editing 'The Industrial Revolution in Metals' published in 1991, with Joan overseeing the project to completion after the death of Professor Tylecote in 1990.

Joan published a number of papers on metallurgy in general and on copper, zinc and brass in particular, publishing papers in the transactions and journals of the Newcomen Society, the Association for Industrial Archaeology, the Historical Metallurgical Society and the Bristol Industrial Archaeological Society. Joan went on to become a Life Member of the Newcomen Society and Historical Metallurgical Society. Joan also made a significant contribution to the Routledge 'Biographical Dictionary of Technology' published in 1992; her contribution comprising 11 biographies, and to the Oxford Dictionary of National Biography, published in 2004. Joan, and her late husband Roy, were most active in the industrial archaeology of the Bath and Bristol Region around their home in Keynsham.

*Joan (centre) with HMS visiting the SS Great Britain in 2012*

Joan was a founder member of the Bristol Industrial Archaeological Society, founded in 1967, and was a lecturer in Industrial Archaeology at the University of Bristol for thirty-eight years from 1970 to 2008.

Joan first attended one of the courses in 1964 which inspired her to conduct her own research. Joan went on to run the course from 1970 with her husband Roy and only retired in 2008 at the age of 80. Her speaking extended to the delivery of lectures in Belgium and Germany and she also contributed to a conference at the British Museum with a paper being published in the museum's Occasional Paper Number 50 '2000 Years of Zinc and Brass' edited by Dr Paul T Craddock. In the field of practical industrial archaeology, Joan's passion was Saltford Brass Mill. Joan was a founder member of the Saltford Brass Furnace Project in 1981 and was active in recording the evidence of what was then a decaying building. She was subsequently involved in the campaign to prevent the site's redevelopment and its eventual restoration. The building was restored by English Heritage in 1995 and thereafter Joan founded the Saltford Brass Mill Project to work with the local council to: conserve the building; interpret the industry for the public; and open the site to visitors.

The Project continues to perform the work she started. Joan last visited the site in late 2018 and remained President of the Project until her death. But Joan's achievements were not confined to Industrial Archaeology. In her youth, she was an active cyclist and for a short time held the Western Counties Road Records Association cycling record for 'Land's End to Bristol'; in 1954 she knocked 1 hr 6 mins of the record, completing the 195 miles in 10 hrs 59 mins. Joan also held a glider pilot's licence and led pony treks in the Brecon Beacons with Roy. Joan was one of a kind.

*Tony Coverdale* *Chair,*
*Saltford Brass Mill Project*

## Joan Day: Zinc and Brass

Bristol has many sites of great interest to the industrial archaeologists. That they are still there and are widely known and appreciated is in no small part due to the city's own industrial archaeologists of whom the doyen was Joan Day.

Joan and I had a shared interest in zinc and brass and we first met over 40 years ago at meetings of the Historical Metallurgy Society. I found Joan's presentations on the Bristol brass industry fascinating. At that time Joan was already engaged with the early brassworks at Saltford, near Bristol, especially salvaging the annealing furnace which had latterly been used as a wine store. Joan invited me and my team of diggers to come and excavate inside, preparatory to preservation.

Joan was also interested in the 18th century remains of William Champion's zinc and brassworks at Warmsley. Thus she enthusiastically followed our work excavating the medieval zinc distillation furnaces at Zawar in India. The process of downward distillation developed there was in principle that adopted by Champion, and Joan suggested that the Bristol process was based on the Indian precursor.

Joan, together with husband Roy, helped to organise a joint British Museum – Historical Metallurgy Society conference in Bristol high lighting some of the discoveries in India and Bristol, but covering the whole technical history of zinc and brass from antiquity to the present (at that time zinc was still being produced by the Imperial Process at nearby Avonmouth). The meeting was a great success with an international audience and the 1998 publication 2,000 Years of Zinc and Brass remains the most comprehensive and reliable source on the subject. As an analytical chemist at the British Museum

I was very interested in the composition of early brasses as an indication of the various processes by which they could have made. In this Joan was very helpful in locating a whole range of brass artefacts that were likely to have been made in the Bristol area, including brass pans, possibly from Saltford, and we published a number of papers on this subject together.

Joan's work was internationally recognised, which together with colleagues from other European countries established the links that Bristol had with continental producers in the 18th century. I was able to join with Joan and Roy on some of their trips across Europe to other big producers such as the Rammelsberg mines at Goslar that they had been invited to visit, as well as some major early castings (Fig.).

When Joan and Roy attended conferences in London they frequently stayed with us in Rochester, and were naturally keen to see our local industrial archaeology, Roy being especially interested in the remains of the 19th century Medway cement industry.

These, and other trips undertaken with the Days, were always so enjoyable because of their unquenchable interest in, and enormous knowledge of, all aspects of Industrial archaeology.

*Paul Craddock*

*Joan Day critically examining a bell parked outside St. Reinold's church, Dortmund on our 1991 trip across Europe.*

*Joan with Tom Shellard in the late 1960s. Tom worked in the Brass Mill before WWI and his recollections featured in Joan's research into the mill*

## ANNOUNCEMENT - COLIN PHILLIPS

HMS is sorry to hear that Dr Colin Phillips sadly passed away on 4th July this year. Colin was a history lecturer at Manchester University and a long-standing member of HMS. His research interests included the late bloomery industry in Cumbria. He and his wife, Jan, joined HMS in 1977 and served on the Council for many years. Colin was Chairman from 1989-91, President between 1998 and 2000, and remained an ordinary Council member from 2008-14. Colin also served on numerous of the Society's committees, organised HMS meetings in Leeds and Manchester, and was a member of the Editorial Board from its inception in 2016. Colin's friendship and advice will be sorely missed by all within our community. We will feature a longer appreciation of Colin's life in our next issue.

*Editors*

## BURKINA FASO: A NEW WORLD HERITAGE LISTING FOR

*Tiwêga furnace, near Kaya (whc.unesco.org, foto by Moriset © DSCPM/MCAT)*

On July 5th this year the World Heritage Committee inscribed five new sites on UNESCO's World Heritage list including **Ancient Ferrous Metallurgy sites of Burkina Faso**. The site is made up of five elements at different locations (Tiwêga, Yamané, Kindibo, Békuy, Douroula) and includes fifteen furnaces still standing, several furnaces bases, assemblages of slag and traces of dwellings and settlements. At Douroula a furnace base dating to the 8th century BCE is the oldest evidence from Burkina Faso and the area has fields of slag, lateritic ore extraction pits alongside village settlements. At Tiwêga there are three natural draft furnaces still standing to 2.6m tall and with tuyere and slag fragments built into their structures. At Yamané there are a further two standing furnaces with numerous furnace bases and slag mounds dating to the 13th and 14th centuries AD. Further standing furnaces at Kindibo date to the 10th and 11th centuries. The evidence at Békuy differs in that the furnaces are constructed partially underground and are built of slag with a clay binding. Together the sites illustrate an intensification of iron production during the second millennium as powerful empires emerged in Ghana and Mali. Iron is no longer smelted in Burkina Faso but traditions of iron-working continue with blacksmith communities in all of the areas of the new World Heritage site. We hope to feature a longer piece on this exciting region in a future issue of ***The Crucible***. It is good to see ancient and pre-industrial metallurgy recognised on the world stage.

*Editors*

## AN UNUSUAL IRON FIND FROM SNETTISHAM

The site at Ken Hill, Snettisham is justly famous for the finds of Iron Age gold torcs (Farley et al. forthcoming). Such quantities of gold are highly unusual, but the site has also produced something apparently even more exceptional, Late Roman ferritic iron that had once been molten.

The presence of iron production in the form of slag scatters was known and was investigated in 1991 (Stead 2014).To the north of the area stripped in 1991 iron slag was scattered over part of the field. It had been noted in 1990, and indeed had been plotted in 1953 on maps in Norwich Castle Museum. But in 1991 it was obvious that clandestine metal detectorists had dug into it. Their back-filled hole was investigated and a mass of iron slag located, the occasional sugar-beet indicating that the disturbance was very recent. A trench excavated in 1991 showed that the slag was the infilling of a Roman ditch, a discovery that prompted a re-examination of air photographs where its line was now quite obvious. Previously it had been confused with a relatively modern field boundary. Air photographs and a geophysical survey defined a large polygonal enclosure of approximately eight hectares. The trench excavated in 1991 revealed a ditch with a steep-sided V-shaped profile and a narrow flat channel at the bottom. It was 1.8m deep below the present ground level and 2.8m wide at the base of the plough-soil. The upper part was filled with a compact mass of slag and furnace debris that seemed to have been dumped from the south side. The deposition of the slag was dated by Roman pottery including a sherd of Oxford ware no earlier than AD 375.

*Fig. 1. Metallographic section showing the dendrites of ferritic iron with slag around the edges*

The metal detectorists really had found metal in the slag heaps, albeit fragments of very slaggy iron. Fortunately these fragments were retained and it was initially assumed that they were fragments of a failed bloom, possibly set aside for resmelting. Metallographic examination of one of the pieces revealed a very different origin, requiring in turn a totally different interpretation.

*Examination of the mounted sample (BM 986, Project file 6483)*

The sample was mounted in cold setting epoxy resin, the surface was ground on silicon carbide paper with water and then diamond pastes with a proprietary lubricant were used to provide a flat surface for optical examination (Figure 1). This revealed a central zone mainly consisting of dendrites of ferrite (α-iron) with interdendritic areas of non-aligned mixed sized graphite flakes. The outer zone consisted of ferritic iron with a slag/iron oxide skin. In the central zone, some pinkish inclusions (usually either cubic or triangular) were observed within the ferrite (Figure 2). Etching with nital (2% concentrated nitric acid in methanol) also revealed some small areas of iron phosphide (steadite) in the central zone. Hardness testing gave a value of 304 HV0.1 in the ferritic areas, which reflects the hardening effect of phosphorus as ferritic iron would normally have a hardness value of c. 200 HV0.1. The presence of phosphorous in the iron could reduce the melting point to below 12000C.

Further examination and analysis were carried out using a S – 3700N Hitachi variable pressure scanning electron microscope at 20kV, 10mm, and 40Pa pressure and current 75mA. The results are shown in the table and the areas analysed shown in figure 3. The analysis of the central area shows that the iron contains traces of nickel, silicon and manganese. The presence of phosphorus (as steadite, a Fe-Fe3P eutectic) was confirmed and the small pink-coloured inclusions were identified as titanium nitride. This indicated that the ore contained some phosphorus and a titanium bearing mineral (probably titanomagnetite).

It is likely that the formation of titanium nitride inclusions took place in the region just above the tuyeres as this reaction only occurs at temperatures above 1100°C (Wen Yu et al. 2017, fig.2).

The material excavated from the ditch, trench ST35, comprised mainly fragments of slag together with some heavily slagged and vitrified rough clay material and a selection was made, concentrating on the slagged clay material as being more likely to be informative of the processes involved.

Fragments of slag and partially slagged and vitrified clay fragments are not uncommon finds on Iron Age and later sites, and are usually to be interpreted as the remains of blacksmithing. Here the considerable quantities of slag are suggestive of smelting.

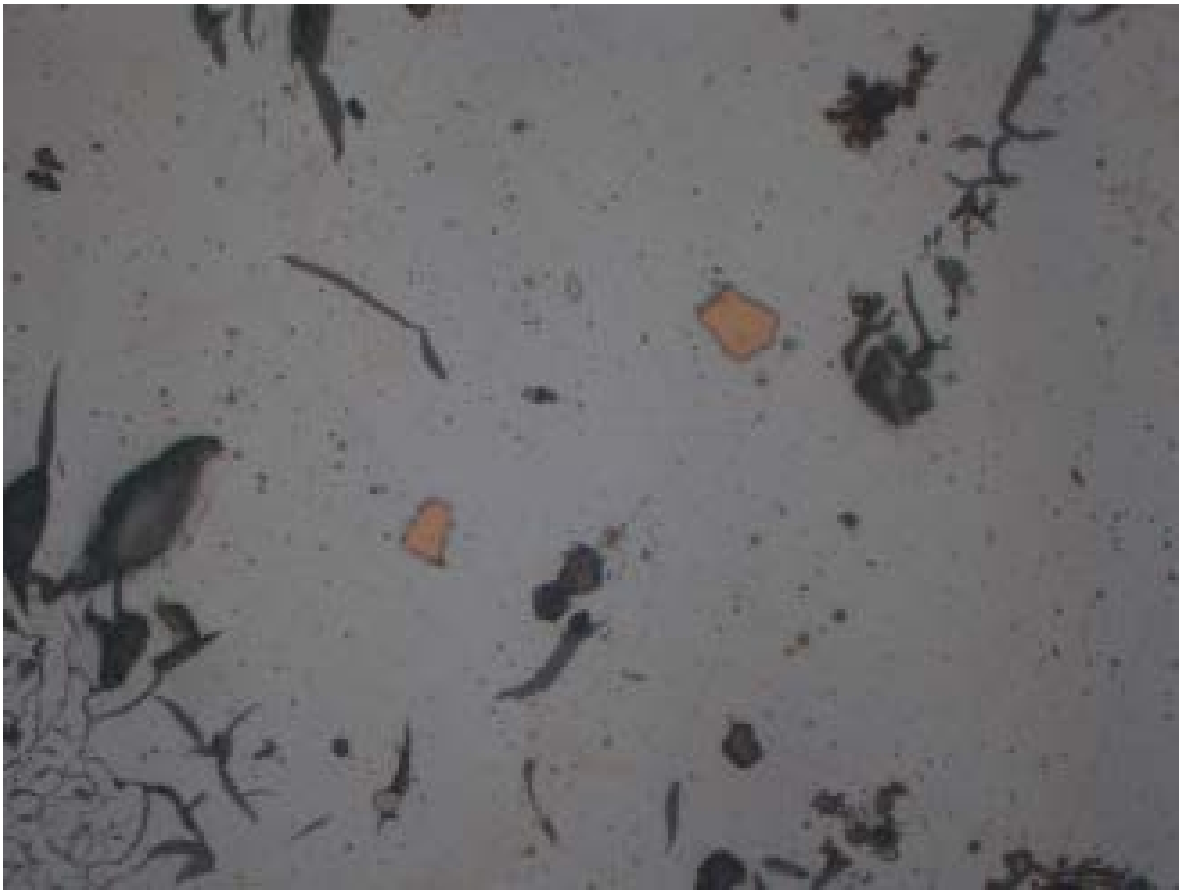


*Fig. 2. Etched metallographic section showing the square inclusion, identified as being of titanium nitride*

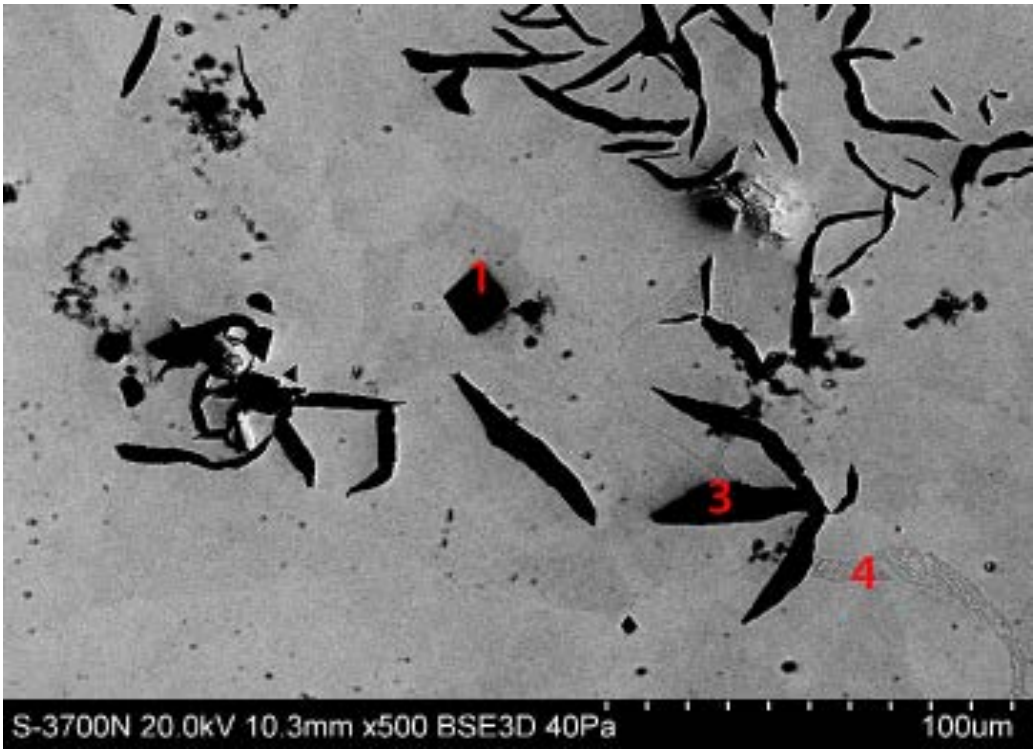



*Fig. 3. SEM photomicrograph of the metallographic section showing the specific areas analysed.*

This is confirmed by the presence of tap slag as only the smelting process generated sufficient quantities of slag to require periodic draining. The slagged and partially vitrified clay pieces had the shape and appearance typical of hearth bottoms and are likely to be associated with the bloom smithing operations, although some blacksmithing operations cannot be excluded.

As already noted the low melting point was primarily due to the phosphorous content which would have been a component of the ore. Iron smelting slags with high phosphorous contents have been noted at other Roman iron smelting sites in Norfolk, including Snettisham (Chirikure and Painter 2002), and Tylecote (1968) found some ferritic iron with a high phosphorous content and nitrides amongst the smelting debris at the Anglo-Saxon iron smelting site at West Runton. At these sites the ore was identified as being composed of iron hydroxides, goethite and lepidocrocite, together with some iron oxide, hematite minerals in a sandy matrice. This is the highly ferruginous Norfolk carstone, usually thought of as a decorative building stone, but which was certainly quarried for iron production in Roman times (Tylecote 1967). The few pieces of slag collected from the ditch excavation were tested with a magnet but none contained metallic iron. This partly reflects the differing collecting strategies, the metal detectorists were seeking metal, whereas the archaeologists were collecting process evidence, mainly the slagged and vitrified clay together with only a small selection of slag pieces that would have formed the bulk of the deposit.

Strictly speaking the detectorist's pieces were unstratified however it is likely that they belong to the same operations as the stratified material excavated from the ditch.

As already noted the phosphoric iron fragments were found by the detectorists in amongst the slag, thus associated with the waste rather than the product, even though that product should have been iron. How is this to be interpreted?

In the solid-state bloomer iron smelting process the iron ore was reduced to metal in the tuyere zone of the furnace. The reduction was direct and did not go through a liquid phase. Instead the forming metal particles coalesce in the protective environment of the forming slag to form the solid bloom, still in the immediate vicinity of the tuyere. The slag being liquid drained to the bottom of the furnace. Due to the high temperatures and phosphorous content, some at least of the forming metal was molten and thus would drain together with the slag phase to base of the furnace, well removed from the bloom. It is very likely that the smelters discarded this iron together with the rest of the slag, not aware that they had unwittingly created liquid iron.

Artefacts of phosphoric iron were not uncommon in the Iron Age, although always made from solid state bloomery iron (Ehrenreich 1985).

It was only due to the unusual circumstances of their discovery and subsequent excavation that these fragments of iron were kept as part of the archive, followed by their scientific examination. We wonder how common such instances of the production of ferritic iron as a molten phase in the standard bloomer process may have been.

*Janet Lang, Paul Craddock, Julia Farley, Laura Perucchetti and Ian Stead*

| *Sample area* | *Element wt %* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *C* | *N* | *Si* | *P* | *Ti* | *Cr* | *Mn* | *Fe* | *Co* | *Ni* | *Cu* | *As* |
| square inclusion (1) | 5.26 | 20.01 | 0.25 | 0 | 55.86 | 0.18 | 0.22 | 18.22 | 0 | 0 | 0 | 0 |
| graphite flake (3) | 73.39 | 9.45 | 0.16 | 0.08 | 0 | 0 | 0.15 | 16.58 | 0 | 0 | 0 | 0 |
| steadite (4) | 8.96 | 0.97 | 0 | 7.81 | 0 | 0 | 0.88 | 80.82 | 0 | 0.4 | 0 | 0 |
| iron (away from main inclusions) | 7.4 | 0 | 1.65 | 0 | 0 | 0 | 0.47 | 89.83 | 0 | 0.64 | 0 | 0 |

*Table 1. SEM XRF microprobe analyses of specific areas on the section (Nos. 1-4 shown on Fig 3) and of the overall iron matrix, confirming that the square inclusion (1) is titanium nitride and (4) is of steadite.*

*References*

Chirikure, S. and Paynter, S. 2002 English Heritage report 50/2002 A metallurgical investigation of metalworking remains from Snettisham, Norfolk: ISSN 1473-9224.

Craddock, P.T. and Lang, J. forthcoming The Debris of iron production, Appendix in Joy and Farley eds. forthcoming

Ehrenreich, R.M. 1985 *Trade, Technology and the Ironworking Community in the Iron Age of Southern Britain*, BAR British Series 144, Oxford.

Joy, J. and Farley, F. forthcoming *The Snettisham Treasure* British Museum Research Publication 225.

Stead, I. M. 2014 *Snettisham Swansong, in Celtic Art in Europe*, eds C. Gosden, S. Crawford and K. Ulmschneider. Oxbow Books, Oxford. 297-303

Tylecote, R. F. 1967 The bloomery site at West Runton, *Norfolk Archaeology* 34 2. pp. 187-214.

Tylecote, R. F. 1968 The Phosphorous content of iron from the Bloomery Site at West Runton, Norfolk Archaeology 34 3. pp. 330-1.

Wen Yu, Xiaojin Wen, Jiangan Chen, Jingzhong Kuang, Qiongyao Tang, Yuechao Tian, Jiali Fu, Weiqin Huang and Tingsheng Qiu , 2017. Preparation of Direct Reduced Iron and Titanium Nitride from Panzhihua Titanomagnetite Concentrate through Carbothermic Reduction-Magnetic Separation. *Minerals* 2017, 7, 220; doi:10.3390/min7110220

# FORTHCOMING EVENTS

| Conference, date and locations | Desciption | websites, emails and prices |
|---|---|---|
| 04/08/2019-09/08/2019<br>Sedgeford, Norfolk | Archaeometallurgy Experimental Course | https://www.sharp.org.uk/product-page/copy-of-copy-of-copy-of-copy-of-basic-excavation-amp-amp-amp-amp-recording-tec |
| 19/08/2019-25/08/2019<br>Co. Galway | Woodford furnace festival | https://www.furnacefestival.org/?fbclid=IwAR2g5Q_dx0P- |
| 04/09/2019-07/09/2019<br>Bern, Switzerland | EAA conference | https://www.e-a-a.org/EAA2019/Home/EAA2019/Home.aspx?hkey=a234d676-083a-4adf-83f8-7929cbf999fa |
| 12/09/2019-13/09/2019<br>Paris, France | Craftsmen and metalworking in medieval cities: 35 years later | |
| 26/10/2019<br>Edinburgh, UK | Crafting Identities: Prehistoric Society conference | mailto:laterprehistoricfindsgroup@gmail.com |
| 16/12/2019-18/12/2019<br>UCL | Micro-worlds, materiality and human behaviour:<br>Magnifying material science in explanations of technology Theoretical Archaeology Group (TAG) Conference Session 13 | https://www.ucl.ac.uk/archaeology/news-events/conferences/tag-2019 |
| 29/06/2021-2/07/2021<br>Fribourg, Switzerland | Iron in Archaeology Conference | |

# IRON SMELTING IN THE CHENGDU PLAIN, SICHUAN PROVINCE, CHINA


*Fig. 1 The experimental smelting team with burning furnace behind*

Modern Qionglai, in Sichuan province, SW China, was known as Linqiong during the Qin and Han dynasties (221BC-220AD) and was one of the most important prefectures of Han because of its abundance of iron resource. It is recorded in Shiji ('Records of the historian', by Sima Qian, who died about 90BC), that Zhuo Wangsun's family and Cheng Zheng's family, who were both experts in iron smelting, immigrated to the Linqiong prefecture in the Qin Dynasty. This is the first written evidence that iron smelting technology was brought to southwest China from elsewhere.

Over the past twelve years, our research team carried out a series of archaeological surveys and trial excavations of iron smelting related sites in the Chengdu Plain region of Sichuan. We have identified and recorded a total of 74 sites, and three of these are dated to the Han dynasty. At one of the three sites, Gushishan, we discovered a well-preserved blast furnace. Based on our investigations at Gushishan, the Archaeology Department of Sichuan University led a cast iron smelting experiment in the December of 2018 at the Archaeological Park of the Qiong Kiln, Qionglai, Sichuan. More than 50 staff and students from China and from our collaborators at Ehime University, Japan, participated in the full process (Fig. 1). Clay was dug from a deposit near the Gushishan site and transported to the park to build the furnace. The iron ore (magnetite, 50-60%) was transported from Xichang, southwest of Sichuan. The ore was roasted and crushed into less than 1cm pieces before being charged into the furnace. The charcoal was made from fagus (beech) by a local family workshop. The charcoal was also crushed into small pieces about 3-5cm.

Smelting started at 5am and lasted for eleven and a half hours. The first charge of iron ore was at 10:35am, and from then the charging frequency was about every 8 mins. The first tapping was about half an hour after the first charging of ore, and the tapping frequency was about every 20-30 mins (Fig. 2). At the end of the smelt a total of 57.5kg iron ore, 25.7kg iron sand, 8.7kg limestone (flux), and 303.5kg charcoal were charged into the furnace.

The furnace was allowed to cool naturally after the smelting and was cut in half when it was completely cool. The metal product from the furnace weighed 27.3kg. Further work is now needed to calculate how much cast iron was produced from the smelt and to analyse the furnace products. However, the experiment represents the first Qiongtie (iron of Qiong) produced after 2,000 years, since the stories of the famous Zhuo and Chen's families were recorded in Shiji.

There will be a further smelting experiment this year. It will be held again at the Archaeological Park of the Qiong Kiln from 15th to 17th Nov, 2019. The plan this year is to build a bigger furnace than last year for the main smelting, and also a smaller furnace is going to be built to try to decarburize cast iron objects in solid state. Any members of HMS or students who would like to observe or participate in the experiments would be very welcome, and it may be possible to offer food and accommodation during the event. Please contact Yuniu Li (through the Crucible editors or xiang0723@hotmail.com).

*Yuniu Li*

*Sichuan University*

*Figs 2 and 3 Prof Yasuyuki Murakami (Ehime University) and Yuniu Li (Sichuan University) oversee furnace operations*

# VANESSA CHEEL

My background is Materials Characterisation, predominantly metals and microscopy. I started in Engineering, continued in Engineering Materials (Warwick University) then moved to Oxford's Dept of Metallurgy & Science of Materials (thankfully now called the Materials Dept) for a D.Phil on the diffraction properties of copper (with light, x-rays, electrons, neutrons and gamma rays). There were a couple of spells in industrial research (first electroplating silver onto heat-shrink polymers, later in nanotechnology), and an assortment of Materials research fellowships. Peter Northover has been teaching me archaeometallurgy since at least the 1980s. After all, it is the characterisation of archaeological materials.

Brian Gilmour persuaded me to volunteer to succeed Aurelie Cuenod looking after the Tylecote collection at the RLAHA as I have the metallurgy experience to compliment her archaeology. Some of the collection information is in poor condition or missing and I have the technical skills to repeat/replace/supplement the data. Although based in the Materials Dept at Oxford, I am an informal visiting scientist in Archaeology as that is where the Tylecote collection is housed and I work on it one day a week.

I have always run several career strands concurrently [Jill of all trades, mistress of some] and the second is education at all levels from primary to graduate. Promoting Science & Engineering, especially attracting girls into the field, is a regular occupation. I've been a teaching head of sciences & maths at several secondary schools, finally resigning from a specialist school for autistic pupils in August 2017. I still have half a dozen international A-level science students. I love sharing science and seeing people succeed.

Another occupation was a part-time role in Oxford University's Maths, Physical and Life Sciences Division (MPLS) as Access & Outreach officer running events for schools & the general public. I am a member of the Materials Dept outreach team (an independent subset of MPLS) which involves a range of undertakings including presentations and workshops.

Much fun and experience have been gained from involvement in the running of various small-scale activities: youth groups, cycling, treasurer for the school shop. Our back garden was home to several experimental furnace designs, lead smelting, tin and copper extraction and bronze production as our children & their friends explored basic metallurgy.


When it came to iron, we had to resort to chemistry and the thermite reaction to get high enough temperatures. Holidays were/are geology field trips. Gradually home is developing into a laboratory and I so wish I could afford to run an SEM in the basement.

Eight years of responsibility for planning, listed buildings, green belt and arboriculture for the local Parish Council have been followed by occasional co-option on hydro-geological matters as that is a particular interest.

The cross-fertilisation and dissemination of ideas is a central tenet so the HMS collections being made widely available as a research and teaching resource for the layman as well as the specialist is very important to me. Eventually the HMS will have a number of collections beyond the current holding and knowledge of more: it is my aim to maximise their availability in readily accessible form for inquirers from whatever background. Needless to say, that will continue beyond tenure of an HMS Council post so carries with it the necessity to have an easily used format. The dream is to see the HMS be the 'go-to' place for all things historical metallurgical. It is so much more than a one person task and I'm looking forward to it being a long term project.

# POWER & CONTROL OVER METALLURGY

On Saturday 8th June HMS held their Annual General Meeting and conference on the theme of Power & Control over Metallurgy Production. We were treated to a range of talks journeying from 1150 BC to the 9th Century AD across Britain and Ireland, Scandinavia, Germany, Caucasus and China. All speakers talked about alternative ways of interpreting the archaeological evidence and exploring what control means for that period. A general pattern emerged out of increased control over time and closer association with powerful individuals or groups, but the detailed evidence from each place showed oscillation and variation and the effects of research paradigms on how we interpret the evidence.

The day commenced with yours truly questioning perceptions of power in relation to Late Bronze Age metal hoards and production evidence. Sticking with the Bronze Age, Nathaniel Erb-Satullo followed with description and analysis of the evidence for smelting, mining and casting copper and alloys in the South Caucasus. Nathaniel has mapped 50 individual Bronze Age smelting sites in the region, only one portion of the black sea coast smelting activity. Here is evidence for potential exploitation of different points in an ore body with mining activity as dispersed as the smelting. The intensity of activity and level of control varying between different regions.

Moving on to iron, Yaxiong Liu explained the detailed evidence from the Qin empire in the 4th to 3rd centuries BC and the metallographic evidence revealed in the objects, all cast iron, 75% grey cast iron. Yaxiong sees the Qin state holding primary control on production but private production also took place. In the 4th century BC bronze weapons at this time appear to be solely ceremonial and iron took over for functional weapons in the Qin army and for agricultural tools (therefore war having an influence on the economy of the people).

The afternoon session commenced with Pieta Greaves taking us through the fascinating reconstruction of the Staffordshire hoard helmet (10 years since the hoard was found). None of the iron elements were included in the hoard so research on other helmets was needed to reconstruct the structure of the helmet. Many materials, makers and skills were involved in making the original and the reconstruction helmet: iron, gold, wax, hoof glue, madder dye, leather, horse hair, silversmiths, leatherworkers, stitching etc. Keeping with the early medieval period, Eleanor Blakelock presented the results

*Fig.1. Audience at the AGM conference*

*Fig.2. Discussion during coffee break at AGM conference*

from Rendlesham with evidence pointing to a metal workshop; making valuable comparisons between different analytical techniques for different metals XRF, SEM, copper alloy and gold. Atypical for the Anglo-Saxon period are the large quantity of sprues from the site (the metal that filled the casting gates of the moulds).

Ellie has found it is possible to identify failed castings from the sprues and a large number of those found at Rendlesham are from failures. Even when the moulds and crucibles are missing, the casting waste and objects can give a great deal of evidence about the processes of production, recycling activity and manipulation of objects.

After many beautiful images of gold, Ole Nordland brought iron back to the fore with an entertaining presentation of the evidence from Trøndelag, Norway c.350 BC - AD 500 (200 registered sites) compared to the Viking Period AD 700 -1200 (<100 sites). The latter period consisting of single furnaces with small clay shafts, charcoal fuel, tapped slag and much smaller scale production than the earlier period. The earlier smelting sites each required a team of 16-20 people to operate, producing slag heaps many cubic metres in size. All this early activity in Trøndelag was focused around good quality agricultural land where hillforts also appear. In the Viking Age there were no hillforts and previous forts only exist as ruins.

Following refreshments, Justine Bayley led the last session of the day beginning in the medieval period where the difficulty of equating archaeological evidence with the written record creates further challenges for metallurgists. At the same time both can expand the record: metallography shows the technology of wire drawing and manuscript images showing the process in action, metal wire for musical instruments. By the late medieval period there is evidence, textual and archaeological, for a good deal of control over metalworking but there is still evidence in medieval London for a 'good bit of anarchy too'.

As the sun filled the room during the late afternoon, the Chair of the HMS, Paul Rondelez, put the history into our historical metallurgy meeting with a presentation on the late 16th to 18th century metalworking in Ireland. An intriguing history of iron production and furnace works; some only planned, others that actually happened; greatly affected by the political processes of the time. Of particular note is the influence of the arrival of newspapers on the developments in furnace technology and iron industry in 1730s in Ireland.

For the final talk of the day, Richard Williams led us expertly through late 18th century Prussian Silesian illustrations and the English influence on the methodology as exemplified in an 1803 technical drawing presented in English feet. John Baildon, a Scot trained in engineering drawing, was 'poached' by Friedrich Van Reven as a 20 year old to create a coke fired furnace. He became the maker of the first cast iron bridge in Silesia. While working for the Prussian state he was also encouraged to participate in private industry.

Thank you to all the speakers, audience and HMS council for an engaging and welcoming event. Thanks to Reading Town Hall for allowing us to use their attractive venue and for the delicious lunch. Extra special thanks to Ellie Blakelock for organising another successful and enjoyable HMS event.

*Sophia Adams*

# WEALDEN IRON - Bulletin of the Wealden Iron Research Group

## A summary of Volume 39, 2nd series, 2019

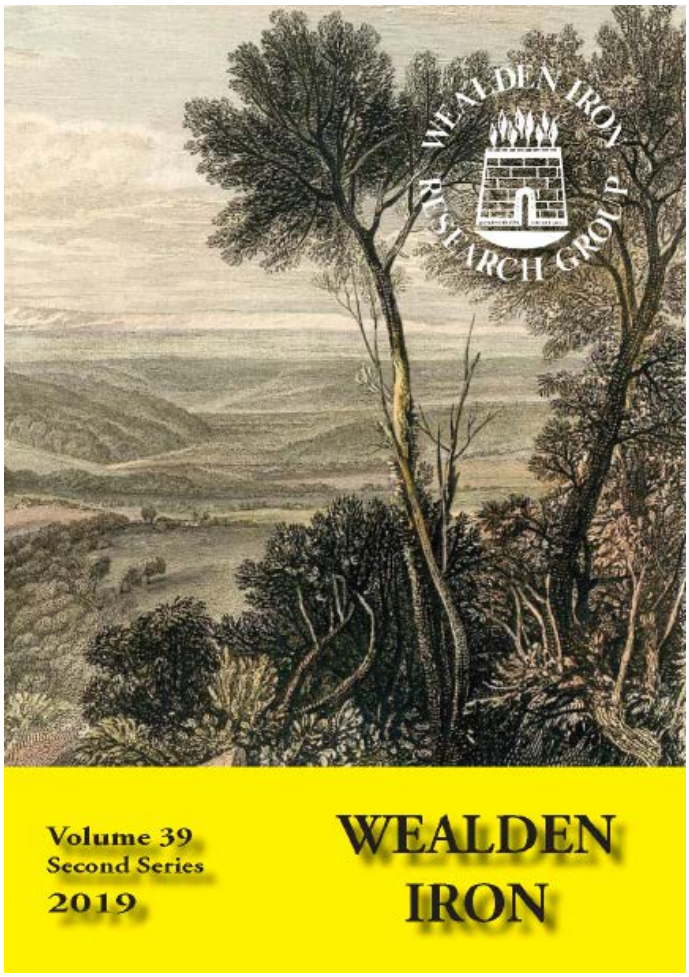
For the second year running the Group has lost one of its founding members - Henry Cleere - prompting an account of his contribution to Wealden iron studies in the opening pages of this year's issue. It is no hyperbole to describe him as the Group's most eminent member.

The usual collection of field notes includes the discovery of two bloomery sites, one only 500m from the Iron Age hill forts at Castle Hill, near Tonbridge in Kent, and the other near Heathfield in East Sussex in an area already much explored. No dating has been attached to either site although a bloomery previously discovered near the latter and dated to the Roman period may suggest other activity in that area at the same time. Nearly 700 bloomery sites have been recorded in the Weald. Further discoveries of a range of Romano-British pottery wares in the curtilage of a bungalow at North Chailey in East Sussex, close to a known bloomery site, add weight to the possibility of a small ridge-top settlement with a possible iron-making function.

The archive of the late Surrey archaeologist George Inwood has recently come to light and the contexts of the finds he deposited in Godalming Museum have been enhanced accordingly. Among them is material excavated on the Thorncombe estate at Busbridge which included pottery, slag and furnace lining from a Romano-British bloomery, details of which had been scant hitherto. An article describes these remains and their dating evidence.

Ernest Straker noted a blast furnace site near the hamlet of Bough Beech in Kent which was later identified by H. R. Schubert as Chiddingstone Furnace, owned by Thomas Willoughby and operated by the royal gunfounder, Thomas Browne, in the 1590s. However, the location Straker recorded was misleading and a pond bay with associated slag was recorded at a different site by the Ordnance Survey in the 1960s. Both sites were included in their gazetteer by Cleere and Crossley. An article sets out the argument for Straker's location to be disregarded.

Wealden churches have an unrivalled number of cast-iron memorial slabs dating from the region's heyday as an iron producer. An unusual find is an apparent duplicate of a slab in Wadhurst church in East Sussex dating from 1688. An article describes this casting and the case for it being a reject because of an error in its inscription.




Two articles focus on the ironworks at Ashburnham in East Sussex, the last to close in the Weald. In the first, a proposed lease in the mid-1730s mentioned in the correspondence of John Collier, of Hastings, is discussed. Collier, a solicitor, had extensive dealings with landowners, and his letters were recently edited by Richard Saville for a volume of the Sussex Record Society. The second article draws upon a letter written in a Hastings newspaper in 1864 by a Samuel Bartlett who, as an 11-year-old, was one of two boys present when Ashburnham Furnace was blown out for the last time in 1813. His letter describes various details of that occasion as well as incidental information about the workings of the furnace and its associated forge. Such first-hand accounts are rare.

*Jeremy Hodgkinson*

# Archaeometallurgy in Europe 2019:
## 19-21 June
## Miskolc, Hungary


*Participants to the Archaeometallurgy in Europe 2019 conference in Miskolc, Hungary*

On my way to an international conference at some stage I am beset with a modest panic that I have got the day and date wrong; this time these were dispelled by meeting a fellow council member at the gate at Luton Airport. Further reassurance came from spotting a number of people with poster tubes on the rail replacement bus leaving Budapest. More colleagues were encountered when I boarded the connecting train to Miskolc. The next day offered a warm welcome at the conference and the opportunity to catch up with many old friends. All in all it was a very friendly meeting and, for those who took it, rounded off by an excellent excursion which included an al fresco lunch in a patch of meadow between a preserved blast furnace and a narrow gauge railway. Many thanks are due to the organisers.

It is difficult for any one person to give a good overview of a conference with two or three parallel sessions grouped in to iron, copper and precious metals. I thought it would be useful, though, to have a brief look at just how international the meeting was by a little statistical analysis of the authors of the papers and posters presented in Miskolc. I chose this way because there is (usually) only one presenter while several people from different countries might have contributed. Two origins for a multi-country paper are the inclusion of colleagues from the museum or archaeology unit in the country providing the study material, and instrument scientists from neutron sources and synchrotrons involved in the analysis.

Taking this approach, and sorting the authors primarily by the country codes in their e-mail addresses, 40 counties were represented, from Albania to the United States of America. As might be expected, the host country, Hungary, was high up the table with almost 50 authors but the leader was France with almost 60. Next in order were Italy, Germany, Spain, United Kingdom, and Russia, all perhaps predictable given the size of the countries and the level of archaeological activity. It was noticeable, though, that the great majority of the UK authors came from just four institutions, and that about half, while presently based in the UK, were from overseas. Of smaller countries, the Czech Republic, Israel, Denmark, and Sweden were the most active and, indeed, the next meeting will be in Sweden in 2022 or 2023.

Upcoming conferences are Metal2019 in Neuchâtel which is concerned with technical analysis and conservation, Big Stuff in Poland which is concerned with the heavy end of the industrial heritage, and the next Beginning of the Use of Metals and Alloys meeting in Bangkok next year. There is, at best, only a small overlap in attendance at all these meetings. Going to conferences can be expensive but I do feel that there should be more interaction between these constituencies. Food for thought?

*Peter Northover*

# Archaeometallurgy in Europe 2019

The fifth international scientific conference of 'Archaeometallurgy in Europe' was held between 19 and 21 June 2019, at the University of Miskolc in Hungary. The main organizer of the conference is Dr. Béla Török, associate professor, director of the Institute of Metallurgy at the university and head of the Archeometallurgical Research Group of the University of Miskolc (ARGUM – www.argum.hu) The local organizing committee consists of a few members from this group, which is the only Hungarian interdisciplinary research group in the field of archaeometallurgy. The international conference, held every four years, is the largest scientific meeting of archeometallurgy not only in Europe but also in the world, and for the first time has been hosted by a Central and Eastern European country.

The conference website is available at http://www.aie2019.argum.hu. The event was attended by about 200 participants and guests, not only from Europe but from more than 30 countries around the world, with the participation of relevant domestic researchers. The three-day scientific program included 109 oral presentations and 57 poster presentations. The opening and closing key lectures were given by Alessandra Giumlia-Mair and Alan Williams respectively. The oral presentations were held in 24 sections, titled Copper, Bronze 1-2, Iron 1-6, Gold, Silver, Lead, Precious metals, Technologies 1-2, Reconstruction of copper technologies, Ancient metallurgy and mines, Technology transfer, Metallurgy and analytical techniques 1-4, Late Bronze Age and Metals in the Roman Empire, with the most well-known and respected scientists and researchers of the field of archaeometallurgy. The Historical Metallurgy Society offered awards to the best young oral and poster presenter.

The program of the event included exhibitions and lectures by companies selling instruments suitable for archeometric investigations, as well as professional demonstration visits (museum visits) in Miskolc and at the University. A representative event of the program was the gala dinner on June 20 at the building of Vigadó in Miskolc. On Saturday, June 22, participants took part in professional and tourist excursions around Miskolc and in the Zemplén area, where preserved and restored iron metallurgical smelters, furnaces, workshops and equipments from the 10th to the 20th centuries, and a reconstructed 17th-century cannon foundry, the remains of which is a European curiosity, can be visited. The Selmec (Chemnitz) Historical Library of the University of Miskolc provided a special experience for the visitors. This library preserves the undamaged library holdings of the university's predecessor, the Selmec Academy for Mining and Metallurgy, operating between 1735 and 1918. The collection of approximately 30,000 items includes the best of technical and scientific literature from the 16th to the 19th centuries.

The abstract collection of the conference - in electronic form - was given to the participants on a flash drive that was included in the conference package distributed. Selected and reviewed papers from the lectures will be published as a book of the conference proceedings next year.

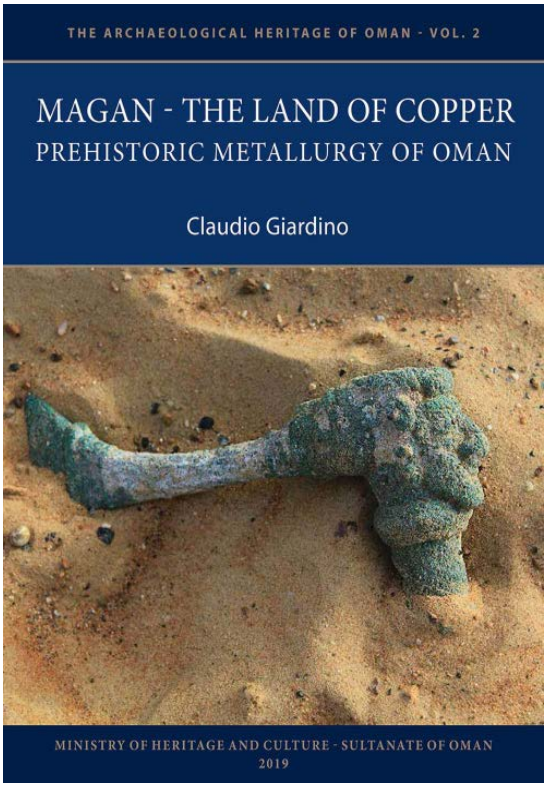
The University of Miskolc, the Special Committee of Materials Science and Technology of the Miskolc Committee of the Hungarian Academy of Sciences, the Herman Ottó Museum (Miskolc), the Hungarian Museum of Science, Technology and Transport (Metallurgical Collection, Miskolc), Miskolc Cultural Centre (Castle of Diósgyőr), Rákóczi Museum of the Hungarian National Museum (Sárospatak) and the Kazinczy Ferenc Museum (Sátoraljaújhely) had been involved in managing the conference. The event is sponsored by the Hungarian Academy of the Sciences, ÁSATÁRS Ltd., OAM Ózd Steelworks Ltd., Hungarian Iron and Steel Association, FUX Ltd. and Borsod-Abaúj-Zemplén County Government.

On the basis of the large number of on-site and post-conference positive feedback on the professionalism and organization of the event, the symposium can be considered obviously a success. This is supported by the fact that the main organizer of the conference has been elected as a member of the Standing Committee of the Archaeometallurgy in Europe.

*Conference Convenors*

## Magan – The Land of Copper

### *Prehistoric Metallurgy of - Oman Claudio Giardino*




Paperback; 210x297mm; xviii+182 pages; 150 figures, 14 tables (colour throughout). Price: £40.00

The development of a prehistoric civilization in the Sultanate of Oman was strongly connected with the exploitation and the use of copper. The Oman Peninsula has several rich copper ore deposits that have been exploited since prehistoric times. The earliest evidence of metallurgical activities in Oman dates back to the end of the Neolithic period in the 4th millennium BC. Thanks to the availability of this precious raw material, Oman became one of the main copper sources for the entire Middle East during the Bronze Age. The cuneiform texts of Mesopotamia referred to Oman as the Land of Magan, a region where the precious copper was found in fabulous abundance. This volume describes the geography and environments of Oman, its rich copper ore deposits and the ancient mining and smelting techniques, and it also includes an overview of the physical properties of the different metals exploited in antiquity and of the analytical techniques used in archaeometallurgy. Moreover, the author presents for the first time a comprehensive and detailed typology of the metal objects discovered at sites in Oman dating to the millennia from the Neolithic up to the Early Iron Age, emphasizing the development of advanced alloying techniques in order to obtain artefacts with specific proprieties and appearance.

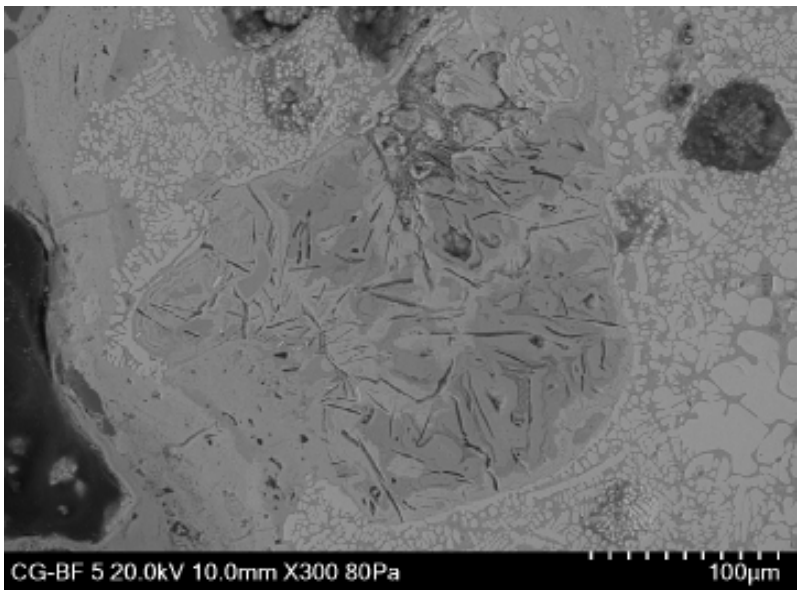
*Archaeopress*

# Out and About

## Post-Medieval Refining of Cast Iron

Metallurgical debris retrieved from the Post-Medieval site of Ausewell Woods, in Ashburton (Devon, South West England) are analysed to gain an understanding of the metallurgical activities that produced them. The presence of the remains of a blast furnace (possibly two) and of glassy silica-rich slag heaps, points to the production of pig iron. This was then refined on site to produce wrought iron in a finery forge located on the same River Dart, at a distance of approximately 300m from the blast furnace. Preliminary results of the assemblage suggest that the materials result from post-smelting operations, such as refining of high phosphorus grey cast iron to produce wrought iron. This was performed probably using the Walloon method of iron refining. Ausewell Woods seems to be the first blast furnace and finery forge installation identified archaeologically in the South West of England. Stay tuned!

*Carlotta Farci, University of Exeter*




Cast iron prill surrounded by wustite crystals and glassy phase