

# Abstracts

## GENERAL

**S De Ceuster and P Degryse. A ‘match-no match’ numerical and graphical kernel density approach to interpreting lead isotope signatures of ancient artefacts.** *Archaeometry* 62(S1), 2020, 107-116.

A new method for interpreting lead isotope ratios of artefacts is presented: a numerical and graphical ‘match-no match’ with possible raw materials. By calculating the definite integral under the kernel density estimate plot of different mining districts, using open-access software and legacy data, the relative probability that an object is made from an ore is indicated. A match with the reference data set may indicate the true origin while no match indicates an unknown origin, *ie* not present in the data set of mineral resources. Likewise, the composite or recycled nature of artefacts can be investigated in a probabilistic manner.

**C Gardner, N S Müller, G Vekinis, I C Freestone and V Kilikoglou. High-temperature performance of two-layered ceramics and the implications for Roman crucibles.** *Archaeometry* 62(5), 2020, 935-951.

Roman metalworking crucibles are frequently characterised by an extra outer layer of clay, applied to a pre-formed vessel. Three-point bending and standardised dead-weight loading tests were conducted to determine the advantages offered by the extra outer layer. Deformation and fracture behaviour, at temperatures up to 1100°C, of two-layer, monolithic and tempered-monolithic briquettes were compared. Measurements indicated that the two-layer briquettes were more resistant to fracture at high temperatures; above 850°C they showed more extensive plastically deformed regions than monolithic briquettes. The influence of temper was consistent with previous results; tempering caused quasi-stable fracture and reduced fracture strength. The results suggest extra outer layers assisted in preventing catastrophic failure.

**D J Killick, J A Stephens and T R Fenn. Geological constraints on the use of lead isotopes for provenance in archaeometallurgy.** *Archaeometry* 62(S1), 2020, 86-105.

Part one is a brief critical history of the use of Pb isotopes for inferring the geological provenance of archaeological materials, with an emphasis on non-ferrous metals. Part two examines variation in the Pb isotopic ratios of oxide and sulphide ore minerals in selected regions of the world, related to the history of their ore formation. This exercise shows that in regions where most ore deposits are of similar geological age (the Andes, Europe and the circum-Mediterranean) provenance analysis with Pb isotopes is

inherently difficult because geographically distant sources often exhibit similar isotopic ratios. Conversely, regions with many periods of ore formation (*eg* southern Africa) appear to be very promising regions for future studies of provenance with Pb isotopes. The wider implication of this exploratory survey is that archaeologists should carefully consider the range and clustering of geological Pb isotopic ratios in their regions of interest before investing large sums of money in Pb isotopic analysis of artefacts.

**S Klein and T Rose. Evaluating copper isotope fractionation in the metallurgical operational chain: An experimental approach.** *Archaeometry* 62(S1), 2020, 134-155.

Until now, raw material information of copper objects is mostly gained from impurities and trace elements and not from the Cu itself. This might be obtained using its stable isotopes but isotopic fingerprinting requires the absence of fractionation during the smelting process. The Cu isotope evolution during outdoor smelting experiments with Cu sulphide ore was investigated. This showed that external materials, in particular furnace linings, clay, manure and sand alter the isotopic composition of the smelting products. Cu isotopes are fractionated within low viscosity slag derived from matte smelting. The metallic Cu produced has a Cu isotope signature close to the ore.

**T Rose, P Télouk, J Fiebig, H R Marschall and S Klein. Iron and oxygen isotope systematics during corrosion of iron objects: a first approach.** *Archaeological and Anthropological Sciences* 12, 2020, article 113.

Iron and oxygen isotope compositions of iron artefacts from marine and water under saturated oxidising environments were analysed to gather information from the corrosion layer without sampling the object directly. No Fe isotope fractionation between artefact and its corrosion products was recognised for both environments but cannot be excluded for marine environments. Hence, the artefact’s Fe isotope composition can be determined from the corrosion layer, which allows the characterisation of artefacts that cannot be sampled directly. Because the data precluded identification of the underlying processes, possible fractionation mechanisms resulting in this situation are presented. Furthermore, the results indicate that corrosion products have the same oxygen isotope composition as their source water. As for marine corrosion, general absence of oxygen isotope fractionation could not be manifested here, because only a small sample was available. However, a complex interplay of many parameters governs the oxygen isotope compositions of corrosion products on metallic iron. Oxidising environments above the water table have a strong impact on the oxygen isotope composition of the corrosion layer. The first-order controlling

mechanisms, such as evaporation, are set by the local environment and cannot be reconstructed. Therefore, the oxygen isotope composition of corrosion products seems to have no potential for archaeometallurgical research.

## BRITAIN AND IRELAND

**J Lang, S Dove, M J Hughes, N Meeks, H Newey, D Ryan and R Ó Floinn. The Derrynaflan Hoard – some technical aspects of the objects.** *Journal of the Royal Society of Antiquaries of Ireland* 149, 2019, 56-123.

The hoard deposited sometime in the ninth century, consisting of a decorated silver chalice, paten, hollow ring and bronze strainer covered by a plain bronze basin, was discovered at the ancient monastic site of Derrynaflan, near Thurles, Co Tipperary, in 1980. During conservation carried out in the Department of Conservation and Science in the British Museum, London (1983-85), it was possible to examine and analyse some of the objects and their components and suggest how they might have been constructed.

**M Knight, D Boughton and P Northover. Poolewe: The last Bronze Age hoard in Scotland?** *Archaeological Journal* 178, 2020. DOI: 10.1080/00665983.2020.1824883.

In 1877, a hoard of nine copper alloy objects was recovered from a peat bog at Poolewe, Scotland, including axeheads, rings and an ornament. For the first time since its discovery, this article publishes the hoard in its entirety, including an assessment of typological features, full illustration and metallurgical analysis. Components of the hoard are characteristic of the British Llyn Fawr / earliest Iron Age period (800-600 BC) suggesting the date of deposition, which is confirmed by a radiocarbon date from the wooden haft of an axehead. However, set in the broader context of Scotland and Britain during this period, it is suggested that this hoard in fact represents the last vestiges of Late Bronze Age hoarding practice in Scotland.

**M A Roxburgh and B J H Van Os. A comparative compositional study of 7th- to 11th-century copper-alloy pins from Sedgeford, England, and Domburg, the Netherlands.** *Medieval Archaeology* 62(2), 2018, 304-321. DOI: 10.1080/00766097.2018.1535390.

As early medieval pins are found in large quantities on both sides of the North Sea and the English Channel, they are one of the few artefact types that can facilitate the exploration of cross-cultural contacts in terms of style, material and manufacture. The analyses of two contemporary groups of copper-alloy pins dating from the 7th to the 11th centuries using XRF are presented. One group of pins was recovered from an excavated Anglo-Saxon settlement at Sedgeford (Norfolk), while the other comes from a coastal settlement at Domburg (Zeeland). The results suggest that while pin production may have been focused around major mercantile, royal or ecclesiastical centres, it was also localised in terms of materials and production methods, suggesting potentially different trajectories in each region for the development and control of specialist production.

**R Williams and D de Haan. A link between the 1780s blast furnaces at Coalbrookdale and Staveley: The note of Mr Chas. Hornblower.** *Industrial Archaeology Review* 41(2), 2019, 122-131. DOI: 10.1080/03090728.2019.1646482.

In what appears to be the divulgence of trade secrets to a potential rival, a Coalbrookdale Company employee provided the lessors of the Staveley furnace in Derbyshire with an account of blast furnace practice. A hurried draft by Charles Hornblower lists in considerable detail the raw materials and their proportions for charging the furnace, transport and labour costs, and advice about building the furnace hearth. Further analysis of the note provides contemporary information about the preparation of the raw materials, their composition and quality of iron produced.

## EUROPE

**G Artioli, C Canovaro, P Nimis and I Angelini. LIA of pre-historic metals in the central Mediterranean area: A review.** *Archaeometry* 62(S1), 2020, 53-85.

Following animated discussions in the 1990-2010 period concerning the validity and potential application of Pb isotope data to yield information on ancient metallurgy, lead isotope analysis has recently been extensively applied, with alternate success and difficulty, to the early stages of copper/lead/silver/tin metal flow in the central Mediterranean area, arbitrarily defined as including Italy, the Mediterranean islands, and the surrounding regions for comparison purposes. A wealth of data is now available in the literature, many of them interpreted within local contexts and limited geographical extension, and often within a shifting conceptual modelling frame. A brief review of the recently published data indicates that the metal flow in prehistory and protohistory is far more dynamic than had been presumed using traditional archaeological models. It is suggested that the isotopic tracers, if correctly applied and interpreted, may substantially help in decoding metal exploitation and trade patterns at different scales, from local links between mines and smelting sites to wider regional or long-distance trade. The abundant available dataset needs a thorough interpretation in terms of wider archaeological and archaeo-metallurgical questions, possibly using advanced statistical methods and unconventional data mining protocols.

**M Castelle, P Dillmann, E Vega, C Blanc-Riehl, A Vilain, P Chastang and E Anheim. Seal the deal: An extensive study of European historical copper-based seal matrices using a multimodal protocol.** *Journal of Archaeological Science* 113, 2020. DOI: 10.1016/j.jas.2019.105061.

During the late medieval and early modern periods seal matrices were used in Europe as personal signatures on official documents. They were frequently made of copper-based alloys. More than 400 such objects were analysed using a recently developed portable XRF protocol for copper-based alloys. Over 100 were also examined on a micro scale to determine the engraving techniques. Cross sections from six broken seal matrices revealed the manufacturing processes. A wide range of copper-based alloys were identified, including bronze, red brass and brass, and two groups of objects could be identified based on the Pb content, suggesting two levels of quality. Three different successive

engraving techniques could be identified dating from the 13th to 17th centuries: engraving, simple stamp combination and letter punches. The similarities in terms of the fabrication process and the alloys used in French and Italian products might suggest a transborder practice.

**P Cruz and F Tereygeol. Estudios Atacameños. Arqueología y Antropología Surandinas estudios atacameños Arqueología y Antropología Surandinas. Estudios Atacamenos, 2020. DOI: 10.22199/issn.0718-1043-2020-0039.**

Information from colonial-era historical sources, archaeological data, and the results of archaeological experimentation, were used to study the reverberation furnaces used from the start of Spanish colonisation to produce silver in the southern Andes. Evidence of this three-chamber oven (composed of a fire chamber, vaulted work chamber, and chimney) has been identified and studied in different mining and metallurgical contexts in the south of Bolivia (eg Potosí, Santa Isabel, Mina Santiago, Escoriani). The continuity between pre-Hispanic metallurgy and the reverberation furnaces was studied. The general characterisation of these furnaces as a European tradition is challenged. It is proposed instead that they were the result of local technological developments and later spread throughout Europe.

**R Grethe, A G Karydas, V Kantarelou and N Zacharias. Micro-XRF analysis of silver decorations on Archaic helmets from Olympia. Archaeometry 62(5), 2020, 974-990.**

Quantitative micro-XRF analyses were performed on 19 silver decorations of six Archaic bronze helmets from the site of Olympia, Greece. The principal aim of the study was to investigate the technological aspects of the smelting process influencing the composition of Ag and reveal possible elemental correlations, shedding light on its source, and assigning a likely provenance. The XRF results revealed that all decorations contain >95% Ag. The quantitative determination of several fingerprint minor elements, such as Au, Pb and Bi, provided information about the efficiency of the cupellation process, the ore type used for the silver extraction and the geological origin of the ores.

**A Mongiatti and I Montero-Ruiz. Rediscovering famous assemblages: A rare Bronze Age crucible from El Argar, Spain. Archaeometry 62(2), 2020, 329-345.**

A rare open shallow crucible from the British Museum collection, excavated at the Bronze Age site of El Argar in SE Spain by Louis and Henri Siret, was studied using X-radiography and SEM. The crucible has relatively thick walls, a spout and a non-refractory fabric. It was used for melting copper alloys at around 1100°C. Both arsenic and tin were detected in various places and concentrations. This crucible could have been used during the period of transition from arsenic-rich copper to tin bronzes in the El Argar culture or used for the recycling of arsenic-rich copper artefacts being alloyed with tin to produce tin bronzes. This melting crucible is a rare example of its kind to have been investigated scientifically, as most crucibles from contemporary sites on the Iberian Peninsula are generally associated with smelting. This study has also crucially shed more light on the types of alloys and variety of activities undertaken during that transitional period between the use of arsenical copper and tin bronzes in this region.

**J Montes-Landa, I Montero-Ruiz, P Castanyer Masoliver, M S Retolaza, J T Trilla and M Martín-Torres. Traditions and innovations: versatility of copper and tin bronze making recipes in Iron Age Emporion (L'Escala, Spain). Archaeological and Anthropological Sciences 12, 2020, article 124.**

Established around 575 BC, Emporion was a Greek colonial enclave in NE Iberia and hence constitutes a good context to study Mediterranean innovations and their adaptation with indigenous technologies. This analytical study of the archaeometallurgical assemblage from a workshop context dated to the start of Emporion's Neapolis (second half of the sixth century BC) includes slag and technical ceramics. Copper smelting and melting and a variety of bronze alloying techniques were identified, together with iron smelting and forging. The use of Fe-rich copper ores with BaO, ZnO and PbO impurities is consistent with the exploitation of local sources, preceding the diversification of raw materials documented for later phases. The contemporary use of co-smelting, cementation and co-melting as bronze making technologies is discussed with reference to parameters of efficiency and cost-effectiveness and contextualised in the broader colonial interaction. The early use of metallic tin for bronze production at the site supports a Mediterranean origin for this innovation in Iberia.

**M Nečemer, P Kump and T Lazar. Seal dies from the National Museum of Slovenia: Non-destructive analyses of medieval and early modern copper alloys. Archaeometry 62(5), 2020, 965-973.**

A representative group of 95 seal dies made of copper alloys from the collection of the National Museum of Slovenia was investigated by EDXRF. Chronologically, the artefacts date from the early 13th century to the present. Non-destructive EDXRF screening of elemental fingerprints of Cu, Zn, Pb, Ag, Sn and Sb was performed, and the elemental data set obtained was further processed by chemometric tools such as principal component analysis. The relationships between the elemental composition of the seal dies, the type of alloy applied and their historical context – date, location of manufacture and, possibly, social rank of the owner – were examined in detail.

**V Orfanou, T Birch, S M Sindbæk, C Feveile, G H Barfod and C E Leshner. On diverse arts: crucible metallurgy and the polymetallic cycle at Scandinavia's earliest Viking town, Ribe (8th–9th c. CE), Denmark. Archaeological and Anthropological Sciences 13, 2021, article 81.**

Results from the analytical investigation of polymetallic, non-ferrous metallurgy at early Viking Age Ribe, Denmark, in the 8th and 9th centuries CE are presented. Extensive surface analyses of crucibles and moulds (handheld XRF) is combined with micro-destructive examination (micro XRF, EPMA) of crucibles, moulds, ingots, blanks, and finished objects from the different stages of secondary metallurgy. Results show the working of a range of copper alloys with (leaded) brass commonest, alongside small-scale working of silver and gold. Analytical evidence suggests a move towards technological standardisation, reflected in tighter compositional groupings for crucible fabrics, the alloy choices for specific artefact types, and an overall move towards high Zn brass from the 8th to the first half of the 9th century CE.

Limitations and potentials of the surface and micro-destructive analytical methods used are discussed and a direction for future research proposed.

**E Ottenwelter, L Barčáková, C Josse, L Robbiola, Š Krupičková, J Frolík and L Poláček. Technological characterisation of early Medieval gilded copper hollow pendants (gombiky), from Mikulčice (Moravia) and Prague Castle (Bohemia).** *Archaeological and Anthropological Sciences* 12, 2020, article 145.

Gilded copper hollow spherical pendants known as *gombiky* (s. *gombik*) were examined to identify the technology of gilding and the material chosen as the substrate. The ornaments, dating from the 9th and 10th centuries AD, had been recovered from elite graves in two major political, ecclesiastical and economic centres of the early medieval period at Mikulčice (Moravia) and Prague Castle (Bohemia). Surface and bulk characterisation of the gilded material were performed, combining optical observation, X-radiography, metallography, SEM/EDS analysis and focused ion beam (FIB) milling mounted on FEG-SEM. The manufacturing procedure was reproduced experimentally. Investigation of the gilded artefacts revealed several types of *gombik* construction including hard soldering the main body parts and the suspension system elements together. The parts are made with almost pure copper or low-purity copper. Fire gilding was used systematically. Differences in the materials and technical quality show the coexistence of finely produced objects by highly skilled and knowledgeable jewellers alongside more coarsely manufactured ones. These variations are discussed in terms of different workshops in a possible relationship with their origin of manufacture.

**P Piccardo, J Vernet, G Voland and G Ghiara. Metallographic investigation of Early Bronze Age armbands from Western Switzerland (ca. 2200–1500 BC): new highlights about early manufacturing processes.** *Archaeological and Anthropological Sciences* 12, 2020, article 215.

A Valaisan-type armband (a specific type of bracelet) is a typical product from western Switzerland belonging to the classic phase of the Aare-Rhone group (BzA2a, ca. 2000–1800 BC). Using metallography and chemical analysis, the investigation aimed to (i) characterise the metal composition, (ii) reconstruct the thermo-mechanical treatments applied during the manufacturing process, and (iii) gather information on the possible exploitation of local ores. The results show that each armband is manufactured from a hammered sheet of copper-based alloy, containing either tin (up to 3.0wt%) or a combination of antimony, nickel, and silver. In several cases it is assumed that minor elements are already part of the original ore, suggesting a conscious selection of copper veins. In other armbands, a direct addition of cassiterite to the copper matrix is suggested by the composition and features of the inclusions. Microstructural features are coherent with mechanical deformation (70–76%), annealing, and quenching as expected in the Late Bronze Age. The analysis of inclusions provides evidence of thermal treatments applied during the manufacturing process and shows that annealing was carried out at low temperatures.

**A G Sinner, M Ferrante, S Nisi and P R Trincherini. Lead isotope evidence of lead supply in ancient Ilduro (second-first centuries BCE).** *Archaeological and Anthropological Sciences* 12, 2020, article 131.

22 lead objects found in excavations (post 1998) on the ancient site of Ilduro (Cabrera de Mar, Barcelona), including 12 bronze coins and 10 lead objects from houses, workshops and the public baths of the town, were analysed by TIMS. This allowed study of the lead supply and trade networks between the Laetani (local indigenous peoples), the Roman provincial administration and the *societates* controlling the natural resources, their exploitation, and distribution during the Late Republic (2nd–3rd centuries BCE). Rome was dependent on the output of the lead and silver from Hispanic mines during this period. All the coins had lead isotope ratios with values compatible with an origin in the Spanish mining district of Cartagena-Mazarrón, but the isotopic compositions of the 10 lead objects allow identification of three distinct clusters. The samples in cluster 3, which include all the artifacts from the bath complex, can be attributed to the mining district of Cartagena-Mazarrón, thus demonstrating that a single mining district supplied the lead for both minting and the construction of the baths. However, the provenance of the lead in the remaining samples (workshops and houses) remains unresolved. The data from Ilduro points towards the existence of different lead supply patterns in the settlement: directly from the mines for public enterprises, in contrast to recycling and mixing practices in houses and workshops.

**Ž Šmit, B Maróti, Zs Kasztovszky, A Šemrov and P Kos. Analysis of Celtic small silver coins from Slovenia by PIXE and PGAA.** *Archaeological and Anthropological Sciences* 12, 2020, article 155.

A series of 74 small silver Celtic coins of 7 types were analysed using PIXE and PGAA to determine the silver and copper concentrations on the surface and in the bulk. The aim of the research was to determine the purity of the metal and the trace element content in relation to coin type. Though no classification could be made, utilising the concentrations of trace elements in the surface layer (as determined by PIXE), the bulk analysis showed a two-tailed distribution of low- and higher-grade silver. This means that the base metal was supplied through two different distribution centres or that the basic alloy suffered a gradual decrease of fineness as a consequence of inflationary movements.

**D Sych, K Nowak, M Maciejewski, B Miazga and J Baron. Influence of conservation of copper and bronze artefacts on traces of production and use-wear.** *Archaeological and Anthropological Sciences* 12, 2020, article 141.

Although a number of studies of production traces and use-wear in copper and bronze artefacts have been conducted, the influence of their conservation has not received much attention. The authors examine the impact conservation has on traces of production and use-wear in bronze artefacts coming from three Bronze Age hoards: Karmin IV, Paszowice and Lubnowy Wielkie. All deposits have been analysed both before and after conservation. Our results show that traces of production and use-wear might either be highlighted or fade during the conservation process. Thus, we should be extremely cautious when examining copper and bronze

artefacts for their presence. The problem is especially critical for items which come from already-conserved museum collections.

**P Valério, I P Cardoso, M Santiago, M F Araújo, L C Alves, M A Gonçalves and R Mataloto. Microanalytical study of copper ores from the Chalcolithic settlement of São Pedro (Portugal): Copper production in the south-western Iberian Peninsula.** *Archaeometry* 62(2), 2020, 314-328.

Copper ores recovered at the 3rd millennium BCE settlement of São Pedro, Portugal, were characterized by micro-Raman spectroscopy, micro-EDXRF and micro-PIXE. The collection shows the common presence of secondary copper minerals (malachite, pseudomalachite and libethenite) combined with iron oxyhydroxides (haematite and goethite), while arsenic-rich minerals are absent and, therefore, can be excluded as the source of arsenical copper. Overall, these copper ores suggest a primitive technology involving exploitation of the superficial zone of ore bodies and reliant on the fortuitous finding of arsenic-rich sources to produce the arsenical copper frequently present among metallic collections of the Iberian Peninsula.

## ASIA

**G Chen, Y Cui, R Liu, H Wang, Y Yang, A M Pollard and Y Li. Lead isotopic analyses of copper ores in the Early Bronze Age central Hexi Corridor, north-west China.** *Archaeometry* 62(5), 2020, 952-964.

This paper explores the possible provenance of ores employed for metallurgical production during the Early Bronze Age (EBA) in the central Hexi Corridor of NW China. 78 sample pieces of copper ore were collected from five EBA sites and the Beishantang Cu deposit in the Heihe River region of the central corridor. These sites were dated to the late Machang (4100–4000 bp), Xichengyi (4000–3700 bp), Qijia (4000–3600 bp) and Siba (3700–3400 bp) cultures. After comparing with published lead isotopic data from other possible Cu deposits in NW China, the results show that the Cu ores collected from the EBA sites were most likely derived from the adjacent Beishan Cu deposit. More intriguingly, for the first time in the Hexi Corridor, a dozen Cu ores were discovered containing highly radiogenic Pb. Though fundamentally different from those in the Central Plains, they illustrate a possible new type of Cu used in Bronze Age western China, and the first-hand materials are significant for further understanding the provenance of raw metals for metallurgical production in the prehistoric Hexi Corridor.

**L Haichao, L Siran, C Jianli, C Jianfeng, L Xingshan, C Jianrong, G Yuewen, L Xingrui and H Yuxuan. Cold-worked and annealed bronze objects and relevant motif techniques in the Chinese Bronze Age: Analysis of bronze sheets found at Songjia cemetery in Shaanxi, China.** *Archaeometry* 62(1), 2020, 54-67.

Six thin Chinese bronze chariot accessory sheets from Songjia cemetery were dated to the late Western Zhou dynasty (9th-8th centuries BCE) and analysed for their elemental composition and motif techniques. The objects were cold worked and annealed with embossed motifs and carved lines. This is the only case of

cold working and annealing with embossed motifs and carved lines in China; these techniques may have come from or been influenced by other cultures. These findings are important for tracing the development of the cold-working, annealing techniques and relevant motif techniques in China.

**J-S Park, K Rajan and R Ramesh. High-carbon steel and ancient sword-making as observed in a double-edged sword from an Iron Age megalithic burial in Tamil Nadu, India.** *Archaeometry* 62(1), 2020, 68-80.

An iron sword from an Iron Age megalithic burial at Thelunganur in Tamil Nadu was examined using metallography. The sword was made of ultra-high-carbon steel with a fairly uniform microstructure consisting primarily of fine cementite particles in a ferrite background free of notable non-metallic inclusions. The morphological control was not perfect and frequently allowed cementite to precipitate in a network along austenite grain boundaries. Carbide particles of varying size and shape often caused microscopic layers to develop, forming a visible pattern to the naked eye on the polished and etched surface of the sword. This pattern likely inspired the later development of various surface markings such as the damask. The detailed analytical data shows that the sword was an early example of high-carbon steel employed in the manufacture of a functional object where the divorced eutectoid transformation technique, rediscovered recently, was used for the control of cementite morphology. It is proposed that technologies for making and handling high-carbon steel were in existence much earlier than previously supposed.

**C Wang, D Ma, W Luo, Ying Qin, D Chen and F Huang. Study on the casting cores to identify the manufacturing place of Chinese bronze vessels excavated in the Qiaojiayuan tombs from Spring and Autumn period.** *Archaeological and Anthropological Sciences* 12, 2020, article 203.

To date, few large-scale bronze foundry sites of the Bronze Age have been found in the middle and lower reaches of the Yangtze River in southern China, but highly developed bronze cultures have occurred here. For instance, in Qiaojiayuan, NW Hubei province, on the border of southern and northern China, a high-level tomb cluster of Spring and Autumn period (8th-5th centuries BC) has been unearthed. The location of the site is identical with the ancient *Jun* state recorded in historical documents. Thus, figuring out where these bronzes were made can shed light on the status of the *Jun* state and its potential links to other great powers. XRF and ICP-AES were used to characterise the major, trace and rare earth elements in the casting core residues of the Qiaojiayuan bronze ritual vessels. They are largely different from the loess in the Yellow River Basin, but very similar to the laterite in southern China. Moreover, from their chemical characteristics, the samples from Qiaojiayuan closely resemble those from Panlongcheng and Zuo Zhong, but differ from those manufactured in northern China, and they are not consistent with the local soil geochemical characteristics. It can be further speculated that the Qiaojiayuan bronzes were first cast and finished in the *Chu* state before being transported to the area of *Jun*.

**Q Ying, G Wei and Q Huang. The provenance of Yin-Shang bronzes with highly radiogenic lead isotopes.** *Archaeological and Anthropological Sciences* 12, 2020, article 99.

Even if the lead isotope results are the same, the significance of the lead isotopic signature is quite different for the provenance study of Chinese bronzes. The published data show that the radiogenic lead signatures in the unalloyed copper and the Yin-Shang bronzes with low lead content are contributed by the copper deposits, while those of bronzes from South Africa and Zimbabwe with highly radiogenic lead were contributed by tin deposits. Combined with the results of lead isotope analysis by LA-MC-ICP-MS and recent archaeological discoveries, it is possible that the copper material for the Yin-Shang bronzes with highly radiogenic lead contents derived from Zhongtiao Mountain copper deposits, while the lead material came from Huojiagou and Zhenggou in the northern margin of North China Craton, but we prefer that the lead materials were from the southern margin of the North China Craton.

**Y Yun and D A Scott. Characteristic features of metal artifacts excavated in western Yunnan in the Bronze Age.** *Archaeological and Anthropological Sciences* 12, 2020, article 127.

A technical study of metal artifacts from western Yunnan (in SW China) can not only improve our understanding of the bronze culture but also fill many gaps in the archaeological studies that have been carried out on prehistoric bronzes from Yunnan. We summarize the results of our analyses of bronzes dating from the 17th-2nd century BCE. Ninety-nine metal artifacts, including weapons, tools, and decorative objects have been analysed by optical microscopy and SEM-EDS to examine the microstructure and composition. The results show that a variety of alloys were employed, including unalloyed copper, copper-tin, copper-tin-lead, copper-arsenic, copper-arsenic-lead, copper-lead-antimony, copper-antimony, lead-antimony-arsenic-copper, carburized bloom steel and hypoeutectoid steel. The copper alloys were fabricated by casting, cold working after casting, and annealing. This study has expanded our knowledge of bronze culture and reveals some of the technological relationships among the regions of western and central Yunnan, the northern steppe, and SE Asia.

**M Zhang, Y Wan, Y Li, F Yang and Y Li. Metallographic analysis of the recent excavated domestic iron objects from Muyi, Yunnan Province, China.** *Archaeological and Anthropological Sciences* 12, 2020, article 144.

Archaeological evidence shows that the use of iron in Yunnan could be dated to as early as the Warring States Period (5th-3rd centuries BCE). There are large numbers of iron objects excavated from Yunnan, but very limited metallurgical analysis. Iron objects from Muyi provide an opportunity to study the iron production technologies in Yunnan during the Han dynasty (202 BCE–220 CE). Three metallographic samples were prepared and analysed and show that mottled cast iron and decarburized cast iron were used in Yunnan during the Han dynasty. The results are discussed in relation to other studies of iron objects discovered in Yunnan and elsewhere of China.

## AFRICA

**S Baron, M Souhassou and F-X Fauvelle. Medieval silver production around Sijilmâsa, Morocco.** *Archaeometry* 62(3), 2020, 593-611.

Sijilmâsa (SE Morocco) was one of the most strategic cities in the extensive Trans-Saharan trade network, linking the Maghreb with West Africa during the medieval period (8th-15th centuries CE). It was also one of the most important gold and silver monetary workshops at the time. Gold came from West Africa, and written sources suggest that silver was produced in Morocco, although archaeological evidence of silver mining and smelting has remained elusive. An analysis of the lead isotopic data from silver mining districts in Morocco and from ores and slags in the study enabled the tracing of materials and provided tangible evidence of medieval mining in the close hinterland of Sijilmâsa city.

**E C Lyaya. Change and continuity in metal technology: iron production in the first and second millennium CE in Mbinga, southwestern Tanzania.** *Archaeological and Anthropological Sciences* 12, 2020, article 125.

The technological change and continuity of iron production in the 1st and 2nd millennium AD are considered by means of ethno-history, archaeological survey, excavation, and physical attribute methods, while archaeometric data were generated through optical microscopy, electron microscopy, and metallographic techniques. The results indicate that over the last 1500 years, there has been technological change in iron smelting techniques in terms of furnace charging platform, slag-pit provision, slag tapping, use of multiple tuyères per tuyère port, reduction efficiency, utilized iron ore, and final smelting product. At the same time, there has been technological continuity in the furnace construction materials, forced air supply, and spatial organization of iron smelting activities. The changes and continuity in the technology of iron production in Mbinga were probably driven by demand for iron tools for socio-economic purposes, environment, technological efficiency, and the demand for production of carbon-rich steel tools.

## THE AMERICAS

**J Fabián-Salvador, J P Diez, R Aristizabal, S Enzo and O Arnache. Pre-Hispanic gold pieces of an enigmatic archaeological finding in Medellín, Colombia: A glance at an archaeometric analysis.** *Archaeometry* 62(6), 2020, 1182-1194.

Pre-Hispanic gold objects found within a structure that probably served as a funeral pyre were analysed. <sup>14</sup>C analyses of the site's organic materials dated the structure to the 5th century CE. The metal objects were subjected to XRD, EDXRF, SEM-EDX, density measurement by the Archimedes method, and metallographic analysis. The pieces were composed mostly of a single phase of gold and silver. Metallography showed equiaxial grains with some annealing twins. The different colours observed correspond to different grain orientations. Pre-Hispanic objects from a second archaeological site in the municipality of Amalfi (Department of Antioquia) were also analysed for comparison. The results showed no evidence of alloying processes but were

instead manipulated in their original form (native gold). The shape of the objects and their microstructure suggested that the pieces were manufactured by casting, mechanical deformation and then annealing.

**M Martín-Torres, J L G Arenas, U Veronesi and H White. Goldsmithing traditions and innovations in colonial Colombia: an analytical study of crucibles from Santa Cruz de Mompox.** *Post-Medieval Archaeology* 52(2), 2018, 147-169. DOI:10.1080/00794236.2018.1515384.

The 16th-century Spanish conquest of Colombia brought new technologies that altered and interacted with native metalworking traditions. In the colonial village of Santa Cruz de Mompox, renowned because of its goldsmithing tradition, indigenous groups and Spaniards experienced momentous encounters of individuals, metallurgical technologies and knowledge. However, little is known concerning colonial metallurgy, its continuities and

changes with regards to the pre-Columbian period. The analytical characterisation of five crucibles recovered in Mompox, together with discussion of relevant archival is given and evidence for the local manufacture of crucibles, the melting of unrefined gold dust, tumbaga (gold-copper-silver alloys) and silver, some possibly illegal activities, as well as continuity with pre-Columbian traditions in the use of tumbagas, and the Spanish-led introduction of silver in northern Colombia.

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