Abstracts

GENERAL

Mecking, O 2021, 'Determination of PGE and Re in archaeological bronzes: New ways to determine the origin of archaeological copper alloys', *Archaeometry* 63(6), 1272–1289. https://doi.org/10.1111/arcm.12669

A method for determining the platinum-group elements (PGEs) and rhenium (Re) in archaeological bronzes was developed. For 20 mg of sample, detection limits of 0.07 (Re) to 1.4 (palladium; Pd) ng g^{-1} were achieved. The method was tested on standards and compared with measurements determined by the PGEs via matrix separation. The method was applied to 45 samples ranging from the Bronze Age to the Middle Ages. The PGEs did not provide further information for the Bronze Age samples, but the Hallstatt and La Tène Period samples showed increased contents of Pd and platinum (Pt) which distinguished them from all other samples, giving an important indication of the possible ores used. Three groups can be distinguished in the samples from the Middle Ages. One group falls into the Bronze Age field, but the other two have significantly higher Pd and Pt contents. One group has a higher Pd than Pt content, while the other group, the reverse. The high contents of Pd and other PGEs may indicate the use of copper shale from the Eisenach area.

Guerra, MF 2021, 'On gold recycling. A physicochemical point of view', *Archaeometry* 64(S1), 134–149. https://doi.org/10.1111/arcm.12710

Gold has been used as an important medium of exchange and in the production of objects with cultural, social, and religious meanings. Being a finite resource, it has often been recycled. Analytical challenges raised by studies on the reuse and recycling of gold are discussed with given examples, focusing on coins, jewellery and ritual objects. To illustrate the different levels of analytical difficulty, some of these objects were made during times of gold scarcity and others in periods of gold influx.

Stepanov IS, Sauder L, Keen J, Workman V, and Eliyahu-Behar A 2022, 'By the hand of the smelter: tracing the impact of decision-making in bloomery iron smelting', *Archaeological and Anthropological Sciences* 14(5), 80. https://doi.org/10.1007/s12520-022-01516-3

This study investigates the effect of an iron smelter's decision-making and skills on the products of the smelting process: iron and slag. Four smelting experiments were carried out in a shaft furnace with slag tapping using iron ores from the Southern Levant. Using portable X-ray fluorescence analysis, optical and electron microscopy, metallography, and hardness tests the properties of the final products were correlated with adjustment of various parameters during the smelting process *eg* airflow and charging rate, temperature, residence time in the reducing zone, ore-charcoal ratio, and control of the slag characteristics. Results demonstrated empirically the direct impact of decisions made by the smelter during bloomery smelting. Analysis also highlights the benefits of moderately reducing conditions controlled by the smelter to produce good-quality, low-carbon iron, which is particularly relevant within the geological setting of the Southern Levant.

Hoyo-Meléndez JM del, Matosz M, Walanus A, and Krupska-Wolas P 2023, 'Advantages and limitations of archaeometric analysis of archaeological metals: A focus on statistical methods applied to portable XRF spectrometry data', *Journal of Archaeological Science: Reports* 51, 104156. https://doi.org/10.1016/j.jasrep.2023.104156

A statistical approach was used for a compositional study and classification of 213 coins from medieval Poland. Radiation techniques, such as X-ray fluorescence (XRF) and neutron activation analysis (NAA), which operate in the X-ray ($0.001–5 \times 10^{-8}$ m) and neutron ($2–40 \times 10^{-10}$ m) wavelength ranges allow the analysis of elemental composition and bulk properties of the coins, providing valuable insights into their metallurgical characteristics and provenance. After portable X-ray fluorescence (XRF) spectrometry, the results were analysed using a series of statistical analyses, which allowed the coins to be classified into groups based on the concentrations of major elements and the presence or absence of trace elements. The examination of classification patterns using this approach allowed similarities and differences to be established, aiding the compositional categorisation of coins. The statistical analysis of the dataset was in agreement with experimental data obtained using other techniques such as proton induced X-ray emission (PIXE) and neutron activation analysis (NAA). Comparison of the results with prior relevant studies revealed that trace elements can be related to different ores or to various manufacturing processes, providing additional information about the chronology, geographic location, and quality of the coins.

Martini C, Bernardi E, Velino C, Lorenzetti L, Balbo A, Zanotto F, Brunet M, Robbiola L, Guilminot E and Chiavari C 2024, 'Corrosion of aircraft heritage: A comparison between modern and historic Duralumin alloys', *Heritage Science* 12(1), 16. https://doi.org/10.1186/s40494-024-01134-3

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The PROCRAFT (Protection and Conservation of Heritage Aircraft) project identifies the constituent materials of historic aircraft and their deterioration. This is necessary to determine and understand the factors inducing aluminium alloy corrosion in order to develop tailored conservation treatments and identify effective protective coatings. Al-Cu-Mg alloys–Duralumin and Super Duralumin, with a higher content of Mg–were the alloys most employed. These materials undergo a wide range of alterations, including pitting, exfoliation and galvanic corrosion. Results of the examination of a North American Republic P-47D Thunderbolt, crashed in Italy in 1945, are reported and compared to results from a crashed French Breguet 765 Sahara n°504 64-PH, built in 1958. The constituent alloys were similar to the modern 2024 and 2017A alloys. To assess the representativeness of these modern alloys in simulating the corrosion behaviour of the historic ones, exfoliation susceptibility (ASTM G34) as well as non-destructive and destructive electrochemical tests in 0.1 M NaCl were carried out on both historic and modern alloys. This assisted the selection of representative substrates for the development of protective coatings as well as to the expansion of the dataset on composition and microstructures of historic Al alloys for aircraft.

BRITAIN AND IRELAND

Davis M and Harris S 2023, 'Textiles in a Viking Age hoard: Identifying ephemeral traces of textiles in metal corrosion products', *Journal of Archaeological Science: Reports* 48, 103796. https://doi.org/10.1016/j.jasrep.2022.103796

Since the 1980s, mineralised textiles (positive and negative casts in Janaway's terminology) have been an important source of archaeological evidence. The identification of textiles in metal corrosion products when only faint traces remain is now a major issue. These traces no longer appear like textiles and may be misinterpreted. They may be confused with metal dendritic structures or the form of corrosion products, they can also be lost through handling or removed during conservation. This loss is cumulatively significant. This paper characterises the form and structure of ephemeral traces of archaeological textiles through examination of metal corrosion products on a Viking Age hoard from Scotland. A new terminology to supplement Janaway is defined: petal shapes, remnant textile surface, ghost textile surface. A Dinolite portable digital microscope, optical light microscopy with Z stacking and a scanning electron microscopy (SEM) were used. The results allow the secure identification of textiles from previously unidentified corrosion features on corroded archaeological metal objects.

Timberlake S 2023, 'Cobble stone mining tools - evidence of their use in the Bronze Age mines of Britain and in current archaeological experiments investigating ancient mining and the processing of metal ores', *METALLA* 27(2), 119–148. https://doi.org/10.46586/metalla.v27.2023.i2.119-148

The characteristic artefacts of Early Bronze Age metal ore mining are cobble stone mining tools. This study suggests that within these tool assemblages it is normal to see some sort of use specialisation and opportunistic re-use of broken tools, whilst the wear pattern and modification to these tools suggests the creation of ad hoc tool kits, and the use of both hand-held and hafted hammers. At some sites, more than 90 % of cobbles used show only minor evidence of purposeful modification (such as a pecked groove designed for hafting), but extensive experimentation has demonstrated that many of these tools could have been, and probably were used with handles. Discrimination in the collection of cobbles at source is suggested by the evidence of consistency in size, shape, weight and lithology of the stones. In West Wales, suitable cobbles were taken up to 25 km inland from coastal beaches for use at upland sites. Experimental archaeology has successfully predicted the types of tools to be found during the archaeological excavation of sites; this includes the use of antler picks and bone scrapers and chisels which often do not survive in acidic mining environments. Experiments have also shown how the most rudimentary stone artefacts might be used in the processing and concentration of metal ores, including those of copper and gold.

EUROPE

Doonan RCP and Marks YA 2021, 'Blowin' in the wind: The beginning of primary metallurgy in the Early Bronze Age Aegean', *Archaeometry* 64(1), 161–176. https://doi.org/10.1111/arcm.12689

Our understanding of Early Bronze Age copper smelting in the Southern Aegean has improved dramatically in the last two decades through fieldwork, laboratory analyses and experimental reconstructions. The current model of Early Bronze Age copper smelting in the Southern Aegean which has emerged from these studies centres on a perforated furnace stack, used with ceramic pot bellows. This study undertakes a critique of the current model and through experimental reconstructions and analysis of the results, suggesting that the current model has conflated various strands of evidence, resulting in a confused model. It is argued that primary copper production in the Early Bronze Age Southern Aegean was more likely a two-stage process that did not rely on the simultaneous use of natural draught and bellows. Along with other examples of wind-powered furnaces, the working of the Aegean perforated furnace is reconsidered. A new model is proposed along with a consideration of the wider implications.

Berger D, Brügmann G, Bunnefeld J, and Pernicka E 2021, 'Identifying mixtures of metals by multi-isotope analysis: Disentangling the relationships of the Early Bronze Age swords of the Apa–Hajdúsámson type and associated objects', *Archaeometry* 64(S1), 44–74. https://doi.org/10.1111/arcm.12714

This pilot study characterises the analyses of 26 well-known Early and Middle Bronze Age bronze objects from Central and Northern Europe, including swords and axes of the hoards from Apa, Téglás and Hajdúsámson, the famous Sky Disc and its accompanying finds from the Nebra hoard and several full-hilted swords from Period I in Denmark. The isotopic systematics of lead, tin and copper are the focus of the present investigation, relating the typologically closely linked or otherwise related artefacts with chemical and isotopic proxies by identifying mixing scenarios. The results show that artefacts from different locations are most likely not directly linked, but mixing lines across isotope systems

suggest the production of items from common sources by mixing of bronze batches (e.g., bronze ingots) which were probably disseminated between 1600 and 1500 BCE. This helps to correlate objects from different locations and to draw conclusions on typological and cultural connections. Isotopic and chemical correlations of objects within the individual hoards, on the other hand, allow the reconstruction of metallurgical practices in single workshops (for example, implying the recycling of metal scrap)..

Vaxevanopoulos M, Blichert-Toft J, Davis G, and Albarède F 2022, 'New findings of ancient Greek silver sources', *Journal of Archaeological Science* 137, 105474. https://doi.org/10.1016/j.jas.2021.105474

The ore sources of ancient Greek silver artefacts have been explored over the last 60 years, mainly using lead isotopic analysis, concentrating on places mentioned in historical sources. Here, Ag-bearing ore sources in the Aegean world were sought based on their geological characteristics, then Pb isotopes were used to determine whether they were exploited in antiquity. Pb isotopic compositions of 17 Ag-bearing mineralisations in Greece with evidence of ancient mining activity have been identified and tested. A further 10 with minor Ag occurrences may also have been exploited in ancient times. We found that the Pb model ages provide better discrimination of ore sources than the more conventional plots of raw Pb isotope data. Lavrion, northeast Chalkidiki, Pangaeon, Thasos, Siphnos, Palaea Kavala, Angistron and south Euboea were established as the most important ancient silver mining districts in Greece. Two previously undiscovered ancient mining areas in Pelion and in the Kroussia mountain range are also documented. The latter may be identified with ancient Mount Dysoron, from which King Alexander I of Macedon reportedly extracted the fabulous sum of a talent of silver per day. Some of the mining districts in Thraco-Macedonia can be differentiated isotopically. The mines of Thasos include geologically different silver-bearing ore sources. We further identified the hitherto unrealized importance of Euboean silver mines and demonstrate that isotopically they overlap those of Siphnos, with major implications for our understanding of ancient Greek history.

Saussus L, Goemaere E, Thomas N, Leduc T, Goovaerts T, and Fourny M 2022, 'Practices, recipes and supply of a late medieval brass foundry: The refractory ceramics and the metals of an early 15th century AD metallurgical workshop in Brussels', *Journal of Archaeological Science: Reports* 42, 103358. https://doi.org/10.1016/j.jasrep.2022.103358

A rare early 15th century workshop in Brussels, producing small copper-based alloy objects in the late Middle Ages, was investigated. It mass-produced metal dress accessories and other personal objects, mainly in brass, by casting or plastic deformation and were widely spread throughout Europe: the techniques were adapted to satisfy this demand of this large market. This is currently the only workshop in the Low Countries allowing insights into the materials and practices. This paper addresses, in particular, the properties and the supplies of the clay used, the different ranges of alloys and the evidence of the brass production by the cementation process, by combining several analysis methods (petrography using PLM and SEM, Energy Dispersive X-Ray Spectroscopy, PIXE, X-ray diffraction). In combination with written sources, this approach shows that distance was not an obstacle for the supply of high-quality crucible clay and zinc ore for brass production, and places the Brussels workshop in a wider network of circulation of raw materials and know-how related to their use.

Außerlechner MV 2022, 'Plant macro-remains from the Late Iron Age smithy at Piperbühel (South Tyrol, Italy)', *Journal of Archaeological Science: Reports* 43, 103407. https://doi.org/10.1016/j.jasrep.2022.103407

Prehistoric human land use (from the Neolithic onward) in the area around a Late Iron Age smithy with a hearth and smithing waste, in Piperbühel (South Tyrol, Italy), was investigated to understand the plant diet and the environment of the smiths, especially in relation to edible fruits and nuts in the Eastern Alps during the Iron Age. Ten stratigraphic units (total weight of 101 kg) were processed archaeobotanically and analysed. Cultivated plants such as *Hordeum vulgare* (barley), *Triticum dicoccum* (emmer), *Panicum miliaceum* (broomcorn millet) and *Vicia faba* (faba bean) were identified. These were the most commonly cultivated plants during the Iron Age. The edible wild fruits and nuts of *Cornus mas* (cornel cherry), *Corylus avellana* (common hazel), *Prunus* cf. *padus* (probably bird cherry), *Prunus* cf. *spinosa* (probably sloe), *Sambucus nigra* (black elder), and *Vitis vinifera* (grapevine) were consumed. Remains of herbs and weeds such as *Arenaria serpyllifolia* (thyme-leaved sandwort), *Chenopodium hybridum* (maple-leaved goosefoot), *Myosotis sylvatica* (wood forget-me-not), *Polygonum lapathifolium* (curlytop knotweed), *Rumex acetosa* (common sorrel), *Silene vulgaris* (bladder campion) and *Solanum nigrum* (black nightshade) demonstrate different habitats. The wild plants reflect a landscape characterised by low-density deciduous stands, hoe weed, ruderal plant and pastureland communities. The most frequently found fruits and nuts at the settlement sites during the Iron Age were *C. Avellana*, *V. Vinifera*, *P. Spinosa*, *Rubus* (raspberry/blackberry) and *Sambucus*.

Bintliff J, Degryse P, and Zwienen J van 2022, 'The long-term programme of trace metal analysis at the ancient city of Hyettos', *Journal of Archaeological Science: Reports* 43, 103432. https://doi.org/10.1016/j.jasrep.2022.103432

Since 1978, the Boeotia Regional Survey Project in Central Greece conducted surface surveys on five ancient cities and across their associated landscapes. During the 1980′s and 1990′s a programme of trace metal soil analysis began in Thespiai and Hyettos, and also at a series of rural farm sites, as well as over areas of countryside marked by ancient manuring carpets. The results of the analyses from the small Greek and Roman city of Hyettos in northern Boeotia province, taken in 2015, are given here, together with their archaeological context derived from surface ceramics, geophysics and historical sources. The integration of these different data sources provides insights into urban transformation and the cumulative effect of long-term habitation in the anthropogenic pollution of associated soils. The various sources of elevated trace elements in urban sediments are also investigated, as well as the contribution of natural elemental levels from underlying geology.

Guerra MF and Tissot I 2022, 'Analytical study of overlooked Bronze Age and Iron Age goldwork from Northwest Portugal', *METALLA* 26(1), 3–23. https://doi.org/10.46586/metalla.v26.2022.i1.3-23

To understand the use of native gold and intentional gold alloys during the Bronze Age in Northwest Portugal, a portable X-ray fluorescence spectrometer was used to study a Late Bronze Age bracelet from Monte Airoso (Viseu), an Iron Age tubular bracelet from Regoufe (Aveiro) and also all the components (bracelets, wires and bands) of the Arnozela (Braga) hoard (so far incompletely studied). The results show that from the Middle Bronze Age onwards, gold containing 8-11 wt.% silver was used, to which gradually increasing amounts of copper seem to have been added, over time. These results support a heterogeneous chronology for the components of the Arnozela hoard and show that the Monte Airoso bracelet is made from an intentional gold alloy used in the Portuguese area during the Late Bronze Age. The bracelet from Regoufe, however, is made from native gold without additions of copper. This could indicate that during a certain period, the goldsmiths used both native gold (as found) and intentional alloys. Two other objects completed the study: one of two Portuguese Early Bronze Age gold sheet ornaments with cut parallel bands (so-called gargantilha de tiras), found in Braga. Made with gold hammered into sheet, this ornament is made from an alloy that seems to correspond to a later period using gold from another origin. Finally, the composition of some of the components of the Late Bronze Age-Iron Age string from Malhada (Vila Real), a set of plaques made from punched gold sheet supports the addition of small amounts of copper to gold to produce intentional alloys.

Bottaini C, Martínez SG, Bordalo R, Beltrame M, Mirão J, Rafael L, and Schiavon N 2022, 'Islamic copper-based metal artefacts from the Garb al-Andalus. A multidisciplinary approach on the Alcáçova of Mārtulah (Mértola, South of Portugal)', *Heritage Science* 10(1), 97. https://doi.org/10.1186/s40494-022-00736-z

A multidisciplinary investigation of the Islamic production technology of copper-based artefacts found during archaeological excavation campaigns carried out in the Almohad neighbourhood of Mārtulah, (modern Mértola, Southern Portugal). In contrast to other Islamic materials found in the same site (common and finely decorated pottery, glass, and bone artefacts), metal objects have received less attention despite the high number of artefacts recovered. This study focuses on the chemical characterisation of 171 copper-based artefacts dating back to the 12th and the first half of the 13th centuries. The artefacts are daily use objects, consisting of personal ornaments (earrings, rings, and casket ornaments), tools (spindles, spatulas, and oil lamp sticks) and artefacts with unknown functions. X-ray fluorescence Spectroscopy (XRF) analysis results provided information not only about technological issues but also the socio-economic implications of metal consumption in Islamic Mértola. Metals were produced using a variety of Cu-based alloys, namely unalloyed copper, brasses (Cu+Zn), bronzes (Cu+Sn), and red brasses (Cu+Sn+Zn), with a variable concentration of Pb, without any apparent consistency, probably a result of recurrent recycling and mixing scrap metals practice or the use of mineral raw materials available locally.

Valério P, Soares RM, Silva RJC, Soares AMM, and Araújo MF 2022, 'New evidence on Iron Age bronze metallurgy in southwestern Iberian Peninsula: Ingots and artefacts from Cabeço Redondo (Portugal)', *Archaeological and Anthropological Sciences* 14(8), 163. https://doi.org/10.1007/s12520-022-01633-z

Archaeological remains of a monumental building in the Guadiana River basin (southern Portugal) included finds (ceramics and metal artefacts) of the sixth–fifth century BC. Metallurgical copper-based debris included ingots, lumps, prills and a massive plano-convex ingot, with tools, small implements, ornaments and rods. A chemical and microstructural study using micro-EDXRF, optical microscopy and SEM–EDS provided some answers about foundry activities and identified the composition and post-casting manufacture of artefacts. Most metal debris was composed of pure copper (>99 wt% Cu), although some bronze and leaded bronze was used at the Cabeço Redondo metallurgical workshop. The artefacts were mainly low-tin bronze alloys (7.6 ± 3.9 wt% Sn) and leaded bronze alloys (7.7 ± 4.4 wt% Sn and 6.0 ± 3.4 wt% Pb). Bronzes were hammered and annealed, but the leaded bronzes were usually not subjected to post-casting work, implying a well-defined understanding of function, composition and manufacture. The evidence from the metal debris and artefacts was compared with coeval sites in the SW Iberian Peninsula in the mid-first millennium BC.

Ottenwelter E, Josse C, Proietti A, and Robbiola L 2022, 'Fire gilding investigation on early medieval copper-based jewellery by focused ion beam (FIB) on FEG-SEM', *Journal of Archaeological Science: Reports* 46, 103602. https://doi.org/10.1016/j.jasrep.2022.103602

The study of ancient gilding is often problematic, as the gilding layers are soft and prone to deformation during sample preparation. Focused ion beam (FIB) milling on a field emission gun scanning electron microscope (FEG-SEM) provides minimally invasive in situ sampling. This process was applied to gilded medieval copper-based elite jewellery (10th century) from Prague Castle. Cross-sections and slices of gilded samples were investigated up to nanometer scale without gilding layer deformation. Coupling structural observation with elemental X-ray analysis (EDS) and electron beam diffraction (EBSD), FIB FEG-SEM provided new data on the physical–chemical characteristics of the gilded layer. The gilding has a two-layered structure, consisting of a quaternary Au (Hg, Cu, Ag) alloy (the gold solid solution fcc phase), and a submicrometric inner sublayer formed by an Au-Cu phase (from the interdiffusion of copper from the substrate during the fire gilding process). The gilding temperature can be estimated as c. 400 °C. Sintering of the mercury-gold amalgam globules during the process is highlighted. The precise characterisation of the gilding layers provided useful comparative parameters for identifying fire gilding skill levels and assessing the overall quality of the archaeological pieces.

Müller J, Delgado-Raack S, Escanilla N, Kienle L, Kneisel J, Czebreszuk J, Jaeger M, Szmyt M, and Schürmann U 2023, 'First evidence for the forging of gold in an Early Bronze age site of Central Europe (2200–1800 BCE)', *Journal of Archaeological Science: Reports* 47, 103748. https://doi.org/10.1016/j.jasrep.2022.103748

Evidence of gold processing in the fortified site of Bruszczewo (Poland) is the first indication of the production of gold artefacts at a domestic Early Bronze Age site in Central Europe. This paper highlights the potential of macrolithic tool assemblages as a key element in the recognition of metallurgical work processes. It presents an optimised methodological approach to tackle the application of stone tools in metallurgical production, based on technological characterisation and use-wear analysis, using portable X-ray fluorescence, transmission electron microscopy and energy dispersive X-ray spectroscopy. The absence of gold sources in Central Europe raises the question about the origin of the metal. This is an important issue, as gold was a raw material of restricted access. As Bruszczewo was one of the few enclosed Early Bronze Age sites north of the Central European Mountain Range, the investigation of metal processing (including gold) sheds light on the mode of the production of metal artefacts, apparently restricted to central sites of power, which controlled the communication trails.

Sdralia A-M, Kassianidou V, and Rehren T, 2023, 'Late Roman copper smelting in Polis Chrysochous, Cyprus', *Journal of Archaeological Science: Reports* 48, 103889. https://doi.org/10.1016/j.jasrep.2023.103889

Two Late Roman slag heaps located near Polis Chrysochous, western Cyprus, were studied to reconstruct the technological processes of copper production. This is the second richest mining region on the island. The Pelathousa slag heap (4th – 6th century CE) is located at the foothills of the Troodos Mountains, about 5 km inland from the coast, while the Argaka slag heap (3rd – 8th century CE) is situated by the coast. An assemblage of 112 slag pieces collected from the two slag heaps was macroscopically examined. Subsequently 49 of the samples were chemically analysed using portable X-ray Fluorescence (pXRF). A smaller subset of these were further examined by optical microscopy and Scanning Electron Microscopy with Energy-Dispersive Spectrometry (SEM-EDS). The samples from both slag heaps have a similar composition, including a wide variability in manganese content (ranging from less than 1 wt% to almost 40 wt%). Manganese was probably added as a flux and procured from the umber deposits of the Pera Pedi formation which is readily accessible from the nearby mines. The prevalence of sulfide inclusions across all samples indicates that the slag assemblage derives exclusively from copper-matte smelting. The results are then discussed to understand the difference in manganese content, and the organization of copper production within the landscape.

Kupczak K, Warchulski R, Gawęda A, and Janiec J 2024, 'Bloomery iron production in the Holy Cross Mountains (Poland) area during the Roman period: Conditions during the metallurgical process and their uniformity between locations', *Heritage Science* 12(1), 147. https://doi.org/10.1186/s40494-024-01266-6

The study assessed the uniformity of the iron smelting processes during the period of Roman influence in Poland. The age of the investigated material was confirmed based on an analysis of the $^{12}C/^{14}C$ isotope ratio in the charcoal found in slag from four Holy Cross Mountains (Poland) locations. The evaluation included smelting temperature, viscosity of the metallurgical melt, oxidation–reduction conditions, and slag cooling rate determination based on geochemical (XRF) and mineralogical (XRD, SEM, EPMA) analyses. Despite the distance between individual sampling sites, the smelting conditions were similar for all samples. The slag liquidus temperature range was 1150–1200 °C. Oxidation–reduction conditions were determined through thermodynamic calculations using SLAG software. In the temperature range of 1150–1200 °C, the oxygen fugacity had to be below log p_2 = − 13.20 to − 12.53 atm to reduce iron oxides to metallic iron. The viscosity of the metallurgical melt was calculated and ranged from 0.15 to 1.02 Pa s, indicating a low viscosity. The slag cooling rate, based on olivine morphology, was in the range of > 5 to 300 °C/h. Smelting parameters were compared with other locations in Poland, and similar results were obtained for slags from Masovia and Tarchlice. In the case of one site (Opole), despite differences resulted from contamination of the slag with material from the furnace/pit walls giving a higher maximum value of liquidus temperature, it appeared that the process probably took place in similar conditions.

NEAR EAST

Ho JWI and Erb-Satullo NL 2021, 'Spatial investigation of technological choice and recycling in copper-base metallurgy of the South Caucasus', *Archaeometry* 63(6), 1306–1326. https://doi.org/10.1111/arcm.12668

The prolific bronze industry of Bronze Age Colchis (modern western Georgia) was investigated by incorporating legacy Cu alloy compositional data with recent research which showed technological choices and spatial patterning. This revealed a massive injection of fresh copper into the system during the Late Bronze–Early Iron Age and a high degree of selectivity in the alloys used for different objects: colour appeared to be as important as hardness in determining these choices. Spatial analyses also show significant geographical variability in alloying practices, which map onto topographical zones in unexpected ways. A range of different reuse activities appear to have been employed under differing economic conditions. The data suggest relatively extensive primary alloying of tin and copper in the Late Bronze and Early Iron Ages, indicating that some local tin sources were exploited.

Hauptmann A, Heil N, Di Nocera GM, and Stöllner T 2022, 'Making copper: Processing in Early Bronze Age Arslantepe (VI B2)', *METALLA* 26(2), 113–140. https://doi.org/10.46586/metalla.v26.2022.i2.113-140

This paper presents results of archaeometallurgical finds from Arslantepe VI B2 with observations and geoscientific analyses of ores and ore deposits in East Anatolia connected with this site. Function and technology of Early Bronze Age crucible smelting in a small-scale domestic mode of production are discussed. Ore and rock inclusions in the slags and lead isotope analyses are consistent with the origins of various copper sources on the Black Sea coast in the north (Artvin/Murgul, Trabzon) and in the south (Ergani Maden, Upper Mesopotamia) and broadens the Early Bronze Age trade of the Kura Araxes cultural network. The petrology of slags also from Çayönü Tepesi and Nevali Çori shows their formation by partial (eutectic) smelting processes and

the non-liquation of refractory materials. The model of deliberate fluxing in smelting copper is proven to be disputable. Smelting of copper was performed in portable crucibles of surprisingly large size with air supply from below.

Güder Ü, Özdemir A, and Verčík M 2023, 'Brass metallurgy in Urartu: Recent evidence from eastern Anatolia'. *Journal of Archaeological Science: Reports* 48, 103898. https://doi.org/10.1016/j.jasrep.2023.103898

Traditionally, the beginning of substantial brass production using the cementation process has been placed to the Early Roman period. Sporadic early finds from at least since the Late Bronze Age are thought to have been the result of various experimentations by eastern Mediterranean metallurgists. Several Anatolian finds, dated to the early first millennium BC, made from zinc rich alloys, have been interpreted within this framework. In ancient Urartu, however, the mastery and application of advanced metal technologies of both casting and working of copper-alloys as well as blacksmithing are well documented. Recent finds unearthed during the rescue excavations at Murat Tepe and Murat Höyük in the Murat River basin in modern eastern Türkiye have shed light on the development of zinc metallurgy in eastern Anatolia. The metal assemblages from stratified contexts at both sites were analysed by multiple archaeometallurgical methods. The results from portable XRF (pXRF), metallography, microhardness, scanning electron microscopy-energy dispersive X-ray spectrometry (SEM-EDS) and Raman spectroscopy analyses showed that zinc was intentionally used as an alloy additive in order to fabricate brass. Moreover, in one case, a composition consisting of zinc (Zn), tin (Sn) and copper (Cu) was detected, which suggests different alloying practices for the production of different types of objects. These new observations raise further questions about the production of brass prior to the wide spread of this metal technology in the Roman period.

Kvavadze E, Chagelishvili R, Rezesidze N, Gilmour B, Beridze T, Tatuashvili N, and Sulava N 2024, 'Palynological study of archaeometallurgical artefacts from the Late Bronze Age copper smelting sites (Georgia): First results', *Journal of Archaeological Science: Reports* 53, 104300. https://doi.org/10.1016/j.jasrep.2023.104300

This article focuses on the palynological (pollen and non-pollen palynomorphs) study of material found with artefacts from Late Bronze Age archaeometallurgical sites in the Lechkhumi area of the mountainous south-west Caucasus region of ancient Colchis. The organic residues recovered from voids in slag and crucible fragments revealed pollen and spores of diverse plant taxa and also many non-palynological palynomorphs. More than 50 palynomorphs were identified. The chemical composition of the copper smelting slag fragments contributed to the good preservation of the pollen grains, although further work is needed. The spectrum from slag includes taxa that are more poorly preserved in sediments, including soil which makes palynological research of slag residues promising in the future. The range of fossilized plants and spores recovered proves that during the Late Bronze Age in Lechkhumi, forests dominated by chestnut (*Castanea sativa*) occupied a much larger area than today, together with other thermophilic trees. Also present were *eg* zelkva (*Zelkova carpinifolia*), oak (*Quercus*), lime (*Tilia*), and hornbeam (*Carpinus betulus*) and thermophilic ferns in the undergrowth. In the 13th–9th centuries BC, warmer climatic conditions in Lechkhumi compared to the present is also confirmed by the presence of freshwater thermophilic algae *Pseudoschizaea*, *Spirogyra* and other Zygnemataceae found in the spectra. Spores of bracken fern (*Pteridium aquilinum*) and fungus *Ustulina* most probably reflect felling and human exploitation of the woodland close to the site. Comparison of palynological and wood charcoal analyses demonstrated that the metallurgists used the nearby woods as a source of fuel. Thanks to favourable climatic conditions, beside copper smelting, some small-scale agricultural activities were evidenced by the composition of herbaceous plant taxa.

Lapérouse J-F de, Eppihimer M, Flisch A, and Zboray R 2024, 'Revealing ancient technology: A high-energy x-ray computed tomography examination of a Mesopotamian copper alloy head', *Heritage Science* 12(1), 307. https://doi.org/10.1186/s40494-024-01417-9

Although the origins of lost wax casting extend back into the 5th millennium BCE, it was not until the development of hollow core casting that life-sized metal sculptures could be produced. Based on existing evidence, the earliest adoption of this technique, which involves the inclusion of a clay core within a wax model, occurred in Iraq (Mesopotamia) during the Early Dynastic III period (ca. 2600–2350 BCE). To date, only one hollow core casting from the succeeding Akkadian period (ca. 2350–2150 BCE)—the Sargon Head in the collection of the Iraq Museum—has been studied from a technical point of view. The recent attribution of The Metropolitan Museum of Art's Head of a Ruler to this formative period of hollow core lost wax casting provided the impetus for its examination by high-energy X-ray computed tomography which was a practical way of displaying the interior morphology of this sculpture, given the considerable thickness of its metal walls and that it was constantly on display. The scan revealed a markedly different style of production to the Sargon Head. The scan of the Head of a Ruler provides evidence of some of the challenges encountered and problem-solving strategies used in the casting process at this period.

ASIA

Liu, Y., Xi, T., Ma, J., Liu, R., Kuerban, R., Yan, F., Ma, Y., & Yang, J. (2022), 'Demystifying ancient filigree art: Microanalytical study of gold earrings from Dongheigou cemetery (4th-2nd century BCE) in north-west China', *Journal of Archaeological Science: Reports 41*, 103344. doi: 10.1016/j.jasrep.2022.103344

Filigree involves soldering together plain or twisted wires of gold or silver, arranged in artistic compositions. The microstructure and craftworking process of a pair of gold earrings found in Tomb 11 of the Dongheigou cemetery (4th-2nd century BCE) in present-day Balikun County, Xinjiang Uygur Autonomous Region were investigated in this study, using 3D digital microscopy and scanning electron microscopy with energy dispersive x-ray spectroscopy. Results show that the earrings were made by hammering gold wires and brazing the components together to produce delicate filigree works, using gold alloys with different

amounts of copper. The microanalysis of the objects provides important information on fabrication, possible origins and dating within a wider Eurasian context.

Pryce TO, Lam W, Cadet M, Jiang Z, Yang W, and Yao A 2022, 'A late 2nd/early 1st millennium BC interaction arc between Mainland Southeast Asia and Southwest China: Archaeometallurgical data from Hebosuo and Shangxihe, Yunnan', *Journal of Archaeological Science* 143, 105612. https://doi.org/10.1016/j.jas.2022.105612

Archaeometallurgical data from the Yunnanese Bronze Age sites of Hebosuo and Shangxihi is used to examine the nature of early exchange networks within Yunnan, across southern China and into Mainland Southeast Asia (MSEA). Traditional perspectives on relations between China and MSEA were viewed from a Core-Periphery perspective, derived from World Systems Theory but this area, though now divided by national borders, has shared ecological and cultural characteristics that allow its definition as the Southeast Asian Massif (SAM). The fourteen analysed samples were all unleaded copper or bronze, mostly as-cast and with some annealing. Their lead isotope signatures did not group at site level but showed broad consistency with the other, limited, signatures available from Yunnan, Sichuan and Guangxi. Critically, comparison with MSEA signatures revealed good isotopic consistency with key Bronze Age sites in Thailand, Myanmar and Vietnam, active within tight timeframes, and mostly lying on or near the path of major river systems that find their source in or via Yunnan. The picture we propose, based on current data, is one of a complex network of autochthonous SAM societies interacting at short (ca. 50 km), medium (ca. 300 km) and long (ca. 800–1600 km) ranges over mountainous and forested terrain.

Li Y, Yang Y, Wang T, Wang X, and Luo W 2022, 'Cultural exchange and integration: Archaeometallurgical case study on underneath-blade bronze dagger-axes from Shuangyuan Village Site in the Eastern Zhou Dynasty', *Heritage Science* 10(1), 151. https://doi.org/10.1186/s40494-022-00786-3

Underneath-blade bronze dagger-axes (henceforward dagger axes) were utilized widely in both the Central Plains and southwest China. However, opinions differ on whether the dagger-axes which excavated from Ba-Shu culture were produced locally. Combined with archaeological typology study, p-XRF and MC-ICP-MS were used to analyse 12 dagger-axes unearthed from Shuangyuan Village Site, an Eastern Zhou cemetery in Chengdu city, Sichuan Province, Southwest China to investigate the cultural exchange and integration centered on the Shu culture. The majority of samples consisted of copper, tin, and lead ternary alloy. Lead isotope data indicate that the dagger-axes have different mineral sources. The lead isotope ratio $^{206}Pb/^{204}Pb$ of 18.3 suggests that the dagger-axes originated in the Chengdu Plain or the Central Plains which is consistent with the typology. The southern China lead materials of dagger-axes in the Ba-Shu and Central Plains style probably came from southern Sichuan; while the rest of dagger-axes in the Central Plains style might have used lead materials in the western Hunan-western Hubei area. The Shu culture (represented by Shuangyuan Village Site in Chengdu Plain during the Eastern Zhou Dynasty) had close cultural communication with the Central Plains and Chu cultures. This study reveals that Ba-Shu had a direct exchange of minerals or metal products with the Central Plains and Chu, as well as imitations based on the identification of the foreign culture and the belief in the local Shu cultural traditions.

Zhang Z, Chen J, Qian W, and Yang Z 2022, 'Characteristics of various non-metallic inclusions in ancient cast iron and solid-state decarburized iron products from a government-run iron workshop during the Han Dynasty in Dongpingling Ruins, Shandong Province', *Journal of Archaeological Science: Reports* 46, 103663. https://doi.org/10.1016/j.jasrep.2022.103663

With low contents of impurity elements and the near absence of large slag inclusions, ancient Chinese cast iron used to be viewed as a kind of pure iron material. Thus, some crucial non-metallic inclusions in cast iron were missed in previous studies. A series of pig iron and solid-state decarburised iron implements excavated from a Han dynasty official iron workshop at the Dongpingling site were analysed to reveal the characteristics of non-metallic inclusions in these iron products. The impurity element content was low. The iron samples were identified with 5 categories of non-metallic inclusions, including silicate inclusions, sulphide inclusions, silica inclusions, endogenous oxide inclusions (agglomeration of multiple oxide) and those recombined by them. In addition, the formation mechanism of each inclusion was also discussed.

Li H, Liu X, Yang F, Ma R, Cui J, Li S, Zhu M, Huo W, and Lv H 2022, 'Analysis of copper-base and gold artifacts from the Phyi Dbang-Dung Kar site in western Wibet, China, 400 BCE–600 CE', *Journal of Archaeological Science: Reports* 46, 103726. https://doi.org/10.1016/j.jasrep.2022.103726

Phyi Dbang-Dung Kar is one of the most important archaeological sites in western Tibet which lasted from the Bronze Age to the 16th century. Nomadic swords found here provide new evidence of interaction outside the western Himalayas. These copper-based and gold artifacts were analysed for their elemental, metallographic, and lead isotopic features. A comparative study suggests that the raw materials used changed over time and show few connections with Nepal or southwest China. However, similar copper-base and gold techniques were seen in Nepal and India. Even though direct trading is not confirmed, interaction regarding techniques in the western Himalayas is a possibility.

Salgado-Pizarro R, Camacho S, Montón-Subías S, Moragas N, and Inés Fernández, A 2023, 'Reused and recycled. Archeometallurgical study of historical nails found in Guam, Mariana Islands, Western Pacific', *Journal of Archaeological Science: Reports* 47, 103746. https://doi.org/10.1016/j.jasrep.2022.103746

This article presents the results of the archaeometallurgical analyses (chemical, compositional, and mechanical) conducted on historic iron nails from the Marianas archipelago, in the western Pacific. The nails were recovered at the archaeological excavations of San Dionisio's church and cemetery (Humåtak, Guam). They all came from abroad and were incorporated by the native communities through exchange, trade, or through the reuse of materials found in shipwrecks, although it is not possible at present to locate their exact origin. However, we know that all the

analysed samples had different metallographic and mechanical characteristics. This is the first study of these characteristics on Micronesia.

Desai M, Jaikishan S, and Rehren T 2023, 'Are crucible steel ingots isotopically homogenous? AMS radiocarbon measurements on ingots from Telangana, India', *Journal of Archaeological Science* 156, 105805. https://doi.org/10.1016/j.jas.2023.105805

Radiocarbon analysis is increasingly used to date archaeological and historical metal objects directly, ranging from low-carbon bloomery iron to steel and cast iron. However, little is known about the isotopic homogeneity of iron-carbon alloys, particularly in relation to the formation of primary cementite. The ^{14}C measurements for five crucible steel ingots and one crucible steel object from Telangana in south-central India are presented. Two of the ingots were analysed twice. The results show a very wide scatter of ^{14}C dates, far exceeding the expected age range for this assemblage. The repeat analysis of one of the ingots gave also widely different results, indicating a fundamental problem with the ^{14}C analysis of crucible steel. We discuss the various factors that could have influenced the measured isotopic values, including variability in raw material, sampling contamination, and fractionation during the cleaning of the metal in hot acid, leading to excessive sample mass losses prior to the extraction of carbon from the metal. We argue that mass-dependant fractionation of the different carbon isotopes between austenite and cementite during solidification of the ingot, and subsequent selective dissolution of one metal phase over the other, led to a distortion of the ^{14}C signature to seemingly older ages. We recommend further research to explore the compound-specific isotopic signature of high-carbon iron alloys and the effect of selective corrosion on such material, to reduce potential errors in ^{14}C dating of steel and cast iron.

Wang N, Zhang R, Wei G, Shi H, Yang T, and Bai Y 2024, 'Determining the foundry area of bronze chariot-horse excavated from Yang'an Han tomb in Qionglai, Sichuan Province: Based on the scientific analysis of residual casting cores', *Journal of Archaeological Science: Reports* 57, 104653. https://doi.org/10.1016/j.jasrep.2024.104653

The bronze chariot-horses excavated from the Yang'an Han tomb in Qionglai, Sichuan Province, were high-ranking burial objects. To investigate their provenance, X-ray fluorescence (XRF), X-ray diffraction (XRD), petrographic and phytolith analyses were conducted to characterize the major elements, trace elements, mineral crystals types and phytoliths in the casting core residues. The chemical and petrographic compositions of the casting cores were significantly different from those of the primary soils and the pottery artefacts from Xi'an, but similar to those of Chengdu, which indicated that the raw materials of the casting cores of the bronze chariot-horses derived from local sources, confirming that the Yang'an chariot-horses were cast locally rather than being transported as finished products from the central government of the Western Han Dynasty.

He X, Sun Z, Liu S, Chen J, and Gong X 2024, 'Provenancing copper in the middle Shang period through isotopic analysis of metallurgical remains', *Journal of Archaeological Science* 168, 106020. https://doi.org/10.1016/j.jas.2024.106020

Archaeological investigations at the site of Tajiasi, a Middle Shang bronze casting workshop, have discovered abundant metallurgical micro-remains from various stages of bronze production processes. Lead isotope analysis of these samples suggests metal sources probably employed during this period. The copper melting and refining slags, characterised by $^{206}Pb/^{204}Pb$ ca.18.0 and very low lead concentrations (4,000 ppm), reliably suggest that the Jiurui metallogenic district in the Middle Yangtze River, the location of the Shang period copper smelting site of Tongling, was the copper source for the Taijiasi site in the Middle Shang period. However, alloying slags and bronze objects bearing highly radiogenic lead (HRL, $^{206}Pb/^{204}Pb > 19.0$) show an elevated, but still relatively low Pb content (~2 wt%), suggesting that the source of the tin introduced Pb which was characterised by HRL. Items including alloying slags, dross, spillages and bronze objects have similar HRL characteristics to the Middle Shang bronzes from other sites. This indicated the Taijiasi site was involved in a multi-line metal circulation during this period, and the complexity and multiplicity of supply networks for different kinds of metals. It also highlighted the great potential of copper melting and refining slags for detecting the copper provenance.

Li Y, Xiao H, Ma C, Murakami Y, Sun T, and Li Y 2024, 'Microstructural and elemental analyses of slags excavated from the Gushishan iron-smelting site, Sichuan Province, China', *Archaeometry*. https://doi.org/10.1111/arcm.13026

The Shu Commandery was an important iron production centre in southwest China during the Han Dynasty (202 BC-AD 220). In 2007, archaeologists excavated a Han Dynasty smelting furnace (L1) at the Gushishan site and collected large amounts of smelting remains including slags, furnace bricks, and ores. Scientific analysis of the excavated slags was carried out to ascertain if the Gushishan site was a pig iron smelting site. No flux was used at the Gushishan site, which is dated no later than the Eastern Han period. No remains related to iron casting of the Han Dynasty were found at or near the iron smelting sites in southwest China, which indicates a separation between iron smelting and iron casting as characteristics of the industrial layout in this region.

AFRICA

Chirikure S 2022, 'Recycling and the material science tetrahedron: Everyday strategies of making in high temperature technologies of Iron Age southern Africa', *Archaeometry* 64(S1), 26–43. https://doi.org/10.1111/arcm.12784

This paper applies the Material Science Tetrahedron concept to explore practices of pottery recycling in selected craft activities performed in first and second millennium CE southern Africa. It combines analyses of pottery decorative styles on vessels and their fragments used for metal processing with fabric inclusion mineralogy and chemical composition to show that recycling was a sociotechnical endeavour integral to making and remaking everyday things in society. Recycling weaved, along the *chaîne opératoire* tapestries of materialities formed by and flowing from relationships between crafting, materials, containers, and humans as part of the daily routines of making, provisioning, and consumption.

Cordivari BW, Nikis N, and Martinón-Torres M 2022, 'Smelting copper in decorated pottery: Communities of practice in the Niari Basin, Republic of the Congo, fifteenth–seventeenth centuries CE', *Archaeological and Anthropological Sciences* 14(11), 210. https://doi.org/10.1007/s12520-022-01653-9

Copper production in the Niari Basin, Republic of the Congo during the period of mid 15th to mid 17th centuries CE was studied, using pXRF, OM, SEM–EDS, and FTIR to assesses the microstructure and composition of slags and technical ceramics from sites associated with two different regional pottery traditions: Moubiri-type (at the site of Kingoyi near Mindouli) and Kindangakanzi-type at Kindangakanzi near Boko-Songho. Both sites are characterised by the use of refractory domestic pottery as crucibles for copper smelting. Moubiri-type pottery is alumina-rich, while Kindangakanzi-type pottery is formed from a magnesia-rich clay, a crucible type unique in sub-Saharan Africa. Similarities in chaînes opératoires at Kingoyi and Kindangakanzi suggest sharing of knowledge at mining and smelting sites, interactions we reconstruct as a metallurgical constellation of practice comprised of the distinct potting communities of practice (see Supplementary information for abstract in Lingala and French).

Rademakers FW, Auenmüller J, Spencer N, Fulcher K, Lehmann M, Vanhaecke F, and Degryse P 2023, 'Metals and pigments at Amara West: Cross-craft perspectives on practices and provisioning in New Kingdom Nubia', *Journal of Archaeological Science* 153, 105766. https://doi.org/10.1016/j.jas.2023.105766

The results of elemental and lead isotopic analysis of copper alloys, copper-based pigments and an extremely rare tin-based alloy from the town of Amara West (Sudan), the centre for pharaonic control of occupied Upper Nubia between 1300 and 1070 BCE are presented. It is the first assemblage of its kind to be analysed for Upper Nubia from this period. The selection and consumption of alloys are examined in a colonial context, in light of earlier and contemporaneous practices and patterns in both Egypt and Nubia, to assess broader systems of resource management and metal production. Drawing on complementary information from pigment analysis, insights into interactions between high-temperature crafts are obtained, particularly in terms of shared provisioning systems. Pigment analysis is used for the first time to illuminate copper sources not reflected in metal assemblages, while scrap copper alloys are identified as a key colourant for Egyptian blue manufacture. The integrated application of strontium isotope analysis further highlights the potential for identifying links between glass, faience and Egyptian blue production systems within Egypt and for distinguishing these from other manufacturing regions such as Mesopotamia. The analysis of a tin artefact further expands our understanding of potential tin sources available during the New Kingdom and their role in shaping copper alloy compositions. Overall, this holistic approach to copper alloys and their application in other high-temperature industries ties together different strands of research, shaping a new understanding of New Kingdom technological practices, supply networks and material stocks circulating throughout the Nile Valley.

Vieri J, Chirikure S, Lane P, and Martinón-Torres M 2023, 'Archaeological science, globalisation, and local agency: Gold in Great Zimbabwe', *Archaeological and Anthropological Sciences* 15(8), 127. https://doi.org/10.1007/s12520-023-01811-7

Great Zimbabwe (CE1000–1600) is world famous for outstanding cultural innovations and localised and globalised evolvement with trans-Africa and trans-Indian Ocean exchange. New excavations yielded fragments of over a hundred gold processing vessels comprising reused pottery and purpose-made crucibles from stratified contexts in the Eastern Ridge Ruins and adjacent areas. Samples were studied using archaeological, microscopic, and compositional (SEM–EDS) techniques. All ceramics were alumina-rich clays, possibly derived locally. These technical ceramics were used for refining and collecting gold at high temperature, probably producing ingots and also finished objects. The composition of the gold prills from crucible slag is consistent with that of natural, unalloyed gold, while the variability in silver levels and minor impurities point to heterogeneous gold sources. These results suggest that local agency and gold consumption were much more significant than generally assumed and that Great Zimbabwe's famous participation in local and global exchanges was backed by internally driven but improvisation laden production and consumption occurring in homesteads located throughout its various settlements. A word of caution is raised about oversimplified narratives of globalisation and their archaeological expressions (see Supplementary Material S0 for the abstract in Shona).

AMERICAS

Arnache O, Ricaurte G, Fabian-Salvador J, and Pimienta H 2022, 'Analytical approach of colour and elemental composition in gold metallic objects from the Quimbaya culture: A case study in Antioquia, Colombia', *Journal of Archaeological Science: Reports* 42, 103290. https://doi.org/10.1016/j.jasrep.2021.103290

Colour has been an outstanding feature in the Quimbaya (pre-Hispanic) culture, especially in relation to its gold artifacts and alloys. To evaluate these characteristics, the relationship between gold contents and colour in these artifacts, the elemental composition and surface colouration of ten goldwork samples found in the Antioquia-Colombia (early and late Quimbaya) cultures were studied. Portable and non-destructive experimental techniques (energy dispersive X-ray fluorescence spectroscopy - EDXRF and UV–Vis fibre optic spectrophotometry) were used. The results indicated that most pieces contained the elements Au, Ag and Cu, with the highest concentration being Cu (~18% – 40%) in seven of the samples tested. At first glance, colour changes due to elemental concentrations are noticeable in all objects. Colourimetric analysis was used to verify those changes using optical reflectance spectrum analysis, with a new empirical model written in MATLAB. This software allows the processing of all reflectance spectra and estimates the colourimetric parameters (a*, b*, c*, L*, h*). We found that the spectra are sensitive to changes in elemental concentrations other than gold and copper (Ag and Cu). According to the colourimetric parameters a* and b*, two groups of objects associated with early and late temporality are differentiated. The results reveal a correlation between the hue (h*) and the Au and Cu concentrations.

Babot P, Gonzalez Baroni LG, and Becerra MF 2022, 'Objetos de cobre arsenical y sociedades agropastoriles en la Puna Meridional Argentina: Nuevas perspectivas sobre la metalurgia del segundo milenio aP en los Andes centro sur', *Latin American Antiquity* 34(2), 295–313. https://doi.org/10.1017/laq.2022.24

We perform the first compositional, morphological, and contextual analysis of metal objects from the Southern Puna of Argentina (1430–2070 BP) which is outside the main productive centres of the south-central Andean copper metallurgy. Unalloyed copper and arsenical and lead-arsenical copper alloys with a variety of minority elements that correspond to different ores and, potentially, different production places within the south-central Andes are identified by scanning electron microscopy and energy dispersive X-ray spectroscopy (SEM-EDS). We argue that the metal would have circulated long distances on different routes within the framework of social networks that linked areas at different heights on both Andean slopes. The Southern Puna constitutes a node in this circulation during the Middle period when metal objects were integrated into domestic rituals of foundation and closure by the co-resident group connected to the agropastoralist annual cycle.

Plaza MT, Garrido F, and Larreina-García D 2023, 'A new piece of the puzzle: Slag and ore analysis to reconstruct the prehispanic smelting technology at the Atacama Desert, Chile', *Heritage Science* 11(1), 171. https://doi.org/10.1186/s40494-023-01017-z

Although various local metallurgical technologies throughout the Andes were appropriated by the Incas during their period of expansion, including the widespread use of tin-bronze, little is known about the technical parameters achieved by ancient metallurgists and the changes that occurred during the Inca expansion. These changes are addressed through a case study of Copiapó valley, focusing on the Viña del Cerro site, one of the most famous Inca smelting centres of the southern Andes, where operations began long before the imperial expansion, using wind-powered furnaces. We analysed 19 slag and 11 copper ore samples using OM, SEM–EDS, WD-XRF, and XRD analyses. Results identified heterogeneous and viscous slags, rich in SiO_2 (43 wt%) and poor in FeO (13 wt%). Copper retention was high (up to 60 wt%). Microstructural analyses indicate that slags were formed under unstable oxidising conditions, reaching temperatures from 1000 to 1100 °C. The copper produced was very pure. High-grade copper ores containing up to 69 wt% CuO were reduced at the site, combining carbonates (malachite, azurite), halides (buttgenbachite, clinoatacamite), and some sulphates (brochantite). Even under the relatively unfavourable conditions for slag formation, the smelting conditions generated at Viña del Cerro were capable of extracting metal, but not necessarily enough to form liquid slag. The local metallurgists' thorough knowledge of the wind flow and their ability to select the right ore facilitated the processes.

Lambert SP, Shane Miller D, Sanger MC, Baumgartel O, Hale M, Raymond T, Neff H, and Dussubieux L. 2024, 'Copper on the Mississippi coast: Assessing provenance of a copper bead at the Claiborne site (22HA501) through LA-ICP-MS compositional analysis', *Journal of Archaeological Science: Reports* 53, 104366. https://doi.org/10.1016/j.jasrep.2023.104366

The Claiborne site (22HA501) is located at the mouth of the Pearl River in southern Mississippi and was occupied sometime between 3990-3340 BP. A copper bead from Claiborne was examined using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) compositional analysis to assess the provenance of the copper bead to understand the extent, direction, and intensity of trade networks integrated into this site and its connection to both Poverty Point and other copper-holding Archaic-era sites in the region, possibly originating from the Great Lakes region, or the Appalachian Mountains/Canadian Maritimes. The compositional results show a significant elemental relationship to copper from the Great Lakes region.

Gassmann G, Klein S, Schäfer A, Welk E, and Wester K 2024, 'Investigating Pre-Columbian gold and copper in Costa Rica – ores, mines and artefact production', *METALLA* 27(2), 149–166. https://doi.org/10.46586/metalla.v27.2023.i2.149-166

The quantity of pre-Columbian gold, copper, tumbaga and guanín (alloys consisting mainly of gold and copper) artwork of Costa Rica suggests that exploitation of its abundant ore deposits goes back to before the Spanish conquest. The name of Costa Rica itself in fact alludes to the large numbers of golden metal objects worn by the indigenous peoples upon arrival of the conquistadors. As little is known about pre-Columbian mining in the country or the raw material provenance of these artefacts, a transdisciplinary project aims to reconstruct the metallurgical process chain by combining (mining) archaeological research with geochemical analysis of local ores and metal artefacts. Four major gold and copper districts with different mineralisation types were identified and surveyed for potential signs of pre-Columbian metal production and sampled for ores and their processing remains. Metal artefacts in museum collections were systematically registered in a database, which serves as a basis to identify correlations between their geochemical signature and possible areas of origin or different workshops. Once the necessary basic data have been collected, the focus will be on the economic and socio-cultural aspects of metal production and circulation. The results from Costa Rica will be put into perspective of New World early metallurgy and can provide a starting point for future research between Mesoamerica and the Isthmo-Colombian region.

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