Abstracts

GENERAL

D Berger, E Figueiredo, G Brügmann and E Pernicka. Tin isotope fractionation during experimental cassiterite smelting and its implication for tracing the tin sources of prehistoric metal artefacts. *Journal of Archaeological Science* 92, 2018, 73-86.

This paper is a contribution to the understanding of tin isotope fractionation on tin ore smelting under prehistoric conditions and discusses the consequences for tin provenance studies. It presents the results of cassiterite smelting experiments that were carried out in both laboratory and field (where recovery was low (20-30%) due to tin losses to fuming and slag formation). If cassiterite is completely reduced the tin metal is enriched in heavy tin isotopes but an estimate of the provenance of the cassiterite is possible because the variability of tin isotope ratios in tin ore provinces is much larger. However, if the cassiterite is incompletely reduced, fractionation increases significantly and conclusions on tin sources are limited. Similarly, condensed tin vapours and slags show large fractionation which makes them unsuitable for provenance studies.

M N Desai. An overview of iron provenance and its possible extension to crucible steel archaeometallurgy. *Heritage: Journal of Multidisciplinary Studies in Archaeology* 6, 2018, 926-944.

The methodologies in iron provenance studies indicate the participation of several intricate parameters in the manufacturing of iron in bloomery furnaces. These parameters have enabled a multidirectional examination of iron. Analytical evaluations of assemblages and artefacts generated from smelting experiments have assisted in exploring the correlation between the assemblages. The contributing factors to the final composition of the iron artefacts are studied through various scientific methods. The research over the years has shown considerable progress in fingerprinting iron artefacts. This study attempts to compile an overview of methods implemented and inspects the possibilities of extending these methods to crucible steel manufactured from in-situ carburisation.

F Rademakers and C Farci. Reconstructing bronze production technology from ancient crucible slag: experimental perspectives on tin oxide identification. *Journal of Archaeological Science: Reports* 18, 2018, 343-355.

Experiments were developed to alloy bronze from a variety of starting products, under varying redox-conditions. Similarly, bronze, tin and cassiterite were heated under varying redox-conditions in clay-lined graphite crucibles. The clay linings were analysed by optical microscopy and SEM-EDS. The morphology of tin oxide crystals embedded in crucible slag can be useful indicators towards identifying ancient bronze technologies. However, most of the widely varying tin oxide morphologies are the result of tin oxidation and (re)crystallisation during the crucible process. Such crystals are largely non-diagnostic and should not be used as a means to distinguish between bronze production processes.

BRITAIN AND IRELAND

J Flament, F Mercier, C S Elliott. Ragstone to Riches: Imperial Estates, metalla and the Roman military in the south east of Britain during the occupation. 2018, Oxford: BAR (B 638).

This book is about the Roman extractive industries of the SE of the province of Britannia. These provided iron to equip the military and ragstone for construction in the region. The major focus is on quarrying, but for both industries the author also explores the role played by the military in running these enormous enterprises.

I Jones, D Williams, S Wiliams, W Carruthers, R Madgwick and T Young. Early medieval enclosure at Glanfred, near Llandre, Ceredigion. *Archaeologia Cambrensis* 167, 2018, 221-243.

Geophysical survey and small-scale trial excavations were carried out on a small enclosure in 2013. An in-situ iron slag deposit was found with an associated C-14 date between the late 7th and 9th century AD. Total slag weight was <5kg. Analyses suggest that the bloomery slags were from smelting bog ores; hammerscale was also identified.

EUROPE

L Chiarantini, M Benvenuti, P Costagliola, A Dini, M Firmati, S Guideri, I M Villae and A Corretti. Copper metallurgy in ancient Etruria (southern Tuscany, Italy) at the Bronze-Iron Age transition: a lead isotope provenance study. *Journal of Archaeological Science: Reports* 19, 2018, 11-23.

In the first millennium BC the Etruscan site of Populonia-Baratti became one of the most important ironworking sites in the Mediterranean as a result of the exploitation of iron ores from Elba. Recent studies, however, have demonstrated that, before iron, copper was smelted at Populonia-Baratti (9th–8th century BC). The Hellenistic text, *De mirabilibus auscultationibus*, states that the inhabitants of Elba firstly exploited copper, and later iron was won from the same mines by the inhabitants of Populonia. However, copper occurrences are extremely scanty on the island, while mainland southern Tuscany has a number

of copper-rich deposits. To investigate to what extent copper mining and smelting/working was practiced in this area in the Final Bronze Age (FBA) to Early Iron Age (EIA), the lead isotope composition of copper slags found in the Populonia-Baratti area were compared with those of copper-rich ore deposits of southern Tuscany and Elba. A few copper-based items from to FBA-EIA hoards of Elba were also investigated. All copper slags from Baratti-Populonia have lead isotope compositions that were fully consistent with results from the nearby Campiglia Marittima district, but the ophiolitic copper (either from Tuscany or Elba) was never worked on this site. None of the hoard items from Elba show a clear relationship either with Elban or Tuscan mainland copper ores but display a 'foreign' lead signature, suggesting that, even before iron exploitation started, Elba was probably involved in metal trading (rather than metal working) with other regions.

D Kotzamani, V Kantarelou, I Karatasios and M Zacharia. 19th century ornamented metal trays from Greece and Turkey: metallurgy and provenance. *STAR: Science & Technology of Archaeological Research* 3(1), 2018, 1-18.

Twelve 'Japanned' metal trays from Greece and Turkey, dated in the 19th century, were subjected to macroscopic and microscopic examination (stereoscopy, metallography, scanning electron microscopy) as well as to XRF and SEM-EDX analysis. The trays represent two stylistic types made of wrought iron, either tin-plated or protected with a primer. Two were manufactured by forging while the rest were made by rolling prior to die forming with drop hammers or machine presses. Wrought iron was produced indirectly from cast iron with fossil fuels. Only in one case charcoal fuel was implied. Most pure iron was recognized for four trays dated at the end of the 19th century. Three of them also revealed the deliberate incorporation of metallic manganese while one of them was found to be alloyed. The other metals used such as copper, brass, silver and tin, as also the methods applied, seem to follow the industrial evolution of the iron substrate but more analysis is required. The metallurgical results, combined with historical information, indicated that the metals/techniques used, probably originated in western Europe.

V Orfanou and T Birch. Viking-age metals and urbanisation: the case of Ribe in Denmark. In: R Raja and S M Sindbæk (eds), *Urban Network Evolutions. Towards a high-definition archaeology*. 2018, Aarhus: Aarhus University Press, 189-195.

Archaeometallurgical investigation of Viking-Age Ribe provided evidence for high levels of standardisation and specialisation. The emporium's connectivity and commercialisation played a fundamental role in the organisation of metallurgical processes, allowing development of characteristics expected in urban production.

M Roxburgh and B J H Van Os. A compositional study of two groups of copper-alloy pins from Sedgeford, England and Domburg, the Netherlands, dating between the seventh to eleventh centuries. *Medieval Archaeology* 62(2), 2018, 304-321.

Two contemporary groups of copper-alloy pins datable to the seventh to eleventh centuries were analysed by X-Ray Fluorescence Spectrometry, one from an excavated Anglo-Saxon settlement at Sedgeford, Norfolk, the other from a coastal settlement at Domburg, Zeeland, the Netherlands, then within the Frankish empire. Pins are found in quantity on both sides of the North Sea and the English Channel, and are therefore one of the few artefact types that allow cross-cultural contacts to be explored, not only in their styles, but in the metals used in their manufacture. This allows questions to be raised about specialist production and its subsequent control.

M Roxburgh and M Olli. Eyes to the North: a multi-element analysis of copper-alloy eye brooches in the eastern Baltic, produced during the Roman Iron Age. *Germania* 96, 2018, 209-233.

Eye brooches are the earliest form of brooch to enter the Eastern Baltic region during the Roman Iron Age. Its form bears strong similarities to those found much further south in Germania and the northern Roman provinces, leading to the conclusion that they originally arrived as imports, perhaps by sea from an as yet undiscovered production centre in an area formerly known as East Prussia. In contrast, the eye brooches found within the Germanic areas, north of the Roman frontier, are thought to have originated as export goods produced within the Roman provinces, some distance from the areas in which they are found. We re-examine therefore the debate surrounding local production versus foreign imports, through an innovative use of pXRF. The study compares compositional data of both imported and locally produced brooches against the current typological framework.

R Warchulski, P Juszczuk and A Gawęda. Geochemistry, petrology and evolutionary computations in the service of archaeology: restoration of the historical smelting process at the Katowice–Szopienice site. *Archaeological and Anthropological Sciences* 10(5), 2018, 1023–1035.

Activity at the smelting plant dates to the 19th century but all technological descriptions were lost. Three historically described samples and additional slag and lining collected directly from the furnace were studied. Geochemistry and petrology provided qualitative information about the samples and smelting process. 'Enriched ore' is dominated by ZnS accompanied by gangue minerals. 'Roasted ore' is composed mainly of zincite. The 'roasted ore with coke' sample contains recycled lining material and coke. The differential evolution algorithm was used for reconstructing the smelting process at the site. The proportion of roasted ore to additions was estimated as 1:1.27 and loss on smelting share from batch was 62%.

NEAR EAST

D Ashkenazi and A Fantalkin. Archaeometallurgical and archaeological investigation of Hellenistic metal objects from Ashdod-Yam (Israel). *Archaeological and Anthropological Sciences* 2017, 1-23.

Non-destructive and minimal-destructive testing methods (stereo microscopy, XRF and SEM-EDS) were used to determine their composition and manufacturing process of the Hellenistic. They were made of copper alloys, lead and iron. The manufacture of the objects involved casting, cold-forging and annealing cycles, drilling, engraving, as well as joining methods such as forge-welding

and soldering. The artefacts were made by trained metalsmiths and were most probably produced in different workshops.

A Eliyahu-Behar and N Yahalom-Mack. Re-evaluating early iron-working skills in the Southern Levant through microstructure analysis. *Journal of Archaeological Science: Reports* 18, 2018, 447–462.

In order to examine systematically the question of whether improved technological skills of Iron Age smiths, such as carburisation and quenching, were behind the significant transition to utilitarian use of iron in the eastern Mediterranean, 59 iron objects from several major Iron Age settlements in Israel were sampled for metallographic analysis. None of the analysed objects were preserved in metallic form and that only in rare cases, were small islands of metallic iron preserved.

Relict ("ghost") structures of the original metallic microstructure, pearlite and cementite, were identified in an overwhelming majority of the samples, indicating that almost all of the objects were made of steel. Estimated carbon concentrations suggested a range of compositions from low-carbon hypoeutectoid to high-carbon and hypereutectoid steels. No clear correlation between object type and steel quality was observed, so it was concluded that steeling was, in fact, a spontaneous and non-deliberate result of the smelting process, rather than deliberate carburisation. Martensitic structures were not identified, suggesting that quenching was not routinely performed and therefore iron was unlikely to have been superior to bronze at this time. It thus appears that the iron-working skills of the Iron Age smiths cannot be used as a factor to explain the advent of iron in the Southern Levant nor as a reason for the dramatic increase in iron production during the 10th–9th centuries BC.

F Rademakers, T Rehren and E B Pusch. Bronze production in Pi-Ramesse: alloying technology and material use. In E Ben-Yosef (ed), *Mining for ancient copper: Essays in memory of Beno Rothenberg*, 2018,.Tel Aviv: Institute of Archaeology of Tel Aviv, 503-525.

The preliminary results of ongoing research into the crucible fragments and technological process of bronze production at ancient Pi-Ramesse, in Egypt, show how the detailed study of a macroscopically homogeneous crucible assemblage can illuminate the variability in production technology and material use. It highlights the importance of detailed slag phase identification, particularly metal prills and oxide crystals, and of tracing bulk chemical changes between ceramic and slag, to distinguish between bronze production techniques and materials. Finally, this paper provides novel contributions to the debate regarding Late Bronze Age metal trade.

ASIA

Kunlong Chen, Yingchen Wang, Yaxiong Liu, Jianjun Mei and Tao Jiang, Meteoritic origin and manufacturing process of iron blades in two Bronze Age bimetallic objects from China. *Journal of Cultural Heritage* 30, 2018, 45-50.

It is widely accepted that meteoritic iron was the first iron alloy used by mankind, however, the manufacturing processes of the earliest iron artefacts remain uncertain and sometimes disputed. Here, we present both chemical and microanalytical results of samples from two bimetallic objects from Bronze Age central China. It is confirmed that the blades were made of meteoritic iron. In-situ photomicrograph and detailed microanalysis provides solid evidence for the cast-on and hot-work processes. We also demonstrate that significant information can be extracted through multiple analyses despite the severely corroded condition of ancient iron objects.

P Johansen and A M Bauer. On the matter of resources and techno-politics: the case of water and iron in the South Indian Iron Age. *American Anthropologist* 120(3), 2018, 412-428.

Water management and iron production were important technologies in northern Karnataka during the South Indian Iron Age (1200–300 BC). A theoretical convergence between 'resource materialities' and 'techno-politics' allows assessment of how technical practices and material properties shape social conditions. Iron Age peoples transformed substances (eg iron ores, bloom and metal) into resources and simultaneously produced a historically unique political sociology of resource relations.

S Liu, K L Chen, T Rehren, J J Mei, J L Chen, Y Liu and D J Killick. Did China import metals from Africa in the Bronze Age? *Archaeometry* 60(1), 2018, 105-117.

The origins of the copper, tin and lead for China's rich Bronze Age cultures are a major topic in archaeological research, with significant contributions being made by archaeological fieldwork, archaeometallurgical investigations and geochemical considerations. Here, we investigate a recent claim that the greater part of the Shang-period metalwork was made using metals from Africa, imported together with the necessary know-how to produce tin bronze. A brief review of the current status of lead isotopic study on Shang-period bronze artefacts is provided first, clarifying a few key issues involved in this discussion. It is then shown that there is no archaeological or isotopic basis for bulk metal transfer between Africa and China during the Shang period, and that the copper and lead in Shang bronze with a strongly radiogenic signature is not likely to be from Africa. We call for collaborative interdisciplinary research to address the vexing question of the Shang period's metal sources, focusing on smelting sites in geologically defined potential source regions and casting workshops identified at a number of Shang settlements.

T O Pryce, K M M Htwe, M Georgakopoulou, T Martin, E Vega, T Rehren, T T Win, T T Win, P Petchey, J Innanchai and B Pradier. Metallurgical traditions and metal exchange networks in late prehistoric central Myanmar, c. 1000 BC to c. AD 500. *Archaeological and Anthropological Sciences* 10(5), 2018, 1087–1109.

Analytical data on copper-base artefacts from several Bronze Age and Iron Age sites in Myanmar are presented. Observed microstructures range from as-cast, worked, to fully annealed; compositions include leaded copper, low-tin to high-tin bronzes, and arsenical copper/bronze. Lead isotope analyses indicate that the metal originates from different geological sources, including known prehistoric copper mines in Thailand and Laos. These

data, including evidence for secondary copper-base production, more than double those currently available for Myanmar and document multiple local alloying and working traditions, perhaps chronologically differentiated, as well as identifying possible links to primary mineral sources across the region.

AFRICA

F Bandama, S Chirikure, S Hall and I Shuro. Iron fabrication during the 'age' of tin and bronze in the Southern Waterberg of Limpopo Province, South Africa. *Studies in the African Past* 13/14, 2018, 1-19.

This article explores iron production and consumption patterns at the 2nd millennium CE sites of Rhenosterkloof 1 and Tembi 1 in the Sand River Valley. It examines iron smithing technology through the analyses of blooms and metallic objects, using optical microscopy and scanning electron microscopy. The results suggest that the objects are products of indigenous bloomery iron technology, which was widely used in southern Africa during the pre-colonial period. Careful hot and cold working achieved optimal qualities of these predominantly non-utilitarian objects. It is clear that iron consumption patterns in the Southern Waterberg were embedded in the local and regional trade networks.

J Humphris, M F Charlton, J Keen, L Sauder and F Alshishani. Iron smelting in Sudan: experimental archaeology at the royal city of Meroe. *Journal of Field Archaeology* 43(5), 2018, 399-416.

The Royal City of Meroe, c. 200km north of Khartoum in the modern-day Republic of the Sudan, was an ancient capital of the Kingdom of Kush. From the 3rd century BC to the 4th century AD Kushite rulers controlled significant territory from the banks of the Nile at Meroe, in part through their ability to ensure the production of significant quantities of iron. The extensive archaeological remains of Meroitic iron production have been investigated over decades, and recently a series of experimental iron smelts in a replica Meroitic furnace has shed new light on the archaeometallurgical evidence. The data generated during the smelting campaigns has provided an understanding of the type of iron ore used, the construction and operating parameters of the furnace, and the workshop space created by the ancient iron smelters during the later and post-Meroitic times.

AMERICAS

M A Hill, M F Seeman, K C Nolan and L Dussubieux. **An empirical evaluation of copper procurement and distribution: elemental analysis of Scioto Valley Hopewell copper**. *Archaeological and Anthropological Sciences* 10(5), 2018, 1193–1205.

In prehistoric North America, native copper artefacts representing social contacts and long-distance interactions are prominent in the Hopewell societies of Ohio's Scioto Valley. The origins of the metal were investigated using LA-ICP-MS; 24 samples came from four copper source regions and 52 from six Scioto Valley sites. A majority of the artefacts are consistent with sources in the Great Lakes, with several classified as Isle Royale. However, 21% of them were most consistent with southern Appalachian sources. High elemental variability suggests that different groups had access to a variety of native copper sources.

The abstracts for the following papers in *Metalla* (Bochum) 24(1), 2018, are available at:
https://www.bergbaumuseum.de/de/archiv-metalla-de/item/metalla-24-1-2018.

Alžběta Danielisová, Ladislav Strnad and Martin Mihaljevič: Circulation Patterns of Copper-Based Alloys in the Late Iron Age Oppidum of Třísov in Central Europe, pp.5-18.

Tal Kan-Cipor-Meron, Sana Shilstein, Yosi Levi and Sariel Shalev: Type, Shape and Composition: The Middle Bronze Age II Daggers in Rishon le-Zion, Israel, pp.19-31.

Peter Rothenhöfer, Michael Bode and Norbert Hanel: Metallum Messallini – A New Roman Lead Ingot from the Danube Provinces, pp.33-38.

Lorna Anguilano, Giovanni Piredda, Cinzia Saba, Danny Aryani, Laura Marras and Elisa Grassi: Working Together and Learning Together: The Study of the Metallurgical Remains of San Tommaso, Pavia, Italy, pp.39-47.

Benjamin Sabatini and Marianne Mödlinger: Identity and Publishing in Archaeometallurgy, pp.49-62.

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