

The Historical Metallurgy Society
50th Anniversary Conference

Abstract Book

14th-16th June 2013

Friends House, London

Programme

14th June - Day One

9.00-9.55	Registration & Tea/Coffee
9.55-10.00	Conference Opens - Eleanor Blakelock
10.00-10.05	HMS Introduction - Speaker Paul Belford

Origin of Metallurgy - Chairs Paul Craddock & Thilo Rehren		
10.05-10.30	Paul Craddock	The emergence of Archaeometallurgy through the second half of the 20 th century
10.30-10.55	Anna Addis, I. Angelini, Gilberto Artioli and P. Nimis	Prehistoric copper metallurgy in the Italian Eastern Alps: recent results
10.55-11.20	Miljana Radivojević	The Origins of Metallurgy: a look under the microscope
11.20-11.45	Paul Ambert, Marie Laroche, Valentina Figueroa and Salvador Rovira	Technological aspects of the earliest metallurgy in France: “Furnaces” and slags from La Capitelle du Broum (Péret)
11.45-12.10	Simon Timberlake , Peter Marshall and Alan Williams	The beginnings of metal production in Britain: new light on the exploitation of ores, from the archaeological and dating perspective

12.10-13.10 Lunch

13.10-13.35	Ann Feuerbach	Origins of Metallurgy: An Anthropological Perspective
13.35-14.00	Lorenzo Nigro	The copper axes hoard of Khirbet al-Batrawy (Jordan), and the role of metal in the urban rise of 3rd millennium BC Jordan
14.00-14.25	Loic Boscher, Thilo Rehren, Ulf-Dietrich Schoop, Lloyd Weeks and Eddy Faber	Early Copper Metallurgy and Arsenical Copper Production at Çamlıbel Tarlasi, Turkey, c. 3500 BC

14.25-14.55 Tea/Coffee

14.55-15.20	Joanna Palermo	The origins of an origin: the development of academic interest in the question of the origins of iron technology from the 12 th to 19 th centuries.
15.20-15.45	Oli Pryce	Between autochthony and allochthony in Southeast Asia’s historical trajectory from the Terminal Neolithic to Full State Formation, c. 1000 BC to c. 500 AD

15.45-16.15 Tea/Coffee

16.15-16.45	Poster presentations, i.e. each person gets two minutes to describe their poster
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Move to the Institute of Archaeology for the HMS evening

31-34 Gordon Square, London, WC1H 0PY
G6 Lecture theatre on the ground floor.

17.30-18.00	AGM
18.00-18.40	Anniversary of HMS a retrospective but also a positive look to the future
18.40-20.00	Wine Reception in Staff Common Room 6th Floor

15th June - Day Two

8.40-9.20 *Tea/Coffee*

The Southern Continents - Chairs Vincent Serneels & Marcos Martín-Torres		
9.20-9.40	Laurence Garenne-Marot and Benoît Mille	The Muslim trans-Saharan copper trade: a reappraisal based on new data
9.40-10.00	Gillian Juleff , S. Jaikishan, B. Gilmour, Sharada Srinivasan and S. Ranganathan	Recent fieldwork in the crucible steel production landscape of Andhra Pradesh: interim observations
10.00-10.20	Edwinus Chrisantus Lyaya and Thilo Rehren	Systematic Slag Evidence for (Secondary) Carbon-rich Steel Production from Mbozi, southern Tanzania
10.20-10.40	Louise Iles	Technological expertise: fiercely protected or freely shared? Networks of knowledge in the iron industries of east Africa
10.40-11.10	Vincent Serneels	What is the Iron Age? Comparisons between Africa and Europe

11.10-11.40 *Tea/Coffee*

11.40-12.00	Benoit Mille , Diego Salazar, Catherine Perlès, Valentina Figueroa, Laurent Carozza, José Berenguer, David Bourgarit, Paulina Corrales, Albane Burens-Carozza and Pierre Rostan	Prehistoric production of Copper: a Comparative Approach between French Alps at the beginning of the Bronze Age and Atacama Desert in Chile during the Late pre-Hispanic period.
12.00-12.20	Jairo Escobar and Nohora Bustamante	Archaeometallurgy of platinum-gold in Pre-Hispanic South America: sintering technologies.
12.20-12.40	Carolina Gutiérrez Neira , A. Perea, A. Verde, P. Fernandez Esquivel, A. Climent-Font, A. Zucchiatti, S. Rovira-Llorens and J.L. Ruvalcaba-Sil.	Metallurgy of gold in the pre-Hispanic Quimbaya treasure

12.40-13.40 *Lunch*

13.40-14.00	Carlos I. Angiorama and M. Florencia Becerra	Reverberatory Furnaces in the Puna of Jujuy, Argentina, during colonial times (end of 16th to beginning of 19th centuries). Between Europe and America
14.00-14.30	Marcos Martín-Torres and María Alicia Uribe	The colour of wax: Technology, composition and context in Muisca goldwork (Colombia, AD 600-1800)

14.30-15.40 *Official Poster Session & Tea/Coffee*

The Northern Continents - Chairs David Bourgarit & Justine Bayley		
15.40-15.50	<i>Justine Bayley and David Bourgarit</i>	Session introduction
15.50-16.10	<i>Janet Lang</i>	Mildenhall and Derrynaflan: a study in two contrasting hoards
16.10-16.30	<i>Eleanor Blakelock</i>	The Staffordshire Hoard: choices of metal composition and the underlying secrets of the Anglo-Saxon goldsmith
16.30-16.50	<i>Mercedes Murillo-Barroso</i> and Ignacio Montero-Ruiz	Colonization and Silver Metallurgy in Iberia during the 1st Millennium BCE
16.50-17.10	<i>Siran Liu</i> and Thilo Rehren	How were gold and silver smelted in the historical period of China? -A case study of gold/silver smelting sites in southern China
17.10-17.30	<i>Martina Renzi</i> , S. Rovira Llorens, M. Hunt Ortiz and I. Montero Ruiz	An innovative metallurgical process in Iberia: liquation as a possible process for silver production in the Phoenician period

17.30-18.45 *Venue remains open, free time to view posters/chat etc
Extracts from the BFI 'Century of Steel' DVD will be shown in main room*

19.00 *Dinner venue opens with glass of sparkling wine
Dinner served at 7.30pm*

16th June - Day Three

8.40-9.20 *Tea/Coffee*

9.20-9.40	<i>Naama Yahalom-Mack</i> , E. Galili, I. Segal, A. Eliyahu-Behar, A. Shilstein and I. Finkelstein	Copper ingots from the southern Levant as indicators of diverse trade networking; A study of their chemical and isotopic composition and microstructure
9.40-10.00	<i>Christina Clarke</i>	A new approach to the identification of inter-regional connections in the Eastern Mediterranean during the third millennium BC.
10.00-10.20	<i>Kristina A. Franke</i>	Metal and elites in Upper Mesopotamia - uniqueness or uniformity?
10.20-10.40	<i>Jean-Marie Welter</i>	Tin bronze sheets: a millennium old material - forgotten - revived

10.40-11.10 *Tea/Coffee*

11.10-11.30	<i>Hugh J. McQueen</i> and Larry McNally	Montreal Metal Industries 1760 to 1910 - Cradle of Canadian Industry
11.30-11.50	<i>Keith E. Morgan</i>	Innovation and Change in the Welsh Tinsplate Industry
11.50-12.10	<i>Tim Smith</i>	The Iron and Steel Industry from the Founding of HMS to the Present

12.10-13.10 *Lunch*

**Future of Historical and Archaeological Metallurgy -
Chair David Dungworth**

13.10-13.30	Andrea Dolfini	Early Metallurgy in the Central Mediterranean: Goals for the next decade
13.30-13.50	Michael Brauns, G. Gassmann, R. Schwab and G. Wieland	Production and distribution of iron in Southern Germany during the Iron Age
13.50-14.10	Brian Gilmour	The Steel Age: When and where did it begin, and how did it develop before the late 1st Millennium CE?
14.10-14.30	Tim Young	Fragments through the smoke: The evolution of the bloomery furnace in Britain and Ireland
14.30-14.50	Philippe Dillmann, Alexandre Disser, Stéphanie Leroy, Maxime L'Héritier, Sylvain Bauvais, Gaspard Pagès, Emmanuelle Delqué- Kolic and Enrique Vega	Provenancing and dating ferrous artefacts: an outcome of two decades of research.

14.50-15.20 **Tea/Coffee**
(Posters removed during this break)

15.20-15.50	Thilo Rehren	Future of Archaeometallurgy
15.50-16.20	Paul Belford	Future of Historical Metallurgy
16.20-16.40	Discussion	

16.40-16.50 Closing Speech Eleanor Blakelock & Eddie Birch

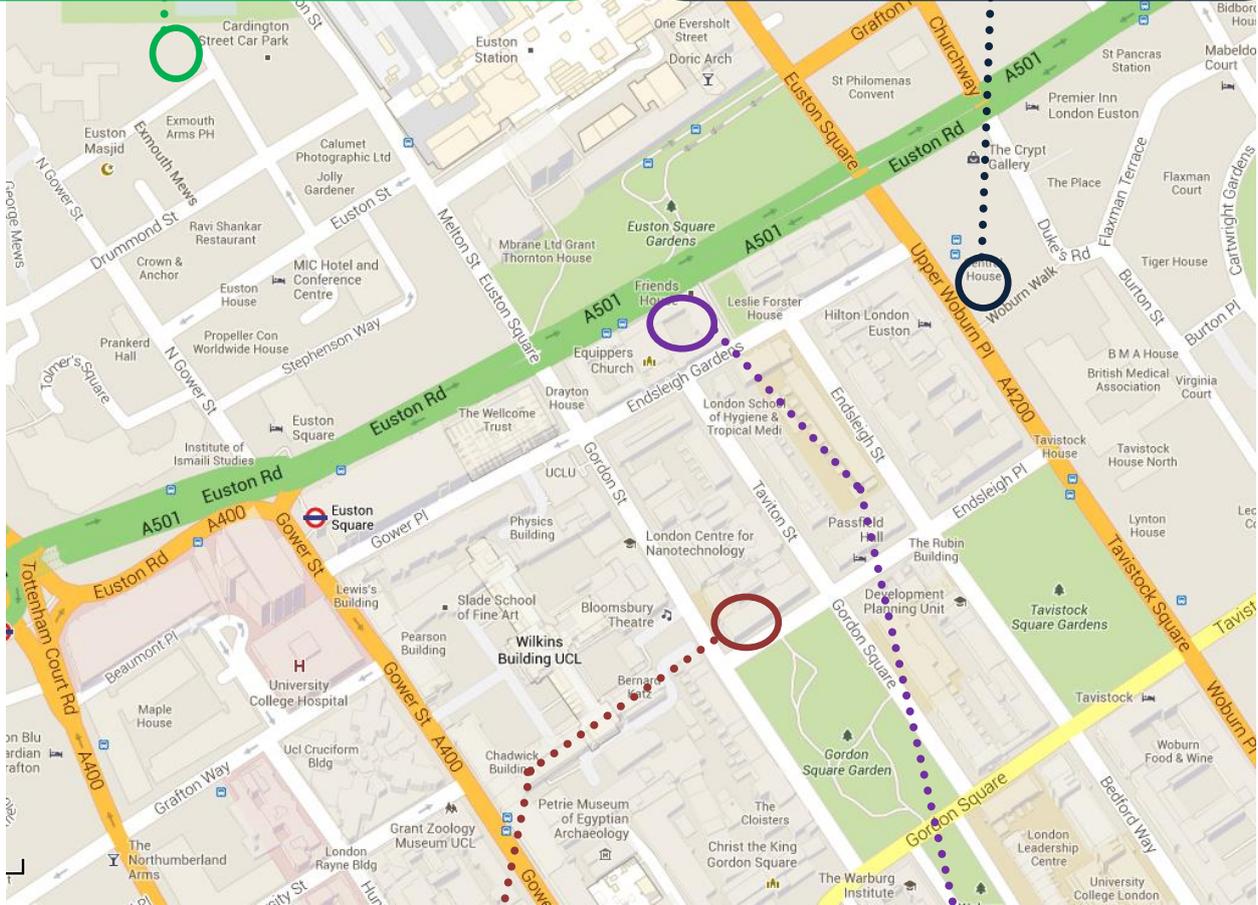
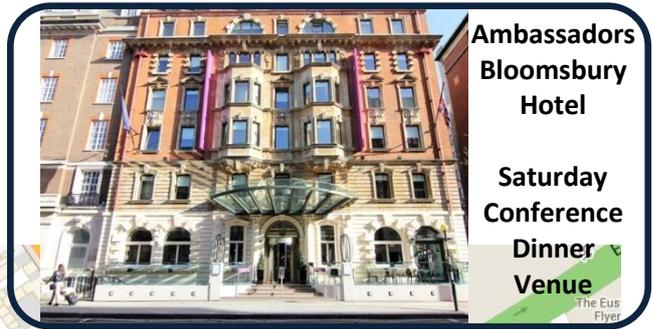
17.00 onwards Meet in pub for more discussions

Poster Presentations

Posters will be on display throughout conference

- Anna Addis**, I. Angelini and G. Artioli Late Bronze Age Slags from Trentino (Italy): Interpretation of the Copper Smelting Model
- Anna Sörman** Casting in Context: Analysing the Social Settings of Bronze Artefact Production in Late Bronze Age Scandinavia
- Arne Espelund** Roman ironmaking without the use of bellows!
- Aude Mongiatti** and Susan La Niece Anglo-Saxon goldsmithing workshop practices seen from the Staffordshire Hoard
- Frederik Rademakers** and ThiloRehren The identification of tin oxide in crucible slag
- Gülde Emre** The History of Tin and Bronze in Anatolia
- Takekazu Nagae**, Yutaka Maebara, Hidehiro Sugiyama, Yasuji Shimizu and HaruhisaMifune Microstructure observation on heat treatable high tin bronze bowls excavated at Japanese antiquities
- Salvador Rovira** and Florian Balestro Ternary bronzes Cu-Sn-Pb in Prehistory: An experimental approach
- Verena Leusch**, E. Pernicka and R. Krauß The Copper Age Gold from Varna – An impetus for social development?
- Simon Timberlake**, Tim Mighall and Douglas Kidd New Research into Roman Metal Mining in Britain
- Jiří Kmošek** and Ing. Šárka Msallamová Research of bronze turban-shape circle from Iron Age
- DamirDoracic**, Roland Schwaab and Hrvoje Potrebica Conservation-restoration and investigation of the Early Iron Age Iron Sword from Kaptol, Croatia
- Elisa Maria Grassi** Metallurgy Beyond Technology: Metalworking Debris as Historical Evidence
- MaximeCallewaert**, Laurent Tholbecq and Helena Wouters Elementary Analysis of Roman Enamelled Brooches in Gallia Belgica and Germania: Preliminary results
- TathagataNeogi**, G. Juleff and Sharada Srinivasan Festival of Mammayee: The socio-cultural context of iron-working in northern Telangana, India

Map and Venues



The emergence of Archaeometallurgy through the second half of the 20th century

Paul Craddock

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The second half of the 20th century saw the emergence of archaeometallurgy as a distinct scientific discipline, fully embracing developments in the excavation of sites and in the scientific examination of artefacts. For the very first time mines and smelters began to be excavated specifically to discover the mining and extractive processes. This has involved not just the conventional archaeological uncovering and recording, but a whole range of sampling strategies collecting materials for scientific study. The ever expanding potential of scientific examination has enabled much of the process metallurgy to be elucidated from the hitherto seemingly formless slags and refractories.

As a result of this work the origins and early development of mining and extractive metallurgy from around the world has begun to be documented, often with unexpected insights such as the general absence of slags but the prevalence of wind blown smelters in early operations.

New analytical techniques, in particular lead isotope analysis, have put provenance studies on a much more secure footing, and new examinational techniques, especially scanning electron microscopy with microanalysis, have transformed our ability to investigate how metal artefacts were made, decorated and deteriorated. These new approaches have together revitalising artefact studies.

These investigative advances in archaeology and science, very often backed up by replication experiments, have transformed our understanding of the history of extractive and production metallurgy across the world.

To some degree this advance in knowledge was driven by developments in available technologies both in the field and in the laboratory, rather than by formulating research priorities and seeking to address them. We now know much more firmly how they did it, we are still rather uncertain why. It is often uncertain why technical developments took the course they did and how they impacted onto society at large. Why did some technologies evolve where and when they did, why were some supplanted but others developed and thrived. Perhaps in the 21st century there is now a need for greater integration of archaeometallurgy with political, economic and social sciences.

Prehistoric copper metallurgy in the Italian Eastern Alps: recent results

A. Addis, I. Angelini, **G. Artioli** and P. Nimis

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The results of archaeometric investigations on copper slags and copper/bronze artefacts of Eneolithic and Bronze Age from North-Eastern Italy are presented. The research has been carried out in collaboration with a number of Regional Superintendencies, Museums, and Universities.

Concerning prehistoric slags, all known occurrences of Eneolithic slags from Trentino (La Vela, Gaban, Acquaviva di Besenello, Romagnano, Montesei di Serso) and Alto Adige (Millan, Gudon, Bressanone Circonvallazione Ovest) have been investigated from the chemical and mineralogical point of view to interpret the copper extraction technology. Lead isotope ratios and trace element concentrations measured on copper droplets and residual sulphides within the slags have been used to locate the ore sources. Analogous characterization measurements were performed on Late Bronze Age slags from three sites in Trentino (Luserna, Segonzano, Transacqua). The critical interpretation of the data confirms that there are two major phases of copper exploitation in the area: one peaking in the latter part of the Eneolithic Age, and one peaking in the Late Bronze Age. Each phase is characterized by distinct metal extraction technologies and geographical distribution of the metallurgical activities.

Concerning prehistoric artefacts, a number of selected copper and bronze objects have been investigated from the area for the interpretation of the manufacturing technology (metallography) and metal provenance (chemical and isotopic analyses). A few objects made with copper ores of East Alpine origin have been positively identified, though the data also indicate a wide circulation of copper metal originating from ore sources outside the Alps.

The Origins of Metallurgy: a look under the microscope

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Scholarly discussions on the emergence of metallurgy are dominated by the pursuit for the earliest evidence of copper extraction in western Eurasia, which largely shaped the debate on single vs. multiple origins of this precious skill. The recent discovery of the world-wide earliest copper smelting in Belovode, a Vinča culture site in eastern Serbia, dated at c. 5000 BC has changed our understanding of when and where metallurgy possibly first occurred. However, the origins of metallurgy have usually been studied in isolation and detached from their technological, social and environmental context, and there has been little research specifically addressing how and why metallurgy emerged and evolved.

Here I present results of an interdisciplinary approach using well-contextualised archaeometallurgical materials in order to address the evolution of pyrometallurgy in the western Eurasia. Microstructural, chemical and isotope analyses of slags, slagged sherds and copper minerals from two Early Neolithic and five Vinča culture sites in Serbia and Bosnia offer unprecedented insight into the development of understanding of material properties of copper ores and the evolution of metal making recipes in the 5th millennium BC Balkans.

Technological aspects of the earliest metallurgy in France: “Furnaces” and slags from La Capitelle du Broum (Péret)

Paul Ambert¹, Marie Laroche², Valentina Figueroa³ and **Salvador Rovira**⁴

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In the mining and metallurgical district of Cabrières-Péret in Southeast France has been discovered the earliest evidence of metallurgical activities, with calibrated radiocarbon dates spanning the third millennium BC. Both mines as some archaeological sites are well known thanks to numerous studies published over the last 30 years. La Capitelle du Broum is the most important Chalcolithic site located less than one kilometre away from some mines.

Systematic excavations at this site have allowed unearth numerous open fire structures used in metallurgical processing activities of local copper ores. The metallurgical hearths Capitelle-type are circular hollow pits of about 40 cm in diameter and 15 cm deep dug in the ground, with a yellow clay lining, into which and long around numerous pieces of ore, slag and metal drops have been collected.

The present contribution addresses the systematic analytical study of a broad representation of such materials using SEM, XRF Spectroscopy and metallographic techniques, from which we can define a metallurgy of primitive features consisting in direct smelting of complex minerals fahlore type, which produce pyroxene slag retaining much copper. The metal obtained is copper containing high impurities of antimony, silver and other substances, characteristic of this region.

The beginnings of metal production in Britain: new light on the exploitation of ores, from the archaeological and dating perspective

Simon Timberlake¹, Peter Marshall² and Alan Williams³

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²*English Heritage Scientific Dating Advisor*

³*University of Liverpool*

Over the last 25 years archaeological investigations carried out by the Early Mines Research Group have identified eleven sites of Early-Middle Bronze Age copper mining. Including the Great Orme there are now more than 100 radiocarbon dates from these prehistoric workings, which when statistically modelled have provided some interesting possibilities on the sequences of exploitation, and also a more meaningful chronology of production. Prospecting and small scale mining for copper begins in West-Central Wales at the end third/ early second millennium BC, and then spreads eastward, mining on the Great Orme reaching its peak in the Middle Bronze Age, declining over the space of a hundred years or so, the latter coinciding with the arrival of recycled metal from the continent, the copper perhaps coming from new Alpine sources.

Some new evidence for the Beaker ‘presence’ being a catalyst to earliest mining operations in Britain will be presented, together with a model linking copper-tin-gold exploitation between Atlantic Iberia-France-SW England-Ireland and Wales at the beginning of the Copper/ Bronze Age.

As regards metal provenancing studies, a much better understanding of the ores being exploited and likely models of smelting are essential pre-requisites; a case being made here for an on-going programme of geo-archaeological fieldwork combined with experimental archaeometallurgy.

Origins of Metallurgy: An Anthropological Perspective

Ann Feuerbach

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Anthropologists have realized that there are positive correlations between subsistence strategies and other economic, political and religious adaptive strategies. It has often been noted that the origins of metallurgy correspond to other cultural changes including the shift from foraging to domestication of plants and animals. The paper will argue that the change from primarily lithic technology to the use of metals is a change in craft strategy and that craft strategies are akin to, and corresponds with, the changes in other adaptive strategies.

**The copper axes hoard of Khirbet al-Batrawy (Jordan), and the role of metal
in the urban rise of 3rd millennium BC Jordan**

Lorenzo Nigro

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Recent excavations carried out by Rome "La Sapienza" University in the site of Khirbet al Batrawy (2005-2012), in north-central Jordan, revealed a previously unknown 3rd millennium BC strongly fortified centre, with a temple and a palace. Inside the latter, a huge building destroyed by a fierce fire towards the end of the Early Bronze III, a great amount of finds were retrieved, including, in a pillared hall which was part of the monumental suite of the palace, five copper axes. The hoard of axes provides an interesting insight in metal technology and distribution in 3rd millennium BC Levant, especially - due to their findspot - in relationship with the rise of the earliest urban culture in Southern Levant.

Early Copper Metallurgy and Arsenical Copper Production at Çamlıbel Tarlasi, Turkey, c. 3500 BC

Loic Boscher¹, Thilo Rehren¹, Ulf-Dietrich Schoop² and **Lloyd Weeks**³

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Çamlıbel Tarlasi (CBT) is a late Chalcolithic site located in the central plateau of Turkey, with a depositional sequence pointing to periodic/seasonal occupation and use in the period around 3500 cal BC. The site produced abundant remains attesting to early metallurgical activities, including ores, slags, crucibles and copper-base artefacts, as well as elaborate pyrotechnological installations that may have been smelting furnaces. Artefacts, installations and soil deposits from CBT have been studied using a variety of techniques (SEM-EDS, EPMA-WDS, pXRF, optical microscopy). Together, these studies attest to the intentional production of arsenical copper at the site by the addition of arsenic-bearing ores to molten As-free copper.

The production process is as follows: The copper ores smelted come from a source within a few kilometres of the site, and rich smelting slags indicate that the furnace charge included predominantly As-free oxide ores, along with lesser amounts of sulfide ores that remained largely unreduced. Subsequently, the raw copper was alloyed with still unidentified arsenic minerals in an “arsenical cementation” process, as attested by As-rich layers found in the inner surface of crucibles from the site. This process produced a final alloy with c. 2-6% As (and occasionally >1% Ni). Finished arsenical copper artefacts from the site displayed highly variable fabrication processes including casting and, in some cases, repeated cycles of forging and annealing.

The analysis of residues from throughout the production sequence at CBT suggests that arsenical copper production was both intentional and controlled, making CBT one of the earliest known sites documenting this practice. The 4th millennium BC represents the floruit of arsenical copper production in the Near East, an alloy that was to become dominant in many metal assemblages for the next millennium or more. When compared with other sites in the highland zones surrounding greater Mesopotamia (especially 4th millennium BC sites in Iran), CBT provides insights into the multiple pathways that led to the development arsenical copper and the human interactions with materials that underpinned them.

The origins of an origin: the development of academic interest in the question of the origins of iron technology from the 12th to 19th centuries.

Joanna Palermo

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One of the most actively pursued questions in historical metallurgy is the origins of iron working, thought to begin in the 12th century BCE Eastern Mediterranean. This paper is a historiographical investigation into the development of academic interest in the question of iron origins. From the 12th to 16th centuries CE, metallurgical texts continued the Greco-Roman tradition that acknowledged the fundamental role that iron working played in creating civilized society. As a departure from the ancient tradition, inquiries into the origin of the metal ceased. In contrast to ancient writers such as Hesiod and Lucretius who formulated several versions of human development modelled around a series of successive technological steps of stone, bronze and iron, for Medieval and Humanist writers like Theophilus, Agricola and Du Bartas, the question of iron origins was already set out in the Book of Genesis whereby God granted the art of smithing to his children through the Patriarch Tubal-Cain in the earliest phases of human history. Intricate attempts by several 17th century Puritan writers to elaborate on the historical conventions of this narrative demonstrate its central position in shaping Western historical thought. The Biblical model remained intact until its gradual replacement in the 18th and 19th centuries with a new origins narrative grounded in the early methods of archaeology and a historical model that arranged human history into a succession of technological stages, the Three Ages System. The work in these later centuries laid the foundations for our modern research on the origins of iron technology.

Between autochthony and allochthony in Southeast Asia's historical trajectory from the Terminal Neolithic to Full State Formation, c. 1000 BC to c. 500 AD

Oli Pryce

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The Southeast Asian Lead Isotope Project's (SEALIP) long-term aims are to inform upon interactions between Southeast Asian populations of different levels of economic, political and social complexity inhabiting distinct ecological zones, as well as relations with neighbouring South and East Asian social groups. This work began in 2009 with the typological, technological, isotopic and elemental analyses of regional metal production and consumption assemblages, now totalling c. 300 samples. With this preliminary dataset I attempt to test the hypothesis that it was the dynamism and responsiveness of Southeast Asian populations to foreign stimuli can partly explain the dramatic historical acceleration the region showed between 1000 BC and 500 AD. As a corollary, I have also tried to begin characterising the cultural sequence of upland 'ethnic minority' populations whose role has until now been largely absent from major historical developments.

The Muslim trans-Saharan copper trade: a reappraisal based on new data

Laurence Garenne-Marot¹ and Benoît Mille²

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² *C2RMF Paris and UMR 7055, PreTech, Nanterre*

Copper was along salt the item most highly demanded in exchange for the gold in the Muslim trans-Saharan trade. The salt has vanished from the archaeological record and gold is but very rarely attested in it. Thus, copper-based ingots and objects derived from them are in most cases the only mean to materialize this trade. Thorough knowledge of the copper-based ingots, their shape but, foremost, the precise metal composition of them give clues to understand the importance and changes which occurred in the trans-Saharan trade routes from the 8th to the 15th centuries AD.

In the course of the excavations conducted at the site of Natamatao (Inner Niger Delta, Mali), 20 long copper-based bars similar in shape to the Ma'denIjâfen ingots discovered by Th. Monod in the Sahara in 1964 were recovered. This was the starting point of a complete inventory of the data available for the copper-based ingots in Westernmost Africa South of Sahara. Following missions, first in the archaeological collection of the Institute Ifan-CAD of Dakar, Senegal to retrieve the Ma'den Ijâfen bars and other metallic material, then at the IRMS in Nouakchott, Mauritania, to study notably the metallurgical remains from the trade outpost of Tegdaoust, all copper-based ingots -together with those from Natamatao, thanks to the support of the Institut des Sciences Humaines and the National Museum of Bamako, Mali-, were systematically examined and sampled. Elemental analyses by ICP-AES were performed at the C2RMF, Paris, leading to circa 100 new analyses. The 50th anniversary conference of the HMS is the occasion to release the results of this large-scale project, an example of a fruitful collaboration between archaeometallurgists and historians.

Recent fieldwork in the crucible steel production landscape of Andhra Pradesh: interim observations

Gillian Juleff¹, S. Jaikishan², B. Gilmour³, Sharada Srinivasan⁴ and S. Ranganathan⁵

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The region of Northern Telangana, Andhra Pradesh, lies in what is now the remote rural heartland of peninsula India and is a landscape characterised by scattered agricultural settlements. In the past, however, it supported an extensive industry in the production and trade of high-carbon crucible steels, and is the region most closely associated with the legendary *wootz* steel. In 2010 the Pioneering Metallurgy project (a collaboration between Exeter University and the National Institute of Advanced Studies, Bangalore) conducted a field survey in the area, re-examining and recording known sites and looking afresh at evidence for the underpinning smelting technologies that sustained the crucible steel refining process.

A landscape-based approach was adopted that recorded, using both conventional reconnaissance survey and GPS/GIS systems, and correlated a range of environmental, geological, settlement, cultural, ethnographic and technological data. Of the 245 locations recorded, 183 were associated with metal-working and spanned archaeological and ethnographic occurrences of smelting, smithing and crucible steel manufacturing. The process of compiling and analysing the collected data is currently active but this paper reports on the survey itself and makes some preliminary observations.

Systematic Slag Evidence for *Secondary Carbon-rich Steel Production from Mbozi, southern Tanzania*

Edwinus Chrisantus Lyaya and Thilo Rehren

University of Dar es Salaam, Tanzania, edwinusl@yahoo.com

Most of the early research on African steel production focussed on examination of forged objects (e.g. van der Merwe and Avery 1982) and experimental smelted products (e.g. David et al. 1989; Schmidt 1997). Unfortunately, there are two problems with the two approaches: (1) carbon in a forged object is unlikely a representative of the carbon in the smelted or refined steel, and (2) there has been no parallel slag evidence studies in favour of the production carbon-rich steel in Africa. Some scholars (e.g. Killick 1991; Ige and Rehren 2003) think that the absence of wüstite in smelting slags indicates highly reducing conditions in the furnace and hence possible steel production, but this alone is not enough. This paper presents systematic slag chemical and mineralogical data indicative of secondary carbon-rich steel production. It is secondary carbon-rich steel production, because in this area secondary iron refining (vintengwe) furnaces were used, and not primary ore smelting (malungu) furnaces. In the end, this paper proposes that secondary steel production is another but different pathway to steel production in Africa.

References

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Technological expertise: fiercely protected or freely shared? Networks of knowledge in the iron industries of east Africa

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The development of, and control over, metal technologies is often associated with a means by which to accrue power and prestige, and has long been linked to significant economic and political change.

Considering the power that early iron production bestowed, it has been suggested that mechanisms were often put in place to restrict access to iron technologies, thus limiting the wealth and prestige acquired from them to certain groups. It is thought that these mechanisms were not limited only to physical restrictions – such as access to raw materials – but also included restrictions on who could access knowledge of the smelting process.

The rich ethnoarchaeological record of the iron production technologies of sub-Saharan Africa provides an unparalleled opportunity to examine the socio-cultural elements of iron technologies, including those associated with the protection of knowledge. But how widespread are these monopolizing approaches, and on the contrary, is there evidence for the sharing of technical knowledge and cooperation between different smelting groups? How might this manifest in the archaeological record?

This presentation will consider the theories that underpin our understanding of these relationships through a discussion of data gathered during archaeometallurgical research in Uganda and Tanzania. It will consider the social and economic organisation of iron production to ask whether technological expertise was fiercely protected or freely shared in these contexts, and how this can inform our growing knowledge of processes of transmission, adoption, innovation and change in past metalworking.

What is the Iron Age? Comparisons between Africa and Europe

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Recent research in Western Africa (Mali, Burkina Faso, Ivory Coast & Senegal)* evidenced archaeological remains of intensive, large scale, production of iron lasting during the entire last millennium. The fieldwork allows also the investigation of traditional iron smelting and ironworking technologies from an ethnoarchaeological point of view. In this presentation, the focus will be made on the way iron is used inside a traditional agricultural society (Dogon group, Mali). By far, most of the iron is devoted to the production and renewing of tools for agricultural purposes (hoes, axes, wood cutting knife). In the past, also weapons were of importance.

With those African observations in mind and by comparison to my knowledge about the European archaeological record, a reflexion on the nature of the “Iron Age” is proposed. From the technological point of view, “Iron Age” started when the first iron artefact entered the archaeological record. From the chronological point of view, “Iron Age” is used in a diachronic but well-established time sequence for Europe (and the Near East). This is not too far from the technological definition but with several distributions resulting of the advances in the archaeological research and special cases (for example : meteoritic iron). A consequent body of literature has been devoted to the process of introduction of iron, its mechanisms and timing. There are several explanations proposed to understand the driving forces of this introduction process (higher efficiency of iron weapons, tin shortage following the Bronze Age Collapse, etc). In the African context, the meaning of “Iron Age” is not so well established, basically because not enough archaeological data of high quality are available. Confusion is also introduced by the tendency to build up an African time sequence as parallel as possible to the European one. A major difference is the absence of significant period of exclusive use of copper or copper-based alloys in most parts of the continent.

In Africa, like in Europe and the Near East, the introduction of the first piece of iron in the archaeological record has not, in itself, a significant impact on the way of life of contemporaneous people. From a socio-economical point of view, the “Iron Age” started when the use of iron modify significantly the organization of the society. In this respect, it is still a matter of discussion if there is a common and specific pattern for the socio-economic organization to all (or at least many) iron-using societies.

My opinion is that the most important impact of iron on societies is the transformation of the agricultural technology induced by the generalization of iron farming tools. There are two main consequences:

- 1) With better tools (and iron ploughing tools are the best over all kinds of other material), each farmer is able to produce a significantly larger surplus of food. This larger surplus allows an increase of the population and/or an increase of non-food producing activities.
- 2) Efficient ploughing makes possible the permanent agricultural use of extended land surfaces that can't be used for crop growing previously. The consequence of this enlargement of agricultural landscape is a significant modification in the settlements pattern.

* This African fieldwork started in the frame of the interdisciplinary project “Populations and Paleoenvironments in Western Africa”, under the direction of Prof. E. Huysecom (university of Geneva). Several contributors are involved: C. Robion-Brunner, S. Perret, R. Soulignac, A. Mayor, M. Mauvilly, A. El Kateb, A. Dembélé, L. Cissé, L. Simporé & H. Kiénon Kaboré.

Prehistoric production of Copper: a Comparative Approach between French Alps at the beginning of the Bronze Age and Atacama Desert in Chile during the Late pre-Hispanic period.

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Recent research carried out on the organisation of copper production suggests that prehistoric metallurgy has not developed on a simple and linear way but along multiple paths. In order to further test this hypothesis, a research project has been recently initiated which aims at comparing two areas where metallurgy has developed in total independence, the Alps and the Atacama Desert.

In the Alps, the fieldwork is focused on Saint-Véran (Hautes-Alpes, France), an Early Bronze Age copper production centre, where the oldest occurrences of 'plate slags' in Europe have been discovered (22nd cent. BC). These slags may testify for the sudden and ex nihilo adoption of a very efficient copper smelting process, appropriate for a large-scale copper production system.

The area under study in the Atacama Desert is located along the upper course of the Río Loa (Antofagasta Region, Chile). Primary production of copper begun during the Late Intermediate period (10th-14th cent. AD) using simple processes. The arrival of the Incas during the 15th cent. AD was accompanied by an increase in the scale of activity, based in some places on large and impressive wind-powered furnaces.

As research progresses in these two regions, complex situations are emerging, where large-scale production systems may cohabit or precede more domestic-like systems. Yet, in the district of Miño-Collahuasi for example, a rebirth of the old indigenous process is evidenced during the early Colonial period (17th cent. AD). In that context and concerning Saint-Véran, what is the correct interpretation of the small immature slags very recently discovered close to the mine? Precursor of the Early Bronze age process, or issued from a later small scale opportunist exploitation?

Archaeometallurgy of platinum-gold in Pre-Hispanic South America: sintering technologies.

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Archaeometallurgy is the discipline that assesses anthropological questions with tools provided by materials science[1]. It is used to study technological processes in order to reconstruct the cultural context of ancient societies. In Colombia lived several ancient metallurgical cultures that manufactured diverse artefacts with complex techniques [2]. In the Colombian case, archaeological context is null so studies of artefacts are a priority. Principles of inverse engineering can be used to study the artefact materials to propose hypotheses about manufacture, raw materials, technical decisions etc.

Systematic protocols were developed in order to study two Pre-Hispanic samples manufactured with platinum-gold alloys. These fragments were supplied by the Central Bank: one nose ornament and a fragment of ornament. The samples belonged to objects from the stylistic group named Tumaco-La Tolita, which were made by social groups inhabiting southern Colombia between 350 BC and 350 AD [3]. Macroscopic and microscopic analyses were done using a Stereoscopic Microscope (SM), an Optical Microscope (OM) and a Scanning Electron Microscope (SEM). Chemical composition was studied using X-Ray Fluorescence Spectroscopy (FRX), X-Ray Diffraction (DRX), and Energy Dispersive X-Ray Spectroscopy coupled to SEM. Microhardness measurements was also applied.

Results showed different microstructural characteristics according to the type of fragments, like diffusional regions, necking and porosity. This suggests the application of sintering processes which required skills and deep knowledge of the metallurgical techniques from the goldsmiths. All these results contribute to understand technological and socio-cultural complexity achieved by Pre-Columbian goldsmiths.

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Acknowledgements

We would like to express our gratitude to the Technical Industrial Department of the Central Bank for supplying the samples for this project. Also we would like to thank the University of Los Andes for their financial support this study.

Metallurgy of gold in the pre-Hispanic Quimbaya treasure

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The Quimbaya treasure is known as one of the most important collections of pre-Hispanic metallurgy. The assemblage corresponds to a funerary set found in two looted tombs in 1890 in the site of La Soledad, near the Municipality of Finlandia (Quindío Department, Colombia). One year later, the Colombian government acquired the treasure and in 1892 it was given as a present to the Regent Queen of Spain, Doña María Cristina de Absburgo Lorena in gratitude for her mediation in a frontier dispute between Colombia and Venezuela. Nowadays, the Quimbaya treasure consists of 135 objects belonging to the named Classic Quimbaya period and it remains exposed at the Museo de América in Madrid, Spain.

The Quimbaya gold metallurgy was studied by the combination of different analytical techniques including optical microscopy, XRF, SEM-EDS and PIXE-RBS. Concerning the elemental composition, the assemblage presents a good quality with gold contents greater than 50% and some objects stand out for their very larger gold content. Regarding the silver content, most part of the items exhibit Ag levels between 12 to 25%. Some casting defaults like voids or porosity were found but in general the quality standard is very high.

Reverberatory Furnaces in the Puna of Jujuy, Argentina, during colonial times (end of 16th to beginning of 19th centuries). Between Europe and America

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The Puna of Jujuy, Argentina, is part of the southern extreme of the Andes High Plateau. In this region there are mineral resources, such as gold and silver, which became a great attraction for the European conquerors during colonial times. This paper focuses on the study of the extractive metallurgical technology that was employed in four mining-metallurgical sites in this region dedicated to silver exploitation. In these sites, we have registered the presence of reverberatory furnaces, a technology that was probably brought to America from Europe and experienced certain changes and innovations in the different places where it was applied for smelting and refining silver or copper minerals. To date, the function and characteristics of this kind of furnaces in the Andes are not well known because there are only few registered and published. The excellent conservation of most of the furnaces found in the sites we are presenting makes them a great source of information for the study of the colonial metallurgy in this region, where the mining and metallurgical activities had a major importance for the Spanish population. Moreover, travellers and chroniclers only wrote about colonial exploitation in the great mining centres with no reference to marginal areas such as the Puna of Jujuy. In that sense, our presentation aims to show the results of the detailed study of these furnaces, its functions and performance, based on our fieldwork and the results of archaeo-metric analyses on samples of smelting slag and vitrified clay.

The colour of wax: Technology, composition and context in Muisca goldwork (Colombia, AD 600-1800)

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The standard archaeometallurgical approach to Pre-Columbian gold is still dominated by manufacture studies that focus on the technical sophistication of individual objects, and/or on chemical analyses that seek to determine authenticity or metal provenance. While technically interesting, these studies yield relatively little information about the societies who made and used those artefacts. Only a closer integration of technical and contextual data can reveal more subtle aspects of cultural diversity, craft organisation, metal value systems or community interaction in specific settings.

This talk will present the main results and implications of a large-scale project focused on the contextual study of the votive offerings made by the Muisca of Pre-Columbian Colombia, blending stylistic, technological and chemical data. We will argue that:

- a) Each multi-component votive offering was made by a single workshop, as a specific commission with a particular purpose, and deposited soon after the objects were cast;
- b) The making of some gold offerings deliberately sought a wide spectrum of gold-copper alloys whose compositions were fundamental to their symbolic code;
- c) The provision and modelling of the wax to create models for lost-wax casting was potentially more important, technologically and symbolically, than the goldwork itself.

These findings challenge many traditional generalisations about Pre-Columbian goldwork. They highlight the potential of contextual studies and have important implications for our understanding of the societies who made and deposited these offerings. We will discuss the significance of this work for archaeometallurgical studies in America and beyond.

Mildenhall and Derrynaflan: a study in two contrasting hoards

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Separated in time, space and style, the two hoards show the pre-occupations of their times and the societies which produced them. The Mildenhall Treasure consists of 4th century AD Roman silver tableware. It was found on farmland near Mildenhall in Suffolk in 1942 and has been in the British Museum since 1946. The Derrynaflan hoard of ecclesiastical vessels, probably deposited in the late 9th century AD, was found in 1980 on the ancient monastic site of Derrynaflan, Co. Tipperary in the Republic of Ireland. It is in the National Museum of Ireland in Dublin. The use of silver is common to both, but the styles of decoration are very different. The materials, technology and tools used in making both groups of objects are discussed and compared in the paper. The craftsmen who might have produced such objects and their role in their societies are also briefly outlined.

The Staffordshire Hoard: choices of metal composition and the underlying secrets of the Anglo-Saxon goldsmith

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The Staffordshire Hoard was discovered in 2009, in a field near the village of Hammerwich, in Staffordshire, England. It consists of more than 3,500 items, many of which are gold. It is essentially military in character with the bulk of the identified pieces coming from the handles of edged weapons, although a small, but significant, number of explicitly Christian items have also been identified. Most of the material belongs to the sixth to eighth centuries and much is richly decorated with intricate interlace patterns carried out using a variety of techniques including cloisonné garnet and filigree.

As part of the wider research project on the Staffordshire Hoard, an initial pilot study of the gold compositions of a selection of objects from the Staffordshire Hoard was undertaken, using a combination of XRF and SEM-EDX. The results are increasing our knowledge of the gold alloys available to the Anglo-Saxon goldsmith and improving our understanding of his skills and choices.

It is well established that gold alloys can corrode and be altered by the loss of copper and small quantities of silver from their surfaces during burial, but it is also known that goldsmithing treatments carried out during manufacture may remove significant quantities of both copper and silver from the surface of gold alloys. Sixteen gold objects representing the known spatial distribution of the Staffordshire Hoard in the ground were analysed. The aim of this pilot project was to determine firstly whether there was any surface enrichment and/or depletion of the gold alloy to be taken account of in any future analysis.

The results from the analysis of these objects have clearly shown in many cases that there is significant but not consistent enrichment of the gold at the surface due to the depletion of both copper and silver. The analysis of areas of ancient but post manufacture damage, probably made when dismantling the swords before burial, indicates the expected loss of copper from the surface during burial, and little loss of silver. However, the results from undamaged surfaces of the same objects suggest that some form of artificially induced depletion took place to remove both silver and copper from the surface. This finding has far-reaching implications for the viability of surface analysis of gold artefacts not just from the Anglo-Saxon period.

Acknowledgements

I would like to express my gratitude to Nigel Meeks, Aude Mongiatti, Duncan Hook and Susan La Niece for their helpful guidance during this research. We would also like to thank English Heritage for providing the funding so that this research could take place.

Colonization and Silver Metallurgy in Iberia during the 1st Millennium BCE

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This paper entails a study of silver production in Late Bronze Age/Early Iron Age Iberia, where interaction between Phoenicians and indigenous communities played a key role in the configuration of a new hybrid society with growing social inequality.

In this context of social contact and interaction, there is an intensification of silver production (with tonnes of slag, cupels and litharge providing the earliest evidence of silver cupellation in Iberia).

Lead Isotope Analyses of more than one hundred samples of silver metallurgical debris as well as objects showed a complex production system covering the whole Iberian Peninsula: LIA of metallurgical debris revealed the import of lead from various parts of Iberia, as a necessary ingredient to extract silver by cupellation from jarositic ores of the Pyritic Belt of the Southwest. Iberian silver objects show 'Orientalising' techniques and decoration (granulation, soldering, Egyptian inscriptions), radically different from the technological and decorative simplicity of earlier metallurgy. However, LIA showed an Iberian provenance of resources, indicating the possible presence of Eastern craft specialists in Iberia.

Silver metallurgy was probably a complex system involving two different societies in a different way: Phoenicians might have played a key role in the distribution of lead by sea (as suggested by the Mazarrón shipwreck) through complex commercial networks while indigenous communities might have played an important role in extractive and intensive mining works. This intensification of production and the amplification of the scale, however, contrast with the scarcity of silver artefacts recovered, suggesting that the Phoenician-led intensification of production would mostly aim at to export silver to the East.

How were gold and silver smelted in the historical period of China? -A case study of gold/silver smelting sites in southern China

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Gold and silver were first used in China as early as the Bronze Age (2000 BC). But only after AD 600 have these two precious metals finally become prominent in Chinese society. They were widely used in gift giving, wealth stock, trade, paying tax and making artefacts, and their productions became an important issue in the empires' economy. From a technical viewpoint, the production of gold and silver is much more complex than that of base metals, involving numerous steps and various reaction containers. More variations should be expected in this technology, and the choices of ancient craftsmen largely depended on the nature of the ores, their access to raw materials, the production scale, and technological traditions.

In spite of its importance, this technology has rarely been studied archaeologically and archaeometallurgically in the Chinese context. Our research is expected to shed some new light on this aspect by looking into four gold, silver, and lead production sites in southern China. The in-progress technological reconstruction has suggested that the ores and technologies used in these four sites are different from each other. In one of these sites, metallic iron might have been used as the reduction and de-sulfurising agent during the smelting of gold/silver/lead ore. Whole ranges of environmental, technological, socio-economic, and historical settings are being examined as part of this ongoing research to identify the factors which affected the technological choices of ancient smelters.

An innovative metallurgical process in Iberia: liquation as a possible process for silver production in the Phoenician period

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The need for silver supply had an important role in the process of Phoenician colonisation of southern Iberia and, up to date, many archaeometallurgical studies have focused on this topic. Yet, there are many aspects of metallurgical technology for extracting silver in this chronological phase that have to be clarified.

The complex metallogeny of Iberian territory led ancient metallurgists to implement new methods to obtain the noble metal, as the use of cupellation to exploit not only argentiferous lead ores like galena and cerussite, but also to benefit the rich deposits of argentiferous jarosites of the Iberian Pyrite Belt. These ores were undoubtedly a major source for producing silver in Phoenician times but recent archaeometallurgical evidence points to the exploitation of other mining resources as well, namely argentiferous copper ores.

In particular, two Phoenician sites dated to the 8th century BC, La Fonteta (Guardamar del Segura, Alicante) and Cerro del Villar (Malaga), yielded some metallurgical debris whose composition and microstructure can be related to the use of the liquation process for extracting silver from cupro-argentiferous ores.

Until now, these ores have not been taken into account by archaeometallurgists as a possible source to produce silver in ancient times, and the use of liquation is hardly known until Late Roman age when it was employed mainly for desilvering copper alloys.

In this paper we present the analytical results of La Fonteta and Cerro del Villar metallurgical materials, suggesting a possible reconstruction of the different stages of the liquation process, a previously unknown technological process employed in Antiquity for extracting silver from silver-rich copper ores.

Copper ingots from the southern Levant as indicators of diverse trade networking; A study of their chemical and isotopic composition and microstructure

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The close correlation of ingots to the smelting operation, and hence to the ore deposit, makes them the optimal candidates for provenience studies and the reconstruction of trade and commerce in antiquity. Ingots from the site of Hazor and from underwater excavations off the Carmel coast were subjected to microstructure, chemical and lead isotope analysis. The results enabled us to follow changes in copper use between the two main copper suppliers; Cyprus and the Arabah (Timna and Faynan). Based on the analyses we show that two of the ingot assemblages correspond with two different phases of Cypriot copper exportation in the second millennium BCE. The earlier phase, identified here for the first time through ingots from Hazor, consisted of trade in black copper in the form of relatively small plano-convex ingots. The later phase, is evidenced through the occurrence of fragments of large oxhide ingots along the Carmel coast. A third assemblage from Neve Yam, also found along the Carmel coast consisted of 54 ingots similar in shape and composition, and is identified here as the hitherto unknown product of the Iron Age large-scale operations at Faynan.

A new approach to the identification of inter-regional connections in the Eastern Mediterranean during the third millennium BC.

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This paper presents a method for studying inter-regional contacts in the Eastern Mediterranean during the Bronze Age. The method identifies evidence of shared metallurgical techniques, in this case those used for the production of metal vessels. Whereas typological similarities between the material cultures of different regions can result from the importation and subsequent imitation of styles, there are some aspects of vessel manufacture which are more likely to reflect temporary or permanent movements of peoples. This is because the complex nature of some techniques would require extended, face-to-face contact between peoples such as would result from the temporary or permanent migration of artisans. Many influences of Egyptian artistic traditions on those of Minoan Crete, for example, result from the import of Egyptian goods, whereas the Minoan influence on Mycenaean traditions is generally regarded to be a result of not only the import of Minoan goods but also of the movement of Minoan artisans to mainland Greece. This paper will describe several metal smithing techniques which might require extended face-to-face contact to be transmitted between regions and, furthermore, will outline shared technical features of the vessels of different peoples of the Eastern Mediterranean and the Near East which would reflect these types of contact.

Metal and elites in Upper Mesopotamia - uniqueness or uniformity?

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The 3rd millennium in Upper Mesopotamia, located in what is today northern Iraq and eastern Syria, is a time of change and innovation. Especially between 2600 and 2350 BC the rather sudden appearance of the so-called city states and the growth of complex urban societies suggests the power of a possibly newly established elite. This is underlined by monumental architecture, the formation of institutions and a complex administrative system supported by the tool of writing. Beside the lack of metal resources in Upper Mesopotamia metallurgy plays a recognisable role within society. However, the uniformity of this possible elite, regarding the contemporary appearance of city states within that region and their control of the urban life and also of the hinterland, appears to be more individual in terms of their metallurgy and metallurgical interests. The analysis of metal artefacts and metallurgical debris from major Upper Mesopotamian sites helps to understand similarities and differences between ruling elites of different city states and the role of metallurgy for their economic, political and social standing. Also, the proximity of many Upper Mesopotamian sites to neighbouring Anatolia, where copper and tin resources were widely available, suggests that this region may have worked as a transmitting area in development of skills and transport of material across Mesopotamia, giving Upper Mesopotamia a pioneer position within Mesopotamian metallurgy.

Tin bronze sheets: a millennium old material – forgotten – revived

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The end of the second millennium BC saw almost everywhere in Europe the beginning of the production of tin bronze sheets. For more than thousand years this new material was the preferred material for making a large variety of religious, civilian and military artefacts.

In comparison to the bronze used for mould castings, the starting material for the fabrication of sheets by cold hammering had to meet more stringent quality requirements concerning the tin content and the purity level. For most products the tin concentrations lay within the rather narrow range of 8 to 10 % by weight and the impurity level is in general extremely low with the notable absence of lead. There are good forming related metallurgical reasons for this.

Besides this standard concentration, another one in the range 12 to 14 % was also used for the production of prestige objects. Aesthetic reasons were probably the main driving force for the development of this type of alloy.

Whereas in Europe bronze was only cold worked, a third brand with tin contents around 22 to 24 % was hot worked in and around India during the last two millennia.

During the Roman Empire bronze was more and more replaced by brass and iron in sheet making. Bronze wrought products were forgotten until the first half of the 20th century. Nowadays, they are mainly used in mechanical and electromechanical applications. A characteristic difference with “old” bronze is the doping with phosphor: its beneficial aspect was discovered firstly for foundry alloys during the 19th century.

Montreal Metal Industries 1760 to 1910 - Cradle of Canadian Industry

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Innovation 1760-1910 in Montreal's iron foundries, machine shops, nail factories and rolling mills was not usually the result of scientific research but implantation (by ambitious craftsmen with sound training) of manufacturing techniques locally novel in response to demand and overcoming local constraints, such as no coal or non-bog ore in 1,000 km. The foundry industry in Montreal started with cupola furnaces about 1800, specializing in potash cauldrons, stoves, architectural decorations/pillars/beams, and after 1860 long-wearing railway wheels. The first marine steam engine was built in 1809 and between 1819 and 1837, 33 low-pressure, walking-beam models were produced powering the entire St. Lawrence fleet. Following 1851 deepening, the Lachine Canal provided water turbines at every lock for nail cutting machines, bushelling and forging of wrought iron, and rolling mills (locally built, 1858-68) for nailsheet. After 1881, steam powered mills for rods, plates and pipes led to conversion to Scottish steel and in 1910, to founding of Canada's biggest steel company (STELCO, Hamilton blast furnaces). The Grand Trunk Railway's main shops at Pointe Saint-Charles in Montreal and the Angus shops of Canadian Pacific Railway were a major manufacturing centres for passenger and freight cars as well as repairs to locomotives. While the Victoria Tubular Bridge (1859) required English pre-fabrication and Irish workmen, Montreal's Dominion Bridge fabricated half the Victoria Truss Bridge (1898) and provided an innovative design for the Quebec Bridge (1917) that saw worldwide use.

Innovation and Change in the Welsh Tinplate Industry

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The Innovation and Change that has taken place in the Welsh Tinplate Industry, is covered from Andrew Yarranton's early contribution which he 'acquired' from Saxony in the 1660s, through the industry's initial 'kick-start' made by the founder of Welsh Tinplating, Major John Hanbury of Pontypool, who introduced iron rolling prior to 1697, right up to to-day's modern highly efficient and competitive Tinplate Manufacturing Plant at Trostre Works in Llanelli.

Along the way, both Innovation and Change are considered that gave the Welsh Tinplate Industry its world-wide prominence from the early 1700s to its decline in the late 1890s. This decline was precipitated by the McKinley Tariff Duty introduced in the United States in 1891. Behind the protection of this duty, the fledgling American Tinplate Industry prospered at the expense of the Welsh Tinplate Trade.

After 1891, the United States set the pace and almost captured the market long held by Welsh Tinplating. A very difficult period of years followed for South Wales and the old industry only began to recover after both new labour saving machinery was introduced and new markets for tinplate were sought and won outside America.

In conclusion, the progress of the Welsh Tinplate Industry is examined through two World Wars right up to the present day. At this point, Trostre Works is examined in detail where Innovation and Change are continuously being introduced to match the development of new technology and methodology, to make it one of the World's most efficient and competitive tinplate manufacturing plants.

The Iron and Steel Industry from the Founding of HMS to the Present

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The production of iron and steel has seen profound changes since 1960, not only in the volume produced but also a marked change in the geographic centres of production. In 1960, around 325 million tonnes of crude steel were made worldwide, by 2011, the figure had increased to 1.5 billion tonnes of which 695 million tonnes was produced by China alone. Asia is now the predominant producer accounting for nearly two-thirds of world production.

This paper will follow the technical developments in iron and steel production since the 1960s and follow the changing philosophy from quantity to quality production. It will also address the issue of CO₂ emissions and the attempts made to abate this by developing technologies through cooperative programmes. Such emissions must be factored in when conducting life cycle analysis to balance the emissions during steel production against emissions saved by the efficient use of steel such as by light weighting vehicles through the use of higher strength thinner gauge steels or the development of high temperature steels for more efficient power generation.

Further Information

Dr Smith is Editor of Steel Times International and has been working on this and its former sister publication, Steel Times since 1988. He also edited Aluminium International Today for five years and is now consulting editor on this publication.

A metallurgist by training, he first worked in the steel industry as a student in 1967 and has since worked in the aluminium industry, the nuclear industry and spent seven years in the copper extraction and mining industry in Zambia.

Early Metallurgy in the Central Mediterranean: Goals for the next decade

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After a long spell characterised by little research on the topic, the last ten years have seen an upsurge in archaeometallurgical work throughout the central Mediterranean region. Significant discoveries have been made including a 4th millennium BC copper mine from northwest Italy – the earliest known in Western Europe (Maggi & Pearce 2005) – and a 3rd millennium BC smelting furnace from Sicily – one of the earliest ever found south of the Alps (Giannitrapani & Ianni 2011). Moreover, radiocarbon has for the first time allowed a full appraisal of the sequence of inventions and innovations that led to the emergence of polymetallic technology in this region. Strikingly, this process is now understood to have begun in the mid/late 5th millennium BC, much earlier than it was until recently believed (Dolfini 2010; in press). However, much remains to be done to obtain a fuller understanding of technological change from the 5th to the 3rd millennium BC, and to detail the picture hinted at by the new data. With this aim in mind, the paper proposes an agenda for future archaeometallurgical research in the central Mediterranean region. This should include long-overdue publication of key sites, analysis of smelting and metalworking residues, and experimental work into the prehistoric chaîne opératoire of copper, silver, and antimony making.

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Production and distribution of iron in Southern Germany during the Iron Age

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Many of the various iron ore deposits in Southern Germany not only have a different metallogeny but also a different history of mining. Research projects of the last twenty years revealed changes from the earliest periods of the Iron Age to the industrial period. Indeed it becomes more and more clear, that ore choice and techniques were already varied in the early stages. Manganese-rich limonite ores in the Northern Black Forest were firstly used in the early Iron Age, followed by hydrated hematite crusts from the Swabian Mountains. Later Iron Age furnaces are mainly found within bog ore deposits. Typical cupola or domed furnaces were continuously used during the Iron Age, but their size and air supply systems were variable. The iron produced in these furnaces is clearly at hand by tools and weapons within burials and settlement, but also by ingots found deriving from hoards as well as from rivers and lakes. So the questions are where, wherefrom and how far the iron was traded. It remains notoriously difficult to establish the origin of iron object from its composition, so we explored the possibility to use osmium isotope ratios for provenance investigations of iron. A first successful study deals with blooms, slag, charcoals and furnace material from a well dated archaeological site as well as with similar materials from a modern smelting experiment (Brauns et al. 2012), and in a case study more than 20 iron ore samples are analyzed for their osmium isotopic composition and compared to the data of archaeological finds from a hoard near smelting sites in the Northern Black Forest. It clearly shows that Os isotopic composition of “black forest type” iron ores, which can be found in all iron blooms excavated in the Northern Black Forest can be detected in the axes from the hoard. The signature of a sickle clearly indicates a different origin.

Within a French-German research project further Osmium isotope data are generated and compared to trace element analysis of slag inclusions.

The Steel Age: When and where did it begin, and how did it develop before the late 1st Millennium CE?

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Why do we not (generally) use the term ‘the Steel Age’ when steel is perhaps the most familiar and arguably the most important of the alloys of antiquity to have come through to the present day. We have the Bronze Age which is fairly well recognised as having developed from the Copper Age but we do not generally use the term Steel Age as a development of the Iron Age, although the logical progression is much the same. Why is this so?

One reason may be that steel, despite being so well known, is perhaps the least well understood of the alloys of antiquity. This situation is not helped by the tendency of most museums to simply label all corroded ferrous artefacts as ‘iron’. Correspondingly, relatively uncorroded – or at least well cleaned – but perhaps fancier ferrous artefacts that appear in many catalogues or displays are very often (and sometimes exclusively) labelled ‘steel’ without any knowledge at all of their actual composition. It is small wonder then that anyone apart from a ferrous archaeo-metallurgist has really any idea of the problem that lurks beneath the surface, or how complex or interesting the actual picture might be.

The main aim of this paper is to take a look at this problem and tease out some kind of cohesive picture from such evidence – archaeological, technological and historical – that exists for early specialised iron alloys. The purpose here is also as to look at ways we might (re-) evaluate that evidence, improve the database, and work towards more systematic ways of looking at it in the future.

Fragments through the smoke: The evolution of the bloomery furnace in Britain and Ireland

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Truncated remains, unsympathetic model-driven excavation, poor scientific dating and the pressures of commercial archaeology have all contributed to a poor understanding of bloomery furnaces in Britain and Ireland. New archaeological data are becoming available, however, even if in large part buried in the 'grey literature'. These data are supplemented by the understanding being generated by the rise in the amount of high quality recreation and experiment being undertaken by skilled crafts persons. This contribution is an attempt to sift current 'knowledge' and to synthesise a coherent evolutionary story, in as far as that is possible with the very limited data. The story which emerges is one of punctuation; new ideas introduced from outside the islands, followed by periods of development and innovation within the region. The evolution of furnace design is mainly one of changing approaches to slag management, particularly when required by the exploitation of iron ores of different composition and by the changing scale on which the operation was undertaken. Different solutions to similar problems are seen at different times. The interpretation of furnace morphology in a functional sense is possible in some circumstances, but validation of the interpretations and assumptions through recreation has only been attempted in very few types, leaving a rich field for future research. That future will build on the developing relationships between 'academic' and 'craft' communities; in particular, relationships are now being forged and strengthened via the global 'social media', a far cry from the world of derivation of the interpretation of bloomery morphology from Tylecote's laboratory experiments in the 1950s.

Provenancing and dating ferrous artefacts: an outcome of two decades of researches.

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Because ancient ferrous alloys produced by the bloomery process and the early indirect process are heterogeneous materials, their understanding is a complex task that needs a rigorous multi scale and multi technique approach. The Laboratoire Archeomatériaux et Prévision de l'Altération from the French Institut de Recherche sur les Archeomatériaux conducts researches on such alloys for several decades. In the general frame of understanding the relationship between iron, its production and ancient societies, several specific themes are studied. Among them, including iron production and manufacturing, technical gesture, appearance and diffusion of processing, three issues constitute a real challenge for archaeological sciences: (i) identifying the ironmaking processes (bloomery vs indirect), (ii) determining the provenance of iron, (iii) approaching an absolute radiocarbon dating of iron.

Concerning processes, circulation and provenance of iron, our work is based on the principle that some of the slag inclusions entrapped in the ancient metallic matrix contain the fingerprint of (i) the smelting system and its thermodynamic conditions, (ii) the elemental signature of the initial ore. Nevertheless, because this initial information can be blurred (other sources of inclusions, fragmentation effect, complexity of the geologic context), specific data treatments (based on the understanding of the process as well as a statistical approach) are necessary to reach the pertinent information. As far as dating is concerned, we will show that it is possible in controlled conditions (specific protocol of sampling to minimize contaminations in conjunction with detailed metallurgical studies) to get a reliable estimation of the age of the ferrous artefacts by analysing the carbon present under carbides in the metallic matrix.

The aim of this communication is to present the methodological results achieved by our team and to propose prospects and breakthrough for the forthcoming years.

Late Bronze Age Slags from Trentino (Italy): Interpretation of the Copper Smelting Model

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At the end of the second millennium BC the extractive metallurgy of copper in North-Eastern Italy achieved a peak of technological efficiency and mass production, as evidenced by the large number of metallurgical sites and the total amount of slags resulting from smelting activities. Though several smelting processes have been proposed, an agreed interpretation of the whole process is lacking.

Based on a collaboration with the Archaeological Heritage Office of the Autonomous Province of Trento and thanks to their recent excavations (directed by Dr. F. Nicolis and Dr. P. Bellintani, with the collaboration of E. Silvestri), over 70 slags from the Luserna, Transacqua and Segonzano sites (Trentino, Italy) have been characterized by means of OM, XRPD, XRF and SEM-EDS. A few metallurgical smelting experiments were carried out in order to explore both the slagging and the matting processes.

Three different types of archaeological slags have been distinguished from the mineralogical and chemical points of view: the two well-known Alpine LBA “coarse” and “flat” slag types, and a new intermediate type of slag here defined as “massive”. The three slag groups differ in the size and relative amount of the unreacted sulphides, the highly Cu-enriched matte, and the metallic copper. The ratio between the restitic quartz and the newly formed fayalite and magnetite is also a distinctive parameter, possibly related to the maximum temperature involved in each step.

It is proposed that the three types of slags are related to three distinct metallurgical steps: 1) the coarse slags are the product of the initial roasting/slagging operations, where a Cu-poor matte is produced, mainly of bornitic composition, 2) the massive slags are the result of the major matting process, where a Cu-rich matte (covellite-chalcocite composition) is produced, and 3) the thin flat slags are the product of the final refining process, formed directly at the surface of the raw molten metal.

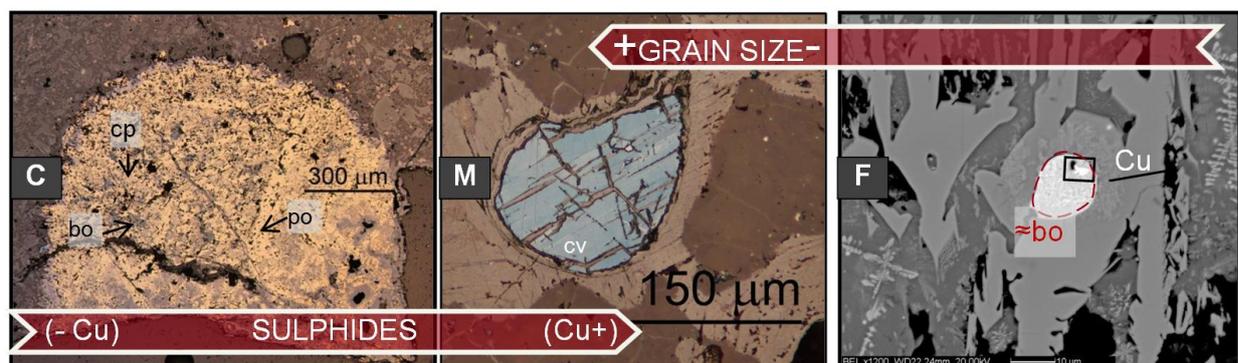


Figure 1: Example of the sulphides (*cp*=chalcopyrite, *po*=pyrrhotite, *cv*=covellite, *bo*=bornite) present into the three slags types at different transformation degrees, (C=coarse slags, M=massive slags, F=flat slags).

Casting in Context: Analysing the Social Settings of Bronze Artefact Production in Late Bronze Age Scandinavia

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Over the last decades there has been a substantial increase in the number of excavated sites with traces of bronze casting in Sweden. In an on-going PhD project these contexts are being systematically surveyed and re-examined with the aim of analysing the social context of bronze artefact production and discussing its implications. In contrast to many earlier works on the subject, my focus is primarily on the social arena in which the casting took place, rather than in the ritual/symbolic or technical character of the technology itself, or the technological choices leading up to the final artefact. By drawing on this contextual approach, looking at differences in where specific types of artefacts were cast, a new perspective emerges with insights about the social meaning of various bronze objects as well as about the social role of the craft. In this poster I will try to exemplify these ideas by drawing on a number of recently excavated Late Bronze Age sites in the Mälaren Valley of south-eastern Sweden. By illustrating that the casting occurred in diverging social contexts, I will suggest that bronze production constituted several different social practices in Late Bronze Age society.

Roman ironmaking without the use of bellows!

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In Mid-Norway and neighbouring Sweden more than 300 large bloomery sites of the type shaft furnace with slag pit from the Early Iron Age have been registered. Being situated near the tree line far from present- day dwellings, they are well preserved and lend themselves to scientific studies.

The slag pit built of stone with diameter < 80 cm with in-situ slag from the last smelting was so-to-speak permanent while the shaft of burnt clay is present as broken pieces only. A standard site will comprise 4 furnaces in a row along a terrace with some 50 tons of slag in front, removed as a solid through a vertical slot in the pit. The furnaces were for re-use.

By dating of pieces of charcoal with the ^{14}C -method we found that the smelters had exclusively used wood from pine while birch was abundant. No pits for charcoal production prior to 700 AD has been found, nor is there any spilling of charcoal around the furnaces. This has led to the postulate that the furnaces were operated by an induced draft(chimney fire), created by combustion of gases of resin and tar from wood, inserted directly into the shaft. Thereby charcoal was created. Experiments have shown that the flames reach some 4 m up in the air, thereby excluding a roof above the furnaces.

A single find of a piece from the shaft with the half of an opening measuring 8 cm represents an air inlet, not the tuyère of bellows.

This idea has led to a chaîne opératoire, consisting of addition of split wood, combustion to charcoal, which sinks down and burns at a high temperature upon the next addition of wood. This represents a cyclic operation, which is documented by decantation of slag in discrete amounts. It can also explain how a high content of FeO in the slag was maintained, required for the carbon control of the bloom.

Split blooms from the period weighing some 17 kg have been studied. They express a metal of high quality, with a low carbon content and a minimum of slag.

Anglo-Saxon goldsmithing workshop practices seen from the Staffordshire Hoard

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The Staffordshire Hoard was discovered near Lichfield in Staffordshire, England, in 2009, and consists of the largest assemblage of Anglo-Saxon gold and silver metalwork ever found, currently dated to the sixth to eighth centuries. Almost all the items represented are military, with a high number of sword fittings and some Christian items. Anglo-Saxon goldsmiths used a few specialist techniques to produce the distinctive style of the period and the hoard exhibits a range in quality of skill and materials employed. Most of the artefacts are decorated with zoomorphic and geometric designs using intricate filigree, niello and glass inlays, and cloisonné garnets.

The pieces are fragmentary, folded or dismantled, apparently much of this occurring before burial: no blades were found amongst the many hilt fittings. This damage has the advantage that it allows access for analysis and examination in order to investigate the materials and techniques used. English Heritage and the owners of the Hoard, Birmingham Museums Trust and the Potteries Museum and Art Gallery, Stoke, have commissioned scientific examination and conservation from specialist centres including the British Museum.

This paper presents the scientific investigation of workshop techniques seen within the Hoard, with particular emphasis on filigree. Selected objects were examined and analysed using a combination of X-radiography, optical microscopy and scanning electron microscopy with energy dispersive X-ray analysis in order to characterise their manufacturing technology and to compare them with contemporary high status items from Anglo Saxon sites such as Sutton Hoo and Taplow.

The identification of tin oxide in crucible slag

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Tin oxide is often encountered in crucible slag of metallurgical operations related to bronze melting, remelting and alloying. Its identification, however, is not as straightforward as one would assume. It can derive from the preferential oxidation of tin from bronze, the oxidation of tin metal, the re-oxidation of cassiterite (mineral tin oxide) previously reduced in the same operation, or it could simply be residual mineral cassiterite. These different processes and origins can give rise to chemically identical (SnO₂), but morphologically different tin oxide phases, though no convincing overview of correlations has been published so far.

In this paper, an overview of previous research related to this topic is given, showing the variety in structural occurrences of tin oxide and the variety in employed nomenclature and interpretation. The implications this has on the understanding of ancient crucible bronze metallurgy are elucidated. A main concern about the inability to ascertain the origin of a particular tin oxide phase in crucible slag is the resulting failure to make important inferences about technological choices and material supplies.

Starting from the author's on-going PhD research (bronze alloying in New Kingdom Egypt), the interpretative consequences of this literature/research hiatus are illustrated and some solutions are suggested. The potential of experimental work in bridging this gap is shown through existing examples in the literature and from the author's own experiments.

The History of Tin and Bronze in Anatolia

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The discovery of metals is one the turning points in civilisation history. The first metal that people of Anatolia came to recognize was copper. With the alloy of copper with tin, which is another metal, bronze was obtained. The information acquired from excavations indicate that bronze artefacts began to be used in ancient times. Bronze artefacts, which showed substantial development in Rome during the Byzantine period, also drew attention during the Ottoman period.

Some other data obtained from the excavations and manuscripts in Anatolia show that although Anatolia had some very rich copper deposits, the tin that originated in Anatolia was not enough for bronze production to be used to manufacture various items, particularly jewellery and weapons. This is why, the tin needed for bronze production was brought to Anatolia from Mesopotamia, Middle East, Mediterranean countries and the tin islands around Britain called the Cassiterites, where the richest tin production and trade all over the world were made.

Thanks to the tablets found in Kültepe excavations, firstly we have found out that tin trade was carried out in Anatolia at the beginning of 2000 BC. In light of the information obtained from these tablets, there is evidence that there was mine trade between Anatolia and Mesopotamia. It was also confirmed that in exchange for tin, which was required for bronze production, copper, gold and silver were sold to Mesopotamia. Initial information related to the tin deposits assumed to be in Turkey points to the early 19th century. These findings reveal how bronze, which is an alloy, was acquired and tin, which was used to obtain bronze, came to Anatolia, and all these historical processes.

Microstructure observation on heat treatable high tin bronze bowls excavated at Japanese antiquities

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In Japan, many high tin bronze wares called Sahari are kept in the Shosoin treasure house and Horyuji temple in Nara. Unearthed case of sahari goes possibly as far back as the late tumulus period (early 6th century AD). The heat treatment process of Cu-Sn binary high tin bronze, which contains more than 15% tin (up to 25%) is different to that of low tin bronze because those high tin bronzes contains brittle δ phase. For eliminating brittleness from those as-cast or as-forged high tin bronzes, a combination of solution heat treatment and water quenching is needed. The brittle δ phase transforms to ductile β phase by solution heat treatment. And water quenching just after solution heat treatment prevents eutectoid reaction which cause re-precipitation of brittle δ phase. The sahari is a kind of those “heat treatable high tin bronze”. Compositions of those wares analyzed by XRF have been published, however, microstructural observation have not carried out because they are designated as national treasure or important cultural assets. Therefore, fabrication method of heat treatable high tin bronze wares in ancient Japan remains to be fully elucidated. In this study, bronze bowl fragments from the antiquities of 8-9th century AD in Gunma-prefecture were subjected to chemical analysis and metallographic observations. Forming and heat treatment techniques on a heat treatable high tin bronze of ancient Japanese local families were examined.

Ternary bronzes Cu-Sn-Pb in Prehistory: An experimental approach

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As is well known, ternary bronze objects are characteristic of European Late Bronze Age, particularly in its later stage, with some scarce examples in the late Middle Bronze. From the geographical point of view, its greatest impact lies in regions where the Atlantic Bronze flourished, with less impact on the Mediterranean basin. Tin and lead mineralizations in Western Europe are also well known. But exploitation of these resources in Prehistory is a pending subject despite its obvious technological importance: there are few metallic items made of lead or tin before the Iron Age when compared with the high production of binary and ternary bronze objects. Furthermore, the use of lead is usually associated with the Phoenician presence in the Iberian Peninsula (8th century BC) and silver production by cupellation.

Seeking answers to the questions posed by the development of ternary bronzes and its importance as a change and metallurgical innovation, several experiments have been performed by a) co-smelting chrysocolla, galena and cassiterite, and b) copper cementation with cassiterite and galena.

The operations were carried out in a very simple installation: a hollow pit dug into the ground about 40 cm in diameter and 15 cm deep, charcoal, four blowing pipes and smelting crucibles to contain the minerals, the latter crushed and mixed in suitable proportions for getting metal of the usual percentages measured in archaeological bronzes.

The results were satisfactory both with the co-smelting process as with cementation. The resulting materials (slag, crucibles and metal ingots) were analyzed in the laboratory using SEM, XRF Spectrometry and metallographic techniques to determine the kinetics of reactions.

The Copper Age Gold from Varna – An impetus for social development?

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Within a long-term research project funded by the German Research Foundation it was possible to gain a more detailed insight in the burial society from Varna (Bulgaria). The cemetery dates to the mid-5th millennium BC (cal.) and provides still the first evidence of a large-scale metal production and a yet unknown level of social differentiation. Since the discovery of the site, archaeologists were intrigued by the question about how these two aspects of society interrelate with each other. Is the social development a result of the developing metallurgy or is it the other way around? Until now there were just a limited number of graves investigated and published in detail and these were the richest and most extraordinary ones, thus reflecting just a small part of the buried society.

During the last two years it has been possible to examine the archaeological material entirely. One focus was put on the investigation of the ca. 3.000 gold objects that could be analysed chemically, typologically and in concern to their production techniques. Additionally geological research was performed in eastern Bulgaria to shed light on the geo-economic situation of this region. The combination of the so gained information helped us to reconstruct the metallurgical chain with its organisational structures. Furthermore, the statistical evaluation of the different archaeological information shows the relative chronological development of the Varna site. On this new basis we again try to approach the question of the progress and the final decline of the Varna society, which shall be discussed within this presentation.

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New Research into Roman Metal Mining in Britain

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Excavations carried out at Alderley Edge, Cheshire in 1997 uncovered an 11m-deep Roman mine shaft and level at Engine Vein where lead or copper, and perhaps a blue azurite pigment were being worked shortly after the Roman Conquest of Britain, perhaps whilst under military control. In Wales archaeological fieldwork carried out in conjunction with palaeo-environmental investigations undertaken on surrounding peat mires has revealed four sites of probable Roman lead and copper mining (Darren, Cwmystwyth, Pen Cerrig y mwyn and Craig y mwyn), the last three of which were associated with hushing, and two lead smelting sites. A significant discovery made in 2002 was that of a Roman lead bole (wind-blown furnace) excavated at Cwmystwyth, the first example of such a site to be looked at in Britain. This work raises some interesting ideas about the prospection and early exploitation of metals in Britain relatively soon after the Roman Conquest, with descriptions of the types of mining and the smelting technology practised.

Research of bronze turban-shape circle from Iron Age

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The work deals with determination of material research and production technology of bronze-shape turban circle from Iron Age found in southern Bohemia. The circle is made from bronze sheet and its entire surface is decorated with extensive geometric linear decoration. Artefact function is not clear, it is probably the decorative object of the human body. During research artefact were observed particular aspects of the chemical composition of the materials, processes of manufacture, reparations from the past, geometric decoration and determine necessary equipment for production the circle. For the examination of artefact were used metallographic analysis, SEM/EDS, XRD and profilometer methods. The research has found that the artefact is made by techniques of mechanical forming of tin bronze alloy with a number of nonmetallic sulphide inclusions. Sulphide inclusions in the material structure are providing us detail information about metal material preparing and forming. Repair cracks caused during the production of artefact were made by technology of overflow on existing metal base. Documentation of linear decoration on circle surface is confirmed assumptions about the technology of engraving according to the geometric plan.

Conservation-restoration and investigation of the Early Iron Age Iron Sword from Kaptol, Croatia

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The poster presents the conservation-restoration treatment of the iron sword found during the 2005 excavation of the unique and rich princely grave which belongs to the oldest group (8th century BC) of tumuli in the early iron age necropolis near Kaptol village, Croatia. The sword was found together with the numerous ceramic vessels and extraordinary metal finds (situla, helmet, swords, axes, spears, horse gear...). It had the wooden scabbard with iron belt mount and had probably been wrapped in cloth before it was put in the grave chamber. In order to get some basic information on the production technology of the sword, metallographic investigation was carried out in Curt-Engelhorn-Zentrum Archäometrie in Mannheim. The results obtained show that the sword was made of heterogeneously carburised steel with no sign of deliberate piling or quenching. The pearlitic structure (0,8 % C) on the cutting edge has maximum hardness of 310 HV 0,1 while the ferritic-pearlitic structure (0,2 % C) in the interior of the blade has maximum hardness of 120 HV 0,1.

So far, it is the earliest iron sword found in Croatia.

Metallurgy Beyond Technology: Metalworking Debris as Historical Evidence

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Finding evidence of metalworking in archaeological excavations can disclose new and unexpected insights into the historical and social context of the investigated sites.

Throughout the past century, building works in Vimercate, a small town some 20 kms from Milan, have yielded archaeological remains, such as burials, epigraphs and the remains of a Roman bridge. Such a scattered evidence, though meaningful, was not enough to understand what kind of settlement Vimercate had been in the Roman age. Lacking written sources, we have no information as to its social and political organizations: was it a cluster of rural villas? A small village? A vicus?

The most recent excavations, carried out in 1999-2000 in Piazza Marconi, provided new and significant information. Alongside with 23 late-Roman burials and the remains of a gravelled road, part of a metalworking workshop was found. It appears that the workshop had been solely devoted to bronze-casting, in use for at least 50 years.

There is no evidence as to the artefacts produced here: all the same, assessing the size, complexity and typology of the casting facilities it was possible to reconstruct a highly professional, specialized workshop used for casting medium- and large-sized objects.

Such a structure is hardly compatible with a rural villa or a small village: therefore, the metalworking evidence has become a significant clue of the possible existence of a vicus, i.e. the smallest unit of a Roman municipal administration, or of a similar organized settlement.

Elementary Analysis of Roman Enamelled Brooches in Gallia Belgica and Germania: Preliminary results

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A research on the technology of Roman enamelled brooches started in September 2011. One of the purposes of this study is to characterise the elementary composition of both the alloys and the enamels of brooches in order to identify technological choices and both chronological or regional differences within the composition. Around 350 Roman enamelled brooches have been selected in order to be analysed by XRF and EDX-SEM analysis. The paper presents the first results of the elementary analysis of both metals and enamels.

The XRF analysis of metal was done on a cleaned surface of the brooches in order to avoid the corrosion effect. Three types of alloy have been identified: Tin bronze, Brass and Gunmetals. Brass brooches seem to exclusively match with 1st century types. Gunmetals tend to be highly used for the Late 2nd century brooches and could be testimonies of recycling process. Significant amount of lead has been detected in some types made by casting. The presence of lead is thus believed to be a technological choice in order to improve the castibility of the alloy. The elementary composition of the enamels was determined by EDX-SEM analysis either directly on the surface of the enamel or on mounted samples. Different colouring agents have been identified for the different colours (black, blue, turquoise, red, orange, green, yellow, and white), and sometimes for the same colour. These variations in the 'recipes' are believed to be due to the production of particular enamels on different areas and/or at different time.

Festival of Mammayee: The socio-cultural context of iron-working in northern Telangana, India

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Archaeological field survey conducted under the Pioneering Metallurgy Project of 2010 in four districts (Karimnagar, Adilabad, Nizamabad and Warrangal) of the south Indian state of Andhra Pradesh has revealed significant evidence of iron and steel production in antiquity. As an integral part of this project, a preliminary ethnographic study was undertaken among the extant traditional iron working community (both erstwhile smelter turned blacksmiths and traditional blacksmith families) and their clientele to salvage the fast disappearing memory of past smelting technology and to aid understanding of the archaeometallurgical record from a socio-cultural perspective.

The first author is undertaking a detailed ethnoarchaeological study of the society, culture, traditions and technology of present day traditional iron-working communities of south and central India as postgraduate research. An important aspect of this ethnoarchaeological study has been recording the annual festival of the local cult of goddess Mammayee. Mammayee is the goddess of metal workers, especially the blacksmiths and the cult, along with its rituals, serve as an important force in determining the social and cultural behaviour of local blacksmiths, both in relation to their craft and in the way in which intra- and inter-caste relationships are defined in social space and played out in physical space. The present poster documents different aspects of this festival and the detailed rituals of renewal that are enacted and seeks to provide insights into an important but fading tradition.