Abstracts

GENERAL

A Dolfini and R J Crellin. Metalwork wear analysis: The loss of innocence. *Journal of Archaeological Science* 66, 2016, 78-87.

Metalwork wear analysis has now been practiced for over two decades. The paper assesses current methodologies and argues that an increase in scientific rigor and a focus on addressing limitations and open problems is required if metalwork wear-analysis is to flourish as a scientific field of research. The focus has been on European prehistoric copper alloys, particularly from the Bronze Age, but it is suggested that the inclusion of analyses of copper alloys from the Americas and iron alloys from historic and ethnographic collections would expand the field and extend its relevance. The creation of digital reference collections, open to all, would provide metalwork analysts with opportunities in related fields of research.

BRITAIN AND IRELAND

S Timberlake. New ideas on the exploitation of copper, tin, gold, and lead ores in Bronze Age Britain: The mining, smelting, and movement of metal. *Materials and Manufacturing Processes* 32 (7-8), 709-727. http://dx.doi.org/10.1080/10426914.2016.1221113

Over the last 25 years, new evidence has emerged on the scale of prospection and mining during the Early-Middle Bronze Age in Britain. The reasons why the richest ores in Cornwall were apparently not worked are discussed. Evidence of tin extraction in Cornwall during the Early Bronze Age come from a dated antler pick from the Caron streamworks, paleo-environmental investigations and isotopic studies of tin in Bronze Age artefacts. Lead isotope studies suggest that alluvial gold, extracted from the Cornish tin streams more than 4000 years ago, might have been the main source of gold during the Copper to Early Bronze Age in Ireland and Britain. Lead, possibly from the Mendips in Somerset, has been used in small amounts since the Early Bronze Age both for artefacts and adding to bronze to aid casting. The earliest silver artefact also dates to this period. The status of miners, exchange, resource protection, experimentation, prospection, and the discovery of ores are also considered.

Q Wang, S Strekopytov, B W Roberts and N Wilkin. Tin ingots from a probable Bronze Age shipwreck off the coast of Salcombe, Devon: Composition and microstructure. *Journal of Archaeological Science* 67, 2016, 80-92.

Nearly 400 objects including copper and tin ingots, bronze artefacts/fragments and gold ornaments were found on a probable Bronze Age shipwreck off the coast of Salcombe in SW England between 1977 and 2013. The tin ingots provided a rare opportunity for a technical study of prehistoric tin. The chemical compositions of all the tin ingots were analysed using ICP-MS and ICP-AES. The microstructures of eight Salcombe ingots, selected to cover the different sizes, shapes and variable impurity levels, and also two ingots from the Erme Estuary, were examined using optical microscopy and SEM-EDS. The Salcombe tin ingots appeared to be quite pure with little variation in composition. Only two samples contained over 0.1% iron and one contains over 0.1% copper. An extensive overview of archaeological tin in Europe allowed comparison with the few available analyses of tin objects, *eg* the Late Bronze Age shipwreck of Uluburun, but did not suggest any connections.

EUROPE

M Benvenuti, A Orlando, D Borrini, L Chiarantini, P Costagliola, C Mazzotta and V Rimondi. Experimental smelting of iron ores from Elba Island (Tuscany, Italy): Results and implications for the reconstruction of ancient metallurgical processes and iron provenance. *Journal of Archaeological Science* 70, 2015, 110-128.

The iron deposits on Elba have been extensively exploited since the 1st millennium BC. Both raw iron ore and smelted blooms were widely traded through the Mediterranean region. As part of the multidisciplinary research project AITHALE, a series of archaeometallurgical experiments were carried out, primarily to investigate the traceability of Elban iron ores throughout the bloomery iron production *chaîne opératoire*. Field tests of a reconstructed bloomery furnace and laboratory smelting experiments in a gas mixing furnace are discussed. Slags produced by smelting W-Sn-rich iron (haematite) ores, like those from Elba, show the presence of these elements in phases of their own, either relict (scheelite, ferberite, cassiterite) and/or newly formed (iron-tin alloys). Iron blooms from this type of iron ore provide evidence of the peculiar geochemistry of the ore, with tungsten preferentially associated with slag inclusions and tin enriched in the metallic phase.

S Delgado-Raack, V Lull, K Martin, R Mico, C Rihuete Herrada and R Risch. The silversmith's workshop of Tira del Lienzo (Totana, Murcia) in the context of Iberian Bronze Age metallurgy. *Archaeometry* 58(5), 2016, 779-795.

The SE of the Iberian Peninsula saw deep social and political changes at the dawn of the 2nd millennium BCE. The emergence of important economic asymmetries inside communities was apparently based to a large extent on the control of the secondary metallurgical production process (*ie* forging). The recently excavated architectural complex at the Argaric site of Tira del Lienzo constitutes an exceptional find. A series of macrolithic artefacts were recorded, relating to the forging of metals and, more

specifically, to the working of silver, according to use-wear and residue analysis.

E Figueiredo, R J C Silva, M F Araújo and J C Senna-Martinez. Identification of ancient gilding technology and Late Bronze Age metallurgy by EDXRF, micro-EDXRF, SEM-EDS and metallographic techniques. *Microchim Acta* 168, 2010, 283-291.

EDXRF, micro-EDXRF, SEM-EDS analysis and metallography were used to study the gilding technology and bronze metallurgy of artefacts dating to the end of the 2nd millennium BC from Crasto de Sao Romao in Central Portugal. Analysis of a crucible fragment suggests bronze production at the archaeological site. A nail with a tin content of 9-15wt% was found to be gilded on the front of the head, although it appears that much of the gold layer has been lost in the most exposed areas. The gilding technique is discussed, based on the gold layer composition and gold/copper substrate interface. So far, this object seems to be the first diffusion gilded artefact identified in Portugal dated to Late Bronze Age.

A H Mason, W G Powell, H A Bankoff, R Mathur, A Bulatovic, V Filipovic and J Ruiz. Tin isotope characterisation of bronze artifacts of the central Balkans. *Journal of Archaeological Science* 69, 2016, 110-117.

Isotopic analysis has proved to be effective in provenancing copper ore sources for the production of bronze artefacts. More recently, methods for tin isotopic analysis of bronze have been developed. However, the paucity of published datasets means that using tin isotopes in attributing groups to ore sources and studying production methods or recycling is still in question. This study reports on the Sn isotopic composition of 52 bronze artefacts from the later Bronze Age (1500-1100 BCE) from Serbia and western Romania. The majority of samples cluster between 0.4 and 0.8 per mil for δ^{124}Sn, and 0.2 and 0.4 per mil for δ^{120}Sn (relative to NIST SRM 3161A). This isotopic group occurs across Serbia. However outlying groups suggest that sources in Transylvania, and placer tin deposits of western Serbia were being exploited.

J F Perez and M G Moret. Early ironwork in Biscay: Survey, excavation, experimentation and materials characterization. An integral study of the mountainside ironworks *(ferrerias de monte* or '*haizeolak').* *Materials and Manufacturing Processes* 32, 2017 (7-8: Ancient Metallurgy), 876-884. http://dx.doi.org/10.1080/10426914.2016.1221111

The production of iron in Biscay (Basque Country, Spain) has been a hallmark of this territory of the north of the Iberian Peninsula throughout its history. The archaeology team of the Basque Country Mining Museum has spent 13 years, so far, studying the origins of this activity through the evidence left at the old pre-hydraulic iron production workshops known as *ferrerias de monte* or *haizeolak* (mountainside ironworks). It has catalogued 170 archaeometallurgical sites of this type, and excavation of some of them has indicated the different stages of the production process in these workshops. Experiments reproduced the work carried out in a mountainside ironworks from the High Middle Ages, and the characterisation of this type of activity through the study of the collected materials has commenced.

A Thiele, J Hosek, N Antonie and T A Racz. Metallographic examination of two medieval knives from Kobilic (Republic of Croatia). *Materials and Manufacturing Processes* 32, 2017 (7-8: Ancient Metallurgy), 867-875. http://dx.doi.org/10.1080/10426914.2016.1232821

Archeological excavation conducted in 2010 in Kobilic yielded two knives, one of which is pattern-welded. This is the first reported Croatian pattern-welded knife. Metallographic investigation showed that both knives are of excellent functional quality. The pattern-welded knife has a single-patterned core, which ends before reaching the pointed part of the blade, and to which another strip of phosphoric iron was welded from above to increase the overall decorative effect. The construction of this knife is fairly typical of such 13th-century pattern-welded blades. The other blade is made of one heterogeneous piece of steel, distinguishing it from the majority of contemporary knives. The origin of the knives remains unknown, but considering that the pattern-welded knife is the only find known from the territory of Croatia to date, it is very likely that it was imported.

H Wrobel Norgaard. Metalcraft within the Nordic Bronze Age: Combined metallographic and superficial imaging reveals the technical repertoire in crafting bronze ornaments. *Journal of Archaeological Science* 64, 2015, 110-128.

Two approaches in the analysis of metal working techniques in the Nordic Bronze Age are reported: a comparison of experimentally-crafted ornaments was used to define characteristic traces of known crafting techniques, and metallographic analysis was used to explain recognisable superficial crafting traces. The metallographic investigation of 24 artefacts, which date to the early period of the Middle Bronze Age (around 1470-1290 BC) from the central Lower Saxony region, revealed an unexpectedly varied technical repertoire, including both casting (including the lost wax method in the Lüneburg group) and cold working. Intensive post-casting reworking was common. Further research will concentrate on regional peculiarities in the Nordic Bronze Age utilising the traces of the crafting process identified in this study.

P Valerio, A M M Soares, M Monteiro, A Pereira, M F Araujo and R J C Silva. A compositional and microstructural study of eighth-century BC bronzes from Moita da Ladra (Tagus Estuary): How did the spread of the Phoenician metallurgy take place in western Iberia? *Archaeometry* 58(4), 2016, 593-609.

Metals from a votive deposit at Moita da Ladra dating to the 8th century bc were studied by micro-EDXRF, optical microscopy and Vickers testing to investigate the adoption of Phoenician innovations by indigenous communities. Artefacts are made of bronze alloys with suitable tin contents (11.6 ± 2.3wt%) and very low iron impurities (<0.05wt%), and were often manufactured using the long post-casting sequence. Comparisons between indigenous and Phoenician metallurgies from western Iberia revealed a conservative technology suggesting that the spread of Phoenician innovations was very slow. In this region, the adoption of a diversified copper-based metallurgy and reduction furnaces only seems to occur during the post-Orientalizing period, *c* 6th-4th centuries bc.

P Valerio, A M M Soares, M F Araujo, R J C Silva and L Baptista. Middle Bronze Age arsenical copper alloys in southern Portugal. *Archaeometry* 58(6), 2016, 1003-1023.

A collection of 53 MBA artefacts from southern Portugal was analysed by micro-EDXRF, optical microscopy, SEM-EDS and Vickers hardness. No technological distinction was found between artefacts from domestic and funerary contexts (radiocarbon dated to 2000-1500 cal BC). The arsenic contents of almost 100 MBA artefacts from this region, including the above-mentioned set, have a Gaussian distribution with a high average (3.9wt% As), although the copper metallurgy from the Chalcolithic to the MBA in the Iberian Peninsula is mostly characterised by low arsenic contents. Possible explanations are discussed for this distinctive metallurgy at the SW end of the Iberian Peninsula.

NEAR EAST

M Jansen, S Aulbach, A Hauptmann, H E Hofer, S Klein, M Kruger and R L Zettler. Platinum group placer minerals in ancient gold artefacts: Geochemistry and osmium isotopes of inclusions in Early Bronze Age gold from Ur/Mesopotamia. *Journal of Archaeological Science* 68, 2016, 12-23.

Gold artefacts from the early dynastic royal tombs of Ur, Mesopotamia contain numerous platinum group elements (PGE) osmium-iridium-ruthenium inclusions. Gold and other heavy minerals are enriched with PGE (PGM) minerals in placer deposits. As they are very refractory, PGMs remain almost unmodified during extraction and the subsequent production of gold artefacts. The chemical and Os-isotope compositions of the PGE inclusions were analysed to evaluate their potential in gold provenance studies. The Ur gold has highly variable concentrations of Os (26-70wt%), Ir (14-62wt%) and Ru (0.4-45wt%). $^{187}Os/^{188}Os$ isotope ratios vary between 0.118 and 0.178. The high Ru content of the alloys suggests a geological context of ophiolite complexes. The various possible sources are discussed and the method is evaluated.

O Oudbashi, R Naseri and M Malekzadeh. Technical studies on the Bronze Age metal artefacts from the graveyard of Deh Dumen, south-western Iran (third millennium BC). *Archaeometry* 58(6), 2016, 947-965.

During the excavations of the graveyard at the site of Deh Dumen in SW Iran, 15 Early/Middle Bronze Age graves were uncovered. Eight broken metal vessels and a decorative strip from the handle of a dagger were analysed using ICP-MS. The bodies of the vessels are made of tin bronze with variable amounts of tin, while the internal piece of the base of one vessel is made from an arsenical copper alloy. SEM-EDS revealed elongated Cu-S inclusions and lead globules as various phases formed in bronze solid solution. The metallic strip is a thin sheet manufactured from silver.

ASIA

P T Craddock, K T M Hegde, L K Gurjar and L Willies. *Early Indian Metallurgy*. 2017. London: Archetype Publications.

The book describes investigations into the production of metals in NW India which lasted for three millennia. It includes chapters on the geography and geology, early metallurgy in the Aravalli Hills and Rajasthan, the history and monuments of Zawar, Rajpura-Dariba and Rampura-Agucha and the foundation of Hindustan Zinc Limited. The investigations of the mining operations, together with surface surveys and excavation work at Zawar, Dariba and Agucha are included. The processes of mining, beneficiation, smelting and the production of silver, brass and zinc are discussed in other chapters. A number of authors contribute to a chapter on the scientific examination of the industrial materials from Zawar, Dariba and Agucha and the book concludes with surveys of the recent history of metallurgy in the area and beyond in India.

AFRICA

J Humphris and C Carey. New methods for investigating slag heaps: Integrating geoprospection, excavation and quantitative methods at Meroe, Sudan. *Journal of Archaeological Science* 70, 2016, 110-128.

This study of the slag heaps at the royal city of Meroe marries together geoprospection data (gradiometry and electrical resistivity transects) with topographic and quantitative excavation data, to provide an analysis and comparison of the total volume, slag component and slag composition of a slag heap. The results demonstrate the limitations of using a topographic-only model and also show that volumetric modelling must be integrated within the quantitative characterisation of slag heap composition. In this case, quantitative sampling of the slag deposits revealed that the composition of the slag assemblage was dominated by a newly defined category of slag which has major implications for reconstructing iron technologies in the Meroitic civilisation. This research highlights the dangers of applying simplistic models and basic investigative strategies to iron slag heaps. It furthers the debate on applying volumetric modelling and excavation sampling to unexcavated areas of the finite and important resource of archaeometallurgical deposit sequences.

B Kaufman, R Docter, C Fischer, F Chelbi and B M Telmini. **Ferrous metallurgy from the Bir Massouda metallurgical precinct at Phoenician and Punic Carthage and the beginning of the North African Iron Age.** *Journal of Archaeological Science* 71, 2016, 33-50.

Excavations of the Phoenician and Punic layers at the site of Bir Massouda in Carthage have provided evidence for ferrous metallurgical activity spanning several centuries. Analyses of slagged tuyeres, slag, and alloys using optical microscopy, pXRF and VPSEM-EDS show that Carthaginian smiths were conducting primary smithing and forging of wrought iron and steel. Although the majority of slag specimens are remnant from ferrous production, a few select finds are from bronze recycling. The corpus represents the earliest known ferrous metallurgy in North Africa. As a Phoenician colony, then later as an independent imperial metropolis, Carthage specialized in centrally organized ferrous technology at the fringes of the settlement in areas such as Bir Massouda and the Byrsa Hill from before 700 to 146 BC.

THE AMERICAS

M Hernandez , M Hernandez-Escampa, C Abreu, J Uruchurtu, M Bethencourt and A Covelo. Characterisation of a historical cannonball from the fortress of San Juan de Ulua exposed to a marine environment. *Archaeometry* 58(4), 2016, 610-623.

Metallurgical analyses and chemical characterisation were carried out on historical cannonballs from the Fortress of San Juan de Ulua, Veracruz, Mexico. Cannonballs dating from the 18th and 19th centuries share similar metallurgical characteristics to material coming from a shipment of ammunition found in the wreck of a sunken French ship from the battle of Trafalgar. The analyses show that the base material is grey cast iron with a carbon equivalent of 4.94 and a ferritic-pearlitic matrix, in which the high phosphorus content has led to the formation of iron phosphide compounds in conjunction with a homogeneous distribution of carbon graphite flakes of Type C. Corrosion products were also studied.

The abstracts are edited by Janet Lang. The Honorary Editors would like to acknowledge her continuing help, and that of others who contribute abstracts. Where no source is given, the abstract has been adapted from that provided by the author(s) of the paper. Other abstracts relating to archaeometallurgy can be found in the British and Irish Archaeological Bibliography, available on line at http://www.biab.ac.uk, and in Art and Archaeology Technical Abstracts, available on line at http://aata.getty.edu/Home.