

Abstracts

GENERAL

M Mödlinger, M H G Kuijpers, D Braekmans and D Berger. Quantitative comparisons of the color of CuAs, CuSn, CuNi, and CuSb alloys. *Journal of Archaeological Science* 88, 2017, 14-23.

The colours of copper alloys are of particular interest in archaeology and can be characterised quantitatively and systematically. The CIELAB colour system determines different colour parameters such as a^* , b^* , and L^* by means of a spectrophotometer that describes the surface colour. Additional information such as C^* and h values can be calculated from these parameters which allows one to build a set of colour-composition diagrams connecting chromaticity and alloy composition. With such data it is possible to estimate the colour of prehistoric metal artefacts with similar chemical composition. A better understanding of the association between metallurgical composition and colour will aid the research of prehistoric metalwork because choices in production and use of metal were likely to have been influenced by this particular quality of a metal.

BRITAIN AND IRELAND

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 were found on a probable Bronze Age shipwreck near Salcombe in SW England. The chemical compositions of all the tin ingots were analysed using ICP-MS and ICP-AES. Eight ingots of different sizes, shapes and impurity levels, and the two Erme Estuary ingots were examined using metallography and SEM-EDS. An extensive overview of archaeological tin in Europe is also provided. All the Salcombe tin ingots appeared quite pure with little variation in composition. Only two samples contained $>0.1\%$ iron and one contained $>0.1\%$ copper. Their compositions do not seem related to the very few analyses of tin objects found elsewhere.

EUROPE

A Garbacz-Klempka, M Wardas-Lasoń, J Kozana, M Piękoś and Z Kwak. Metallurgical slags as traces of a 15th century copper smelter. *Archives of Foundry Engineering [Poland]* 17(2), 2017, 25-30.

Geochemical mapping located Jan Thurzo's 15th-century smelter, located in Mogiła near Krakow (southern Poland). Slag samples

contained mainly copper, lead, iron and also silver so copper was probably refined and silver separated from copper there. Using the same approach with these samples as with modern hazardous waste, an attempt has been made to assess their impact on the environment. The smelter probably left large-scale changes in the structure and chemical content of the soil. Discovering areas which like this are contaminated can help to identify historical human activities. The operation of Jan Thurzo's smelter is significant for the history of mining and metallurgy of Poland and Central and Eastern Europe.

J Hošek, P Bárta and J Šmerda. Metallographic examination and reconstruction of the 6th-century lombardic sword from Kyjov. *Materials and Manufacturing Processes*, 32(7-8), 2017.

A Lombardic cemetery was excavated at Kyjov (Czech Republic) in 2010, and a warrior's grave (no 881) were uncovered. The burial included a sword which was subjected to a detailed conservation survey and then to metallographic examination. The weapon can be characterised as a pattern-welded sword with cutting edges and an inner core of steel. Its construction and heat treatment are discussed in a broader context of 5th–7th century swords and sword-making. Experimental reconstruction of the sword shows that pattern-welded composites reveal a clear pattern after being exposed to controlled corrosion in vinegar vapour.

J Lang. Roman iron and steel: A review. *Materials and Manufacturing Processes* 32(7-8), 2017, 857-866.

The production of ferrous metal increased during the Roman period. The direct bloomery process was used to extract the metal from its ores using slag-tapping and slag-pit furnaces. The fuel was charcoal and an air blast was introduced by bellows-operated tuyères. Iron formed as a bloom which contained impurities from the smelting process, and the metal was often inhomogeneous with varied carbon contents. Blooms were either smithed directly into bars or ingots or they were broken up, which allowed a selection of pieces with similar properties to be made. These could then be forge-welded together and formed into characteristically-shaped ingots. Making steel in the furnace seems to have been achieved: it depended on the ore and the furnace and conditions within it. Surface carburization was also carried out. Iron and steel were used extensively in construction and for tools and weapons. Fire welding was often used to add pieces of steel to make the edges of tools and weapons, which could be heat-treated by quenching to harden them.

M Murillo-Barroso, M Martín-Torres, M D C Massieu, D M Socas and F M González. Early metallurgy in SE Iberia. The workshop of Las Pilas (Mojácar, Almería, Spain). *Archaeological and Anthropological Sciences* 9, 2017, 1539–1569.

The archaeological excavation of a 3rd millennium BC early metallurgy context on the site of Las Pilas, in Iberia, allows the whole metallurgical chaîne opératoire to be documented. The study includes microstructural, mineralogical and chemical analyses of ores, slag, technical ceramics and finished artefacts, as well as domestic pottery used for comparative purposes. These results are discussed with reference to the archaeological context and evidence for other domestic activities and crafts. The direct production of arsenical copper in a low-scale, low-specialisation, low-efficiency set up is demonstrated. This involved the crucible smelting of complex oxidic ores in a context suggesting associations with cereal roasting and, indirectly, with basket and pottery making.

H W Nørgaard. Portable XRF on prehistoric bronze artefacts: Limitations and use for the detection of Bronze Age metal workshops. *Open Archaeology* 3, 2017, 101–122.

The results of two analytical techniques, one destructive and one non-destructive, on two separate groups of bronze ornaments dating from 1500–1100 BC are compared. The possibilities and limits of non-destructive XRF analyses of corroded bronze artefacts are defined. One group was sampled, and polished sections were analysed using a SEM. Results from the corrosion crust of copper-tin alloys, and the change in measured elemental composition from the bulk metal to the surface, greatly influenced the interpretation of the second data set, from a handheld XRF. The surface of corroded bronze ornaments consists mostly of copper carbonates, oxides, and chlorides. Chemical processes change the composition so the original alloy cannot be traced with a non-destructive method.

N A Rueda and J A Escobar. Reconstruction of the lost Muisca Siecha raft pouring process by reverse engineering methodology. *Materials and Manufacturing Processes*, 32(7-8), 2017, 749-755.

A reverse engineering methodology was used to study a pre-Hispanic artefact, in which the object was reconstructed by computer-aided design to obtain information. The Siecha raft, a Muisca goldwork piece that disappeared in the 19th century, was reconstructed based on historical sources. The pouring process of the raft was studied by characterizing the metal flow within a mould, by using the analytical, experimental, and computational fluidity length parameter. By using estimated parameters from the previous three methods, the flow in the reconstructed geometry of the raft was studied. Pouring temperature, materials, and temperature of the mould, entrance velocity, and other parameters of the fabrication process were calculated. The results showed that the geometry of the raft could have been cast by gravity casting pouring process, with the calculated parameters.

R W Vernon. John Taylor and Sons and their three “Drops of Comfort” – their lead mines at Linares, Jaén, Southern Spain. *British Mining* No 103, 2017.

The world famous mining house of John Taylor and Sons developed three large companies: the Linares Lead Mining Company, the Fortuna Company and the Alamillos Company which together paid consistent dividends for well over 50 years from about 1850 until the start of the First World War. These companies were the

Taylor's ‘Three Drops of Comfort’, which brought great wealth to the family. British companies exploiting the rich mining areas of Spain brought with them substantial capital and technological resources. This was an important factor in the decline of lead mining in the UK.

MIDDLE EAST

D Cvikel, D Ashkenazi, V Spiegelman, A Stern, S Klein and G Rimer. Flintlock brass fittings from the 19th-century Akko I shipwreck, Israel. *Arms and Armour* 14(2), 2017, 138-164.

Remains of six flintlock muskets were retrieved from the Akko I shipwreck, an Egyptian vessel built at the beginning of the 19th century, and were characterised by various metallurgical methods. The aim was to study the composition and microstructure of the musket fittings and their manufacturing processes, and if possible, to determine the date and origin of the raw materials. The lead isotope analysis of the fittings suggests that their raw material originated in Great Britain. Based on their typology and composition, the fittings were made in Great Britain of brass alloy and manufactured by casting; the staple was manufactured by casting and drawing. The zinc content, combined with the manufacturing techniques, suggest the fittings were manufactured in the late 18th to early 19th centuries.

A Greener and E Ben-Yosef. The ground stone assemblage of a metal workers community: An unexplored dimension of Iron Age copper production at Timna. *Journal of Lithic Studies* 3(3), 2016, 191-220.

More than 1000 ground stone tools present at the Late Bronze and Early Iron Age copper smelting sites were identified and registered, including grinding stones, pounders, anvils and mortars. Most were manufactured of compacted sandstone and granite, exposed in several locations in the Timna valley. A typology and quantitative analysis of the ground stone tools used by the metal workers is presented, and an interpretation offered of how the various types of tools were employed as part of the copper production process. This provides new insights regarding the smelting process and the conditions needed for its successful outcome.

S Merkel, A Hauptmann, T Kirnbauer and F Téreygeol. Silver production at al-Radrad: Archaeometallurgical analysis of ore, slag and technical ceramics from early medieval Yemen. *Arabian Archaeology and Epigraphy* 27(1), 2016, 107-126.

The zinc-lead-silver deposit of al-Jabali, about 65km NE of Sana'a in Yemen, has been identified as the location of the late antique/Islamic period silver mine al-Radrad. Exploitation of the mine is known from the account of al-Hamdani, an Arab geographer of the 10th century AD. The al-Jabali area has been the focus of geological and archaeometallurgical surveys, and extensive metallurgical remains have been discovered. Samples of ore, slag and technical ceramics were collected for archaeometallurgical analysis. The technology of silver production is discussed in relation to the historical record, and elemental and lead isotope characterisation of ore and slag provides a basis for future provenance studies.

S Moureau and N Thomas. Understanding texts with the help of experimentation: The example of cupellation in Arabic scientific literature. *Ambix* 63(2), 2016, 98–117.

The article aims to show how experimentation can help us understand historical texts by focusing on the specific case of cupellation in Arabic scientific literature. It also provides new information about cupellation in the Arab-Muslim middle ages. The texts consist of translations of three of the most detailed accounts of cupellation: Hamdānī's *Kitāb al-jawharatayn al-'atīqatayn* (first half of the fourth/tenth century), Maslama b. Qāsim al-Qurṭubī, *Rutbat al-ḥakīm* (339–342/950–953), and Manṣūr b. Ba'ra, *Kitāb kashf al-asrār al-'ilmīyya bi-dār al-ḍarb al-miṣriyya* (615–635/1218–1238). These are accompanied by commentaries based on a series of experiments carried out in the course of archaeological research on cupellation, which are here used to shed new light on the medieval texts and resolve several problems in interpreting them.

M Ponting and D Levene. 'Recycling economies, when efficient, are by their nature invisible'. A first century Jewish recycling economy. In M J Geller (ed), *The archaeology and material culture of the Babylonian Talmud*. Leiden: Brill, 2015, 39–65.

This article cross references archaeometallurgical finds with late antique Jewish texts to provide glimpses of sophisticated Jewish metal recycling technologies. The cross-disciplinary approach offers information that each discipline on its own cannot provide. Archaeological analysis shows complex alloys that have hitherto been considered to have been achieved from the mixing of freshly mined and smelted constituents. The texts, however, offer a unique record that shows an established recycling industry which has never been matched to the material finds.

AFRICA

F Bandama, A J Moffett and S Chirikure. Typological and technological attributes of metallurgical crucibles from Great Zimbabwe (1000–1700 CE)'s legacy collections. *Journal of Archaeological Science: Reports* 12, 2017, 646–657.

The typological and archaeometallurgical studies of an assemblage of long-forgotten but often misidentified metallurgical crucibles and moulds from Great Zimbabwe's century-old archive are reported. Specialised crucibles, non-specialised crucibles (common pottery) and an eclectic assortment of moulds were primarily used to hold the melt and to form non-ferrous ingots throughout the site's occupation (1000–1700 CE). Some moulds appear elongated but others were more circular, as if they were used to produce small gold 'buttons'. Available records indicate that the metallurgical ceramics were often found in the same contexts as domestic debris. The two types of crucibles were made using local granitic clays and were used to process similar metals and alloys, but sometimes at different stages in the chaîne opératoire. This raises significant questions relating to the techno-cultural choices behind the typological variation, if the intention of their producers and users was to work the same metals and alloys.

J Humphris and C Carey. New methods for unlocking the secrets of slagheaps: integrating geoprospection, excavation and quantitative methods at Meroe, Sudan. *Journal of Archaeological Sciences* 70, 2016, 132–144.

This study of one of the slag heaps at the royal city of Meroe in Sudan combines gradiometry and electrical resistivity transects, topographic data and quantitative excavation data to provide an analysis and comparison of the total volume, slag component and slag composition of a slag-heap. Significantly, the results demonstrate the limitations of using a topographic-only model, but also demonstrate how volumetric modelling must be integrated within quantitative characterisation of slag-heap composition. In this case, quantitative sampling of the slag deposits revealed 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, and furthers the debate on applying volumetric modelling and excavation sampling to unexcavated areas of the finite and important resource of archaeometallurgical deposit sequences.

FAR EAST

A M Pollard, P Bray, P Hommel, Y-K Hsu, R Liu and J Rawson. Bronze Age metal circulation in China. *Antiquity* 91 (357), 2017, 674–687.

The Shang (c1500–1045 BC) and Zhou dynasties (c1045–771 BC) are famous for their ritual bronze vessels. Sourcing the leaded tin-bronze has, however, proved to be a challenge. A new systematic approach to metal chemistry uses trace elements and isotopes to characterise the underlying circulation pattern. It reveals the complexity of the copper sources utilised, suggesting the transport of copper from distant regions in the south and from NE China. The new interpretational system furthers our understanding of the network on which successive Chinese dynasties depended for copper, lead and tin, and attempts to give equal weight to the archaeological and chemical data.

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>.