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DEWA 2023

FROM MINE TO OBJECT

Dialogues between Eastern and Western Archaeometallurgy (3rd-1st mill. BC)

ABSTRACTS

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Rolande SIMON-MILLOT, Musée d'Archéologie nationale et Domaine National de Saint-Germain-en-Laye

ABSTRACTS

Session 1
Mining and ore extraction activities

Ancient Southwest Asia - a 'heartland of metallurgy' - but where are the mines?

Vincent C. Pigott

The intent of this presentation is to overview the archaeologically documented evidence for ancient mining, primarily of copper and tin, first in Iran and Anatolia to be followed by evidence from the southern Levant. Southwest Asia witnessed the earliest use of native metals and brightly colored ores among agricultural and agro-pastorialist peoples between the 11th – 9th millennia BCE to ornament the living and the dead. In Anatolia and Iran, native copper artifacts and malachite beads are among the most common finds. Here the numerous deposits are mostly weathered, copper sulfide ore bodies that formed during metallogenic activity resulting from plate tectonics. Native copper and oxidic ores are to be found in the gossan cap (*chapeau de fer, eisenhut*) at the surface or in the underlying oxidized zone of such ore bodies from which these materials could be easily collected or extracted. Massive sulfide deposits in the Anarak mining district in central Iran and in eastern Anatolia at Ergani Maden, sources of native copper and oxidic ores, have not yielded much evidence of prehistoric extraction due to huge modern mining operations. But, for example, the ca. 8th millennium site of Çayönü in southeastern Anatolia, not far from Ergani Maden, yielded some of Southwest Asia's earliest metal artifacts arguably fashioned from native copper from this deposit. Simply put, during the Neolithic in Iran and Anatolia, the collection or surface pitting of native copper and/or colorful ores could easily have been so shallow as to be unrecognizable by archaeologists and/or the evidence of working was mined away by more recent mining.

Moving from a virtual lack of direct Neolithic mining evidence in Iran/Anatolia, the discussion segues to the Bronze Age, ca. 3rd /2nd millennia, and here again the evidence for archaeologically excavated mines remains markedly sparse. Over the years exemplary mining archaeology has been conducted by teams from the Deutsches Bergbau-Museum (DBM) in Bochum, Germany who included the late, great Dr. Gerd Weisgerber who conducted mining surveys in Iran, but no excavations. Recently, the DBM team of Drs. N. Nezafati and T. Stöllner undertook excavations at the late 3rd to late 2nd millennium mines at Veshnaveh in central Iran - to be discussed by them later. The discussion turns to tin mining and mention is made of N. Nezafati, E. Pernicka and M. Momezadeh's fieldwork at the widely distributed, open-pits found at Deh Hosein in central western Iran. The polymetallic deposit contains complex copper/tin ores like stannite and is arguably a major tin source for the greater region. A single ^{14}C date suggests open-pitting at ca. 1500 BCE, but evidence suggests mining back into the 3rd millennium. In south central Anatolia, during the 3rd millennium, the large-scale excavations at the enormous tin (cassiterite) mine at Kestel lead by Prof. Aslihan Yener as well as new mines near Kayseri are detailed next.

Whereas, in contrast to the sulfidic geology of the deposits mentioned above, in the southern Levant, in Israel and Jordan at the enormous copper mining sites at Timna and Faynan, geological conditions of ore emplacement are quite distinct from Iran/Anatolia. At Faynan, Jordan, Prof. T. Levy and his team as well as other research teams of distinguished colleagues have revealed the exploitation of its copper deposits from the Neolithic on with massive exploitation emerging in the Early Bronze Age. Results are summarized with regard to mining activity at this site.

At Timna, sandstone cliffs were shot through with veins of oxidic copper ores like malachite with little evidence of copper sulfides. Generally, here, mining from the Chalcolithic onward usually involved shallow, open-pitting and later shaft and gallery extraction penetrating into deeply bedded sedimentary deposits. Over time archaeologists have documented mines now numbering in the thousands and their results are summarized. Timna and Faynan are remarkable mining contexts in the Old World and their research provides among the best models for how to undertake the archaeology of mines and related technologies. As an example of innovative mining research, Prof. E. Ben-Yosef, Director of the Central Timna Valley Project, has pioneered the application of Optically Stimulated Luminescence (OSL) to "chronologically anchor" mining sediments in mining context that otherwise might be impossible to date with any precision. This new advance is briefly detailed and may well have broad applications in ancient mining contexts elsewhere.

This presentation concludes with mention of the pressing need for preservation of ancient mines as a part of every country's cultural heritage. Ancient mines are being lost at an alarming rate.

Vincent C. Pigott
Consulting Scholar, Asian Section
University of Pennsylvania Museum, Philadelphia, PA. USA
vcpigott@aol.com

Firesetting and Herding as practices of Early Mining Communities between Europe, Eurasia and West Asia

Thomas Stöllner

The presentation aims at the dissemination of knowledge stocks within mining communities between Europe, West Asia and Central Asia between the 4th and 2nd millennium BCE. Within this vast space, remarkable technical similarities in subsistence practices and ore extraction can be observed. They include ore extraction by means of fire-setting, the extraction of ores with the help of stone mallets and the subsequent ore dressing before the pits, as well as the regular transport of ore concentrates to settlements nearer or further away, where the ores were further smelted and cast into shape with the help of crucibles. These techniques required the appropriation of montane resource spaces through more or less permanent, but mostly seasonal practices and a way of life equally tied to this rather extensive and mobile strategy at certain times during the year. It can be assumed that the management of grazing zones and animal herds had to adapt to these conditions in a specialised way and that other agricultural strategies were added in phases, when greater continuity in the year-round care of the fields was possible in the settlements. Climatic and subsistence conditions in the montane resource areas thus played an important basic prerequisite for the adaptation of technical practices in ore mining. Just as the basic geological conditions favoured the spread of certain techniques. The lecture focuses on several intensively studied ore mining sites (Georgia, Kazakhstan, Iran, Jordan) of this period and sheds light on similarities, but also differences in a time before the development of intensive metal mining, which took place between the 3rd and 2nd millennium BCE in different places of the larger area. In particular, the question of the importance of different conditions for connectivities in the montane deposit areas is investigated and it is asked whether certain technical patterns could not spread in particular environments that proved favourable for the implementation of an already tested body of knowledge. In contrast to the dissemination of metallurgy, the focus is placed more on the appropriation of peripheral environments and the application of knowledge practices in such spaces.

Thomas Stöllner
Deutsches Bergbau Museum, Bochum, Germany
thomas.stoellner@bergbaumuseum.de

The Roua mines: a Neolithic native copper extraction in the Southern Alps (Alpes-Maritimes)

Romain Bussone

The Roua mines are small native copper extractions located at the Dôme de Barrot in the Southern Alps (Alpes-Maritimes). Explored by archaeologists in the 1990s, they have yielded the remains of fire-settings and stone tools, testifying to an ancient copper extraction. The ore veins were the subject of mining research in the 19th century, and the fillings of the old galleries that yielded coals and bones have now disappeared, their existence being attested only by a mention in the archives. Thus, no dating had been established for these old excavations. The dating of the ancient excavations and the estimation of the volume of copper extracted were obtained during the fieldwork carried out as part of a thesis. In the absence of charcoal, the archaeomagnetic method was used on the old excavations by fire to obtain an age for the opening of the galleries. For the same purpose, thermoluminescence and optically stimulated luminescence methods were used on the walls in ancient mining remains. During the field surveys, unexplored galleries were discovered. These galleries, not much impacted by the recent blast excavations, have yielded stone hammers, fire-settings and charcoal remains. The charcoals were analysed by radiocarbon method to obtain a dating of the mining activity: beforehand, they were classified according to anatomical and taxonomic criteria and palaeo-thermometry analyses to select the most favourable individuals for obtaining an age for the diggings The combination of all these methods provides coherent ages: the Roua mines were dug during the 4th millennium and the first half of the 3rd millennium. The galleries were documented by means of photogrammetry and cave surveys techniques for the study of the volume of the fire excavated parts. In this way, it was possible to obtain an estimate of the amount of copper metal mined in ancient times. Only a few dozen tons of copper metal were extracted from the galleries in all periods. For the oldest periods, this quantity is estimated at a few tonnes.Isotopic analyses were carried out on the ore to characterise the copper from this mine and to enrich the reference systems for the study of provenances. The results obtained are compatible with a native copper awl discovered in a Chassaean context in Liguria (Italy). All these elements attest to a very early age of copper extraction in Western Europe, contemporary with the ages obtained from the Monte Loreto and Libiola (Liguria) extraction. Compared to other protohistoric extractions, the Roua mines are small native copper ones. Given the scarcity of metallic objects identified in the Neolithic period, they have delivered significant tonnages of copper for this period.

Romain Bussone
UMR 5140 ASM, LabEx Archimede, Université Paul Valéry – Montpellier 3, France
romain.bussone@hotmail.fr

Project Ancient Tin : Did British tin sources and trade make Bronze Age Europe?

Alan Williams, Kamal Badreshany, Matthew Ponting, Mia Montesanto & Benjamin Roberts

A remarkable change occurred in c. 2200 BC when Britain and Ireland were the first regions in Europe to completely switch over from copper to harder and more gold-coloured bronze for their tools and weapons, typically with around 10% tin. This change (bronzization) spread across the rest of Bronze Age Europe and the Mediterranean over the following centuries, reaching southern Spain and Greece only by c. 1500/1400 BC.

The tin required to make the bronze was much scarcer than copper, with the main potential sources being in South-West England (Cornwall/Devon), the Germany-Czech border (Erzgebirge), the Iberian tin belt and smaller deposits in France (Brittany and Massif Central). Even at 10% of the bronze, large amounts of tin were required for the copper production from the 50+ confirmed Bronze Age copper mines across Europe, with two of the largest probably requiring around 10,000 tons of tin. As South-West England possessed probably the richest and most accessible tin deposits in Europe and close to the coast, there has long been speculation that this region traded tin across the continent and even supplied Bronze Age civilizations in the Eastern Mediterranean. Identifying a major role in this vast production and trade network for the dispersed and small farming/mining communities of Bronze Age Britain would radically change the perception of the island's relationship with the rest of Europe and beyond. In parallel, the relationship between Bronze Age sites in Cornwall/Devon with tin deposits will be examined with a GIS database.

Project Ancient Tin, funded by the Leverhulme Trust, has sought to 'fingerprint' tin ores and tin artefacts from Britain relative to those from tin sources elsewhere in Europe using three independent analytical techniques (multi-element chemical analysis, lead and tin isotopes). This builds on the work of the ERC Bronze Age Tin project that was initially focussed on tin isotopes of ores and bronzes but later used these three techniques on tin artefacts. We have now extended the use of multi-element chemical and lead isotope analysis to tin ores, despite the technical challenges, and applied this approach to over 100 tin ore samples collected from across South-West England and, in addition, those from elsewhere in Europe mainly provided by CEZA Mannheim. Furthermore, we are obtaining several samples of Bronze Age tin artefacts from across Europe and beyond for analysis. During 2023 the results of all these analyses will be examined and the initial conclusions regarding tin provenance and tin trade in the European Bronze Age and beyond will be presented. The project is led by Durham University in collaboration with the University of Liverpool with support from CEZA, Mannheim, the Cornish Archaeological Unit and many other organisations and individuals.

A few of the 39 tin ingots from the probable Bronze Age shipwreck near Salcombe in SW England.

Alan Williams
Kamal Badreshany,
Matthew Ponting
Mia Montesanto
Benjamin Roberts
Project Ancient Tin,
Durham University,
Leverhulme TRUST,
University of Liverpool, UK.
Project website: https://projectancienttin.wordpress.com

The prehistoric copper mine of Veshnaveh and its relation to some ancient metallurgical sites in central Iran; A mineralogical and archaeometric approach

Nima Nezafati & Thomas Stöllner

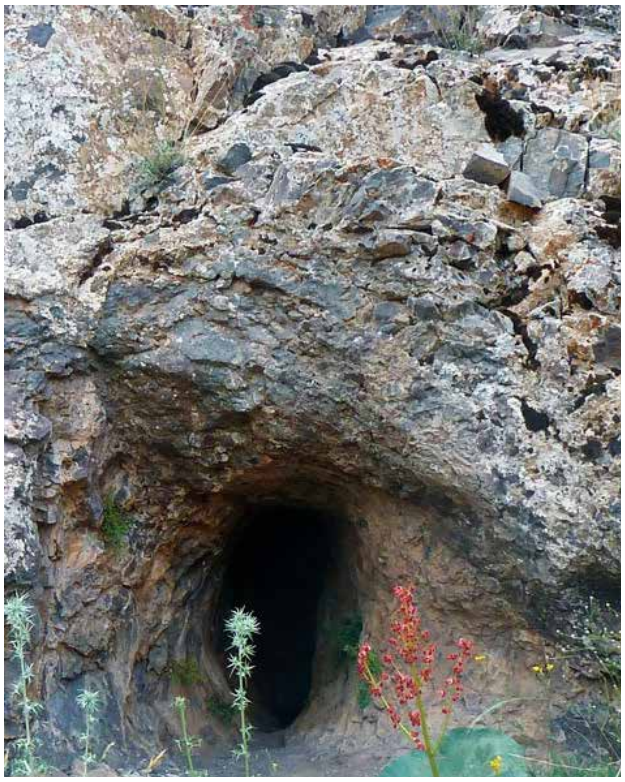
The Veshnaveh copper mine in central Iran is among the rare ancient mines of the country that have systematically been investigated from both ancient mining and archaeometric points of view. Veshnaveh is situated in the middle of the Orumieh-Dokhtar volcanic belt in north central Iran and is hosted by middle-upper Eocene volcanic and sedimentary rocks. The mine consists of three mining sites with more than 60 large and small ancient diggings and holes. The pre-

View of the ancient quarries in Veshaneh (Iran).

Ancient quarries at Vesnaveh showing traces of fire.

Ore pieces (left) and typical stone mallets (right)..

This *Amosstein* lay at the entrance of an ancient quarry



An antique man-hole quarry showing traces of firing

sence of grooved hammer stones, traces of fire-setting for exploitation of the ore, and archaeological and radiocarbon dating data show that the mine has been active for copper production from the late 3rd millennium until the mid and late 2nd millennium BCE.

The ore and rock samples from Veshnaveh were investigated using diverse geochemical and mineralogical methods including ore microscopy, scanning electron microscopy, inductively coupled plasma mass spectrometry, and lead isotope analysis in order to better understand the nature of mineralization. In addition, the ore of Veshnaveh was compared with the analytical results from the ancient metallurgical relics of some key sites in central Iran including Tappeh Sialk, Arismān, Tappeh Sarm, and Jamkarān.

The results show that despite the proximity of the mine to the ancient metallurgical sites of Sialk and Arisman, the ore of Veshnaveh has not been used for copper extraction in these two ancient sites. Nevertheless, the Veshnaveh copper mine could have been an ore supplier for the second millennium BCE ancient sites of Jamkarān and Tappeh Sarm, a suggestion especially based on lead isotope analyses.

Nima Nezafati
Thomas Stöllner
Deutsches Bergbau-Museum, Bochum, Germany
Nima.nezafati@bergbaumuseum.de
thomas.stoellner@bergbaumuseum.de

Chalcolithic and Bronze Age Copper Mining in the Internal Betic Ranges (South-East of the Iberain Peninsula)

Ignacio Montero-Ruiz, Mercedes Murillo-Barroso, Aaron Lackinger, Daniel Pérez L'Huillier

The first metallurgical cultures in the South-East of the Iberian Peninsula, Los Millares (Chalcolithic) and El Argar (Bronze Age) cultures, developed in the geographic area covered by the Internal Betic Ranges (from Estepona (Málaga) to the West to Cape Santa Pola, between Murcia and Alicante, to the East). In this area, copper resources are abundant and widely distributed, but contrary to other regions, such as the North of the Guadalquivir Valley (Sierra Morena), few direct evidences of prehistoric mining are known, despite the fact that a great number of metal items and metallurgical debris have been archaeologically recovered.

Through indirect evidences based on lead isotope analysis, the perception of copper mining at this time changes dramatically, and it is possible to identify some mining areas where copper ores were exploited.

In this presentation we summarize the state of art on studies based on lead isotopes analysis (LIA) that identify prehistoric mining works without archaeological record, some of them with potential to future archaeological research.

The identification of copper resources could help to assess the scale of local metallurgy, the exchange of raw material or metallic objects between geographic areas in the same region or the control over the metal production in order to understand the role of metallurgy in the process of social complexity.

Ignacio Montero-Ruiz
Instituto de Historia-CSIC
ignacio.montero@cchs.csic.es

Mercedes Murillo-Barroso
Universidad de Granada
murillobarroso@ugr.es

Aaron Lackinger
Universidad de Granada

Daniel Pérez L'Huillier
Universidad de Granada

Session 2

Tools, actors and production loci: specialization and organization

Fine metalworking tools from Western and Northern Europe during the metal ages

Barbara Armbruster

This paper deals with an aspect of the history of technology, more precisely with a diachronic overview of tools and workshops used for fine metalworking. It gives a comprehensive assessment of the enhancement in morphology, materials and function of early metallurgists' tool equipment. From the inception of metallurgy in Western and Northern Europe in the third millennium BC to the first millennium BC, tools and manufacturing techniques for gold, silver, and bronze artefacts developed in step with each technological improvement. An interdisciplinary approach to the study of metalworking tools and workshops – combining archaeology, tool mark analyses, ethnoarchaeology, experimental archaeology, iconography, and information from ancient written sources with analyses from material sciences – is proposed. Case studies from Western and Northern Europe illustrate the various specialized implements employed in the fine metalworker's workshop, the raw materials chosen, the tool making, and how tools were handled. This diachronic vision allows for drawing a picture of the metal workshop's equipment and organization through time and space.

Barbara Armbruster
CNRS-UMR 5608-TRACES Toulouse, France
barbara.armbruster@univ-tlse2.fr

Economy and status of the metallurgist according to Babylonian texts of the 1st mill. BC

Francis Joannès

Francis Joannès
University Paris 1 – Panthéon-Sorbonne, UMR 7041 ArScAn, Nanterre, France
francis.joannes@gmail.com

The discovery of new melting furnace types at Ayn Soukhna (early Middle Kingdom) and intentional arsenic alloying for metal casting: an interdisciplinary approach

Georges Verly, Frederik Rademakers, Florian Téreygeol, Florence Maqueda, Claire Somaglino & Pierre Tallet

The 2019-2022 excavations have uncovered previously unknown melting furnaces for the production of arsenical copper alloys. In contrast to the Middle Kingdom melting furnaces already known from Ayn Soukhna, these portable furnaces provide a completely new perspective on metallurgical traditions inherited from the late Old Kingdom.This unique technical ceramic type stands out from the revised Ayn Soukhna crucible typology, yet is clearly related to metallurgy. Interdisciplinary archaeology and the study of Old Kingdom metallurgical scenes identify this flared cylinder as a portable furnace for secondary metallurgy in an expeditionary context.

Furthermore, a second exceptional discovery provides evidence of deliberate arsenic alloying at the very end of the *chaîne opératoire* at Ayn Soukhna and at Wadi el-Jarf. Archaeological excavations combined with in situ p-XRF analysis have demonstrated that all raw copper produced at Ayn Soukhna was highly pure, yet arsenic was added during certain melting operations to create an alloy. These discoveries are a crucial *first* towards understanding the production of efficient stone and woodworking tools.

This deliberate addition has become a fundamental issue, to be explained in relation to the technological contributions of arsenic. Our holistic method gathers archaeological evidence (working spaces, forced ventilation methods, material selection, furnace and crucible types, metals and ores) to reconstruct as closely as possible the working conditions of the ancient metallurgists.

This has enabled experimental archaeological research to successfully create alloys - varying between 1 to 8% arsenic content - from metallic copper and arsenic ores. These alloys were melted and cast to produce chisels in sandstone moulds. Such technological studies of the mechano-physical properties of arsenical copper and its impact on casting are challenging our understanding of Old and Middle Kingdom metallurgy.

Georges Verly
PhD student at the Sorbonne university,
UMR 8167 (Orient & Méditerranée), équipe Mondes Pharaoniques
archaeologist (Wadi el-Jarf and Ayn Soukhna sites)
g.verly@outlook.fr

Frederik W. Rademakers
Metals and Inorganic Analysis , British Museum, Department of Scientific Research
& KU Leuven, Earth and Environmental Sciences
FRademakers@britishmuseum.org

Florian Téreygeol
Directeur de recherches CNRS,
UMR 7065 IRAMAT LAPA et NIMBE UMR3685 CEA/CNRS,
directeur de la plateforme expérimentale de Melle (Deux-Sèvres, France)
florian.tereygeol@cea.fr

Florence Maqueda
PhD student at CNRS UMR 7065 IRAMAT LAPA, NIMBE, UMR3685 CEA/CNRS
& UMI 209 UMMISCO
florence.maqueda@ens-rennes.fr

Claire Somaglino
Maîtresse de conférences, Sorbonne université
UMR 8167 (Orient & Méditerranée), équipe Mondes pharaoniques,
co-directrice de la mission archéologique d'Ayn Soukhna (Égypte)
claire.somaglino@sorbonne-universite.fr

Pierre Tallet
Professeur, Sorbonne université,

directeur de l'UMR 8167 "Orient et Méditerranée", directeur de l'équipe Mondes pharaoniques,
directeur de la mission archéologique d'étude du Sud-Sinaï (Paris-Sorbonne, IFAO),
directeur de la mission archéologique du ouadi el-Jarf (Paris-Sorbonne, IFAO, université d'Assiout,
co-directeur de la mission archéologique d'Ayn Soukhna (Paris-Sorbonne, IFAO)
pierre.tallet@sorbonne-universite.fr

Late Bronze and Early Iron Age Transformations in South Caucasus Metallurgy

Nathaniel Erb-Satullo

With its abundant ore deposits, rich assemblages of metal artifacts and numerous metal production sites, the South Caucasus is among the best places in the world to investigate ancient metallurgical innovation. Indeed, the region saw early use of many globally important metals, and is known for several distinctive metallurgical technologies, such as widespread use of antimony and copper-antimony alloys.

Centering on the Late Bronze and Early Iron Age, this paper synthesizes a decade of research by myself and colleagues on metallurgy in the South Caucasus, analysing patterns of technological innovation, reorganisation, and rejection in iron, bronze, and gold metallurgy. Recent work has significantly revised prior claims for early 2nd millennium BC iron smelting in Colchis, and has begun to construct a robust framework of analytically-verified iron metallurgical sites throughout the region. The results bring the data on production sites into closer agreement with the appearance of iron metal objects in the region. It has also uncovered evidence that certain stages of bronze and iron metallurgical activities were intertwined, with implications for the economic conditions driving the innovation of iron.

Field and laboratory research on copper smelting has documented prolific industrial landscapes in western Georgia, with unusually decentralized patterns of organization that differ markedly from contemporary smelting landscapes elsewhere in the Near East.

Finally, geospatial modelling of a database of more than 4500 gold artifacts, assembled from nearly 130 years of archaeological research reveals a ~700-year disappearance of gold metallurgy in a large portion of the South Caucasus during the Late Bronze and Early Iron Age, and tests models to explain this technological discontinuance.

Within the wider Near East, the Caucasus is unusual in that broader trends in settlement patterns, social organisation, and material culture display a high degree of continuity across the Late Bronze to Early Iron Age transition. While elsewhere, empires collapsed and economic systems were disrupted in the so-called 12th Century Crisis, continuities in the South Caucasus make it a useful test case for exploring the interplay between technological change and societal resilience. The paper concludes with some reflections and points for discussion on what makes the South Caucasus different in this regard, moving from metallurgical data to a broader consideration of archaeological research in the region.

Nathaniel Erb-Satullo
Cranfield University, UK
n.erb-satullo@cranfield.ac.uk

From mold to object... The workshops of metallurgists of the Late Bronze Age in Montélimar and Aubervilliers (France)

Muriel Mélin & Éric Néré

The places dedicated to bronze casting are mostly revealed indirectly, through material that is often very discreet, such as fragments of molds, crucibles or nozzles, as well as rare metallic waste. These objects are generally found in a discarded position. Direct traces that would indicate the precise place where the smelting took place and the work spaces related to it, remain extremely rare.

This paper will highlight two particular sites from the Late Bronze Age, «Rue Saint-Denis» at Aubervilliers in Seine-Saint-Denis and «Rue du Bouquet» at Montélimar in the Drôme, sites that have yielded remains related to important metallurgical activities, one thanks to the exceptional preservation of soil levels, the other through a significant quantity of mold remains. Their comparison will be the starting point for more global considerations on the metallurgist's workshop as it is perceived today.

Montélimar (Drôme), view of the ground level during excavation and bronze pin in place (photo E. Néré)

Aubervilliers (Seine-Saint-Denis), fragments of cast waste discarded in a pit and sample of clay molds

Muriel Mélin
Service départemental d'archéologie du Morbihan
UMR 6566, CReAAH
muriel.melin@hotmail.f

Éric Néré
Inrap, UMR 8215, Trajectoires, Paris
eric.nere@inrap.fr

Stones in the toolkit. Contribution of use-wear and residues analysis to the identification of metals production between Europe and the Near East.

Caroline Hamon & Selina Delgado-Raack

The emergence and development of copper and bronze metallurgies, but also of precious metals such as gold and silver, are major issues in addressing the cultural and economic dynamics of prehistoric Europe. However, since research has focused on typologies and distribution of metal objects (found mainly in graves), the documentation on the structures of ore extraction and metal production workshops remains disparate, and only partially enlighten the stages of production.

The identification of the stone tools involved in these technical processes makes it possible to partially fill this gap. Thus, recent work in use-wear and residue analysis (for example, XRF, SEM-EDX) on different categories of stone tools (picks, crushers, grinders, casting moulds, anvils, abraders, hammers, whetstones, etc.) from Europe to the Near East have made it possible to specify the technical processes used for extracting ores, transforming them into metal, shaping metal objects and maintaining them.

Through different examples from Europe and the Near East, this paper will discuss the contribution of functional analyses to the identification of these tools and beyond the contexts of metal production during the Bronze Age. The presence of such tools in settlements, primary or secondary workshops, as well as in particular funerary contexts, allows us to better understand the organisation of production, the degree of specialisation of metalworkers and their status in the societies of the 3rd to 1st millennium BC.

Caroline Hamon
CNRS, UMR 8215 Trajectoires
9 rue Mahler
75004 Paris
caroline.hamon@cnrs.fr

Selina Delgado-Raack
Department of Prehistory
Universitat Autònoma de Barcelona
Facultat de Lletres, Edifici B,
08193 Bellaterra, Barcelona, Spain
selina.delgado@uab.cat

Un habitat du Bronze final et son atelier de métallurgiste à Saint-Avé (Morbihan, France)

Stéphane Blanchet & Muriel Melin

Durant l'été et l'automne 2022, une fouille préventive conduite sur près de 5 hectares dans le cadre de l'aménagement d'un pôle sportif a permis la découverte et l'étude d'un habitat de la fin de l'âge du Bronze. Les éléments de datation obtenus jusqu'à présent situent l'occupation entre -1000 et -800.

Le site d'habitat se matérialise par une dizaine de maisons presque toutes construites suivant le même plan circulaire et regroupées sur un espace relativement restreint (5000 m²). Elles sont accompagnées de différentes constructions annexes, en particulier de greniers. L'organisation du site, le mobilier associé (meules en pierre, vases de stockage) indiquent que nous sommes en présence d'un habitat groupé principalement tourné vers des activités agro-pastorales. Au sein de cette occupation, un petit dépôt d'objets en Bronze étroitement associé à une construction de plan ovalaire, à une fosse riche en rejets de terre cuite ainsi qu'aux restes d'un four témoigne en outre d'une très probable activité métallurgique.

La fouille étant très récente, l'exploitation exhaustive des données ne fait que démarrer. Cependant, les observations effectuées sur le terrain offrent un premier aperçu des éléments associés à cette activité présumée. Concernant le dépôt métallique, il se trouve donc à l'intérieur d'une construction dont le plan ovalaire diffère nettement de celui des autres constructions. Déposé dans un petit creusement circulaire, l'assemblage métallique compte une douzaine d'objets, tous fragmentés, parmi lesquels on compte deux fragments de lingots plano-convexes, des fragments de hache ou encore un fragment de lame. D'après les premières observations cet ensemble s'inscrit dans le Bronze final 3.

Egalement située à l'intérieur de la construction, une fosse aux contours assez irréguliers montre un remplissage constitué d'une succession de niveaux plus ou moins charbonneux associés à de très nombreux fragments et blocs de terre

cuite. Certains s'apparentent à des parois de four, d'autres à de possible moules de métallurgistes. Des fragments de tuyère proviennent également de ces niveaux. Le contenu de la fosse a été intégralement prélevé et fera prochainement l'objet d'une étude approfondie. Quoiqu'il en soit, la stratigraphie montre de multiples phases de remaniement qui, en l'état, semblent témoigner d'une aire de travail.

Soulignons enfin que la sole d'un four ou tout du moins d'une structure de chauffe est conservée en surface de l'aire de travail présumée. De plan quadrangulaire (0,50 m de côté), cette sole est dotée de légers rebords.

Ces différents éléments suggèrent fortement la présence d'un atelier de bronzier étroitement associé à un site d'habitat.

Stéphane Blanchet
Inrap, UMR 6566 CReAAH
stephane.blanchet@inrap.fr

Muriel Melin
Service départemental d'archéologie du Morbihan,
UMR 6566 CReAAH
muriel.melin@hotmail.f

The spatial, social and political organisation of metalworking in southern Scandinavia during the Bronze Age (1700-500 BC)

Anna Sörman

Production and use of metalwork in southern Scandinavia during the Bronze Age (1700-500 BC) has above all been attributed to emerging elites. That bronze was a source and medium for social power is evident from its use in socio-political and ritual spheres, the multiple skills and elaborate aesthetics involved in its crafting, and arena for influence and control offered by the acquisition of metals through long-distance exchange. Bronze crafting is often assumed to have been organized at two levels: elite-controlled prestige goods production at centralised workshop sites, set against widespread (controlled or independent) production of utility objects in common households. However, this model is inferred from a functionalist view of finished goods (utility versus prestige) and inspired by anthropological theories, rather than from the material remains of production itself. With evidence of metalworking practices now rapidly increasing due to large-scale contract archaeology, it has become evident that these concepts and interpretations need to be reassessed.

This paper presents the main findings from my thesis, published at Stockholm University 2018, where the craft organisation in Bronze Age Scandinavia was analysed through an investigation of physical casting sites. Mould and crucible fragments, and their spatial relation to contemporary buildings and other activities, formed the main focus of the analysis. These data demonstrate that bronzes were cast at most, if not all, settlements during the mid-late Bronze Age. Metalworking also occurred at small single farms; a production argued to be dependent on visiting specialists. The results reveal a complex, user-oriented and multi-tiered craft organisation from Period III onwards. A distinction between prestigious versus utility objects did not structure production. Instead, the organisation and staging of bronze working was shaped by various social roles of the items produced. Rather than special workshop areas, castings were spatially oriented towards future owners. Prestige objects were manufactured in both longhouses and cult-houses within larger settlement complexes, in settings related to the status and gender of their intended users.

Further, metalworking often appeared in central and highly visible settings, suggesting it had the character of a performance. I therefore discuss how casting – the most dramatic event in the bronze-crafting sequence – could have been exploited in public or semi-public rituals. Taking into account the social projects and motifs behind new objects, castings were probably linked to transformations such as initiations, inaugurations or establishment of new households. Thus, metalworking played an active and conspicuous role in social reproduction at various levels and arenas in the decentralised, heterarchical societies of Bronze Age southern Scandinavia.

Dr. Anna Sörman
Nantes University, LARA/UMR 6566 CREaAH)
& Stockholm University, Department of Archaeology and Classical Studies
anna.sorman@univ-nantes.fr

Session 3
The production process, from metal to finished objects

Precious metal work from the Early Bronze Age Maikop kurgan, Kuban region, north-western Caucasus (mid-4th millennium BC)

Barbara Armbruster

The Maikop kurgan, situated in the Kuban region, North-western Caucasus, Southern Russia (today Adygei republic) is eponym of the Early Bronze Age Maikop culture (3600-2500 BC). The so called large Oshad kurgan, 11 m high, about 200 m in diameter, excavated 1897 by Nikolai Ivanovich Veselovsky is dated to the mid-4th millennium BC. The primary burial in the centre with rich grave goods, contained about 3 kg of gold and 5 kg of silver, including arms, vessels and a cauldron made of arsenical copper, stone and ceramic vessels, 10 silver and 2 gold vessels, silver and gold bars with figurines, gold and silver ornaments and beads, as well as corneal and turquoise beads. The skeleton was covered with cinnabar. The excavation findings are hosted at the Hermitage Museum St. Petersburg, Russia.

This paper deals with early fine metal working technology, studying the tools and techniques of the ornament and vessel production. The early Bronze Age gold and silver production at Maikop comprises several techniques. On the one hand, most of the grave goods are hammered and chased artefacts and pressed sheet, such as appliqués, vessels and beads. On the other hand, small, massive figurines are cast in lost wax technique. All the fine metal work from Maikop attests to a high standard in metal technology with serial production and access to a considerable amount of precious metal resources at an early stage of precious metal metallurgy.

In "Royal tombs", belonging to a nomadic society, a remarkable accumulation of wealth and prestige objects of high technological level takes place. The explanation might rely in the Maikop culture with a mobile herding economy based on interaction with settled communities and complex state societies, unless it seems a quite singular phenomenon.

Barbara Armbruster
CNRS-UMR 5608-TRACES Toulouse, France
barbara.armbruster@univ-tlse2.fr

Gold and its alloys at Middle Bronze Age Byblos

Ziad El Morr

Excavations at Byblos have uncovered several kilograms of gold alloy artefacts from Middle Bronze Age contexts. These constitute one of the most important collections in the Levant and include weapons, jewellery and vessels. The finds come mostly from the offering deposits of the Obelisks Temple and the Royal Tombs. In this paper we will present the results of our on-going work on this collection. Our aim is to characterise the craftsmanship of Byblos' goldsmiths. We use exclusively non-invasive observation and analysis methods on-site and at the laboratory. Given the diversity of the finds' archaeological contexts we had the opportunity to compare items used in different social settings and by different classes of society. We also focused on differentiating between fully local, Egyptizing and Egyptian gold alloy artefacts. We believe that this might contribute to the current debate on the chronology of the Royal Tombs.

Ziad El Morr
Lebanese Atomic Energy Commission
National Council for Scientific Research, Lebanon
ziadelmorr@gmail.com

The Rise and Development of Tin Bronze Metallurgy in the Iranian Plateau During the Second and First Millennium BCE

Omid Oudbashi

The history of copper-base metallurgy on the Iranian Plateau has been the subject of numerous research works over the last few decades. Although production of metallic artefacts with tin bronze has been emerging on the Iranian Plateau since the third millennium BCE (the early and middle Bronze Age), this innovative technology was widespread during the second millennium BCE (the late Bronze Age and Iron Age I) and then became the main copper-base metallurgical approach during the first millennium BCE. According to the literature, the distribution of tin-bronze artifacts in the Iranian Plateau during the second and first millennia BCE is limited to a few archaeometallurgical studies. Nevertheless, a considerable number of archaeometallurgical and laboratory works have been undertaken in recent years to characterize the technology of tin bronze production during the second and first millennia BCE. These studies are done on some excavated archaeological sites such as Marlik, Shahrak-e Firouzeh, Sagzabad, and Haft Tappeh (second millennium BCE) and Sangtarashan and Baba Jilan (first millennium BCE). The experiments include chemical, microscopic, and isotopic analyses. The results revealed new aspects of copper-base metallurgy in the period, showing a transition from copper/arsenical copper to tin bronze in the second millennium BCE, widespread use of tin bronze in the first millennium BCE, and evidence of long-distance metal trade during the period.

Omid Oudbashi
Department of Conservation of Cultural and Historical properties,
Art University of Isfahan, Iran
& Department of Scientific Research,
The Metropolitan Museum of Art, New York, USA
o.oudbashi@aui.ac.ir;
Omid.Oudbashi@metmuseum.org

Bronze weapons in the tombs in Talysh area (Azerbaijan, Iran)

Mathias Haze, Christine Lorre & Benoît Mille

Based on research carried out over four years (2012-2015), under the Franco-Azerbaijanise joint archaeological Mission of the Lenkoran River valley, in the Lenkoran basin and his tributaries in the province of Lerik, dealing with the question of the transition between Bronze and Iron Ages in southern Azerbaijan (co-directed by M. Casanova† and A. Alekperov†), the presentation will address the main features of the composition and the distribution of metal artefacts within the burials, with comparisons in the wider context of Talysh (Iran and Azerbaijan) as well as neighbouring regions of the Caucasus. The contribution of technological studies applied to archaeological metallic material (copper alloys) will be discussed based on the results of recent X-radiography and PIXE analyses conducted by the French laboratory C2RMF, on a set of objects, partly previously discovered by J. de Morgan (1889-1890) and partly found during last fieldworks.

Mathias Haze
Société Archaios
& UMR 7041 ArScAn-VEPMO, Nanterre, France
mathias.haze@gmail.com

Christine Lorre
National Museum of Archaeology, Saint-Germain-en-Laye
& UMR 7041 ArScAn-VEPMO, Nanterre, France
christine.lorre@culture.gouv.fr

Benoît Mille
C2RMF, Paris, France
benoit.mille@culture.gouv.fr

Technological study of the Atlantic Middle Bronze Age ornaments

Marilou Nordez

The Atlantic Middle Bronze Age is characterized by a considerable increase in the metal mass buried in hoards, which are mainly composed of palstaves and ornaments. Palstaves are the majority in northwestern France, but ornaments are also well represented. On the contrary, on the other side of the Channel, the latter are the majority, leading to the creation of a so-called 'Ornament Horizon'. Several tons of metal were thus removed from the production-consumption-recycling loop over about 150 years. This amount was never reached afterwards, despite the intensification of hoarding and the increased number of fragments in the Late Bronze Age hoards.

From a technological point of view, macroscopic study and the use of several experimental procedures has made it possible to demonstrate the extensive use of lost-wax casting technique for manufacturing the massive annular ornaments. Lost-wax casting is a metalworking technique that has long been regarded as an innovation imported from the eastern Mediterranean and only became widely used in Western Europe during the Late Bronze Age. We now have evidence that this technique was in fact largely used from the Middle Bronze Age onwards for the production of copper alloy ornaments in the Atlantic area from the 15th to the 13th centuries BC. Thanks to detailed morphological and technological study, combined with an experimental approach and analysis of their elemental composition, we can propose new *chaînes opératoires* for the manufacture of massive annular ornaments with geometric decoration.

Marilou Nordez
CNRS CReAAH UMR 6566, Nantes& UMR 5608 TRACES, Toulouse, France
marilou.nordez@cnrs.fr

Making Bronze Age solid-hilted swords: from *chaînes opératoires* to craftsmen

Léonard Dumont, Ivan Josipovic & Matthieu Boone

There is a long-lasting research tradition around Bronze Age swords, with many publications since the beginning of the 20th century, for example in the framework of the *Prähistorische Bronzefunde* project. Most studies focus on the evolution of swords' morphological and ornamental features to build typo-chronological systems. Questions related to craftsmen's identities, production organisation and exchange networks were mostly addressed thanks to these typological classifications, as stylistic variations have been used to identify products from different workshops. However, we believe this approach is flawed as our knowledge of production organisation is not good enough to assert that the aspect of the swords was determined by craftsmen. Other scenarios where shapes and ornaments are chosen by users, for example if swords are made to order, can be imagined. On the other hand, it seems likely that craftsmen were the only ones involved in the choice of production techniques used to transform a piece of metal into a sword. Studying the variations within the *chaîne opératoire* of Bronze Age swords therefore appears like a reliable method to address questions related to craftsmen and production groups, and ultimately to discuss production organisation and exchange networks on a sound basis.

Although Bronze Age swords' production techniques were investigated from the end of the 1950s to the 1970s with the development of X-Ray radiography in archaeology, for example in Mainz or in Bonn, there have been a lack of data on the way swords were made. In the last two decades, the development of new techniques such as digital radiography and tomography (CT-scan) enabled a breakthrough in our knowledge of production techniques (fig. 1). Thanks to technological data currently available, we propose the creation of a new tool in addition to the existing typological framework: a techno-typology. This new classification system is purely based on the variations observed at different steps of the *chaîne opératoire*. Thanks to this tool, we can evaluate the technological homogeneity of swords at the scale of a type, a region or a period, giving us an insight into the organisation of production and the number of production groups providing swords to the users.

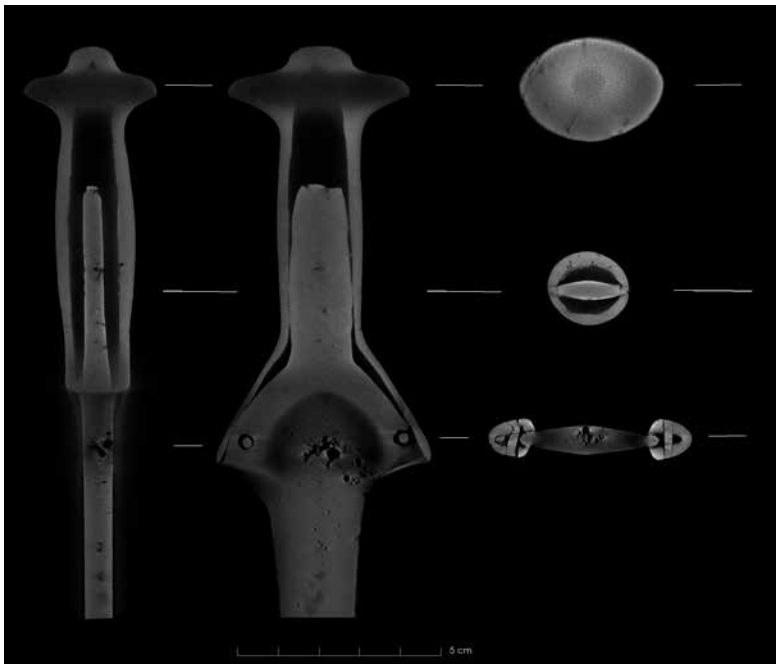
This new classification based on technological features gives us the opportunity to revisit to history of swords production in Europe during the Bronze Age. Three main phases can be identified:

1. Experimental phase (1800-1450 BC): swords are produced in small-scaled and versatile production units experimenting various techniques and processes.

2. "Monopoly" phase (1450-900 BC): the few types of swords form a very homogenous technological group; the important standardisation probably corresponds to a centralised production in a few highly specialised workshops.

3. Break phase (900-800 BC): major shift in the aspect of the swords coming along with the development of various technological traditions corresponding to the development of many versatile production groups.

Each of these phases correspond to cultural variations among both users and craftsmen that can be connected to socio-economic and political changes within Bronze Age societies.



µCT-scan of the hilt of the sword from Champagneux (Savoie). © I. Josipovic, UGCT.

Léonard Dumont
PhD, Ghent University, Department of Archaeology
& Université de Bourgogne, UMR 6298 ARTEHIS
leonard.dumont@ugent.be (corresponding author)

Ivan Josipovic
Support scientist, Ghent University, Department of Physics and Astronomy
ivan.josipovic@ugent.be

Matthieu Boone
Professor, Ghent University, Department of Physics and Astronomy
matthieu.boone@ugent.be

Session 4

Exchanges and uses of metal:

from archaeological contexts to the laboratory

Metallic deposits in the Ancient Near and Middle East during the Iron Age

Zahra Hashemi

This communication will address the concept of "metallic artefact deposition" in the history of human societies in the ancient Near and Middle East during the Iron Age.

The act of the deposition in its various forms has a long history through time and space. Archaeology attests that since thousands of years ago, man, in different societies, has intentionally deposited objects in specific places, temporarily or permanently, for various reasons. Dedication in temples or tombs, hiding the valuable objects as treasure and storing the

working or personal materials are among different intention which are hide behind the act of deposition. These reasons, are not easy to be ascertained at the time of discovery. The content and the environment of the deposit are among the decisive characteristics which can inform us about the reason of the action.

Through a typological study based on different physical characteristics, this study tries to classify different types of deposits and identify different intentions which could governed behind the act of deposition. Thus, the diversity of deposits will be evaluated according to different regions of the ancient Near and Middle East during Metal Ages with a particular focus on the Iron Age (end of the IInd millennium-beginning of the Ist millennium BC)..

Zahra Hashemi
Research associate, Louvre Museum, Paris
zahra.hashemi@louvre.fr

Metals in the Oxus Civilization and the Andronovo Community: goods, practices and exchanges in Bronze Age Southern Central Asia

Élise Luneau

Bronze Age in southern Central Asia is defined by a broad cultural overlap derived from the local development of the proto-urban Oxus Civilization and the expansion of the Andronovo communities over this territory (2300-1400 BCE). Metal items and metallurgy have been traditionally used as chronological and cultural indicators in Central Asia. Recent laboratory analyses bring new data on the provenience of the raw materials and the variability in the production of the

Cosmetic flask of the Oxus Civilization from a tomb of Sapallitepe, Uzbekistan (© State Museum of the History of Uzbekistan).

Bracelet from an Andronovo grave at Beshmullah, Uzbekistan (© N.A. Avanesova/E. Luneau).

metal items used by the Oxus and Andronovo communities.

In addition to domestic contexts, metal items are particularly numerous in graves, both in the Oxus Civilization and the Andronovo culture and often related to the social identity of the buried individuals. This paper will first address the diversity of metal objects at the Oxus and Andronovo sites and evaluate their value, uses and functions, especially in relation to burial practices. Connections between materials, types of items and human individuals can be traced, which participate to discuss the specific relationships between metals, metallurgy and society in Bronze Age Central Asia.

The discovery and study of protohistoric mines and production sites, above all located in mountainous areas of Central Asia, have allowed large progress in the understanding of metal production and circulation across time and space. In addition to the composition analyses of objects, these pieces of information make it possible to draw the outlines of the trade and exchange networks in distance and density. Central Asia has been particularly highlighted as a major region for metal supply and trade with the various neighbouring protohistoric communities in Middle Asia. Drawing upon a wide range of existing archaeometallurgical and archaeological data, we will assess present interpretations of the evolution, directions

and scale of interregional interactions. The paper will discuss how raw materials, goods and technological knowledge were exchanged and shared between cultural groups. We argue that metal production, circulation and consumption highly reflect changes in the evolution of the Bronze Age communities in Central Asia and the interaction processes between them.

Elise Luneau
German Archaeological Institute, Eurasia Department
& CNRS UMR 8215, « Trajectoires. De la sédentarisation à l'État », Paris
elise.luneau@gmail.com

Metrological standardisation of metallic artefacts: between production and exchange requirements: The example of Médoc axes

Thibaud Poigt, Nicolas Frerebeau, Alexis Gorgues & Thibault Picard

The idea that some part of Late Prehistory metallic production follows metrological requirements is deeply embedded in Bronze Age European research. It is traditionally considered that such a standardisation through measures aims to facilitate exchanges and economic transactions. That trading process can take two forms: the homogenisation of the quantities of products or the creation of a consensual mean of exchange, in other words moneys or *paléomonnaies*.

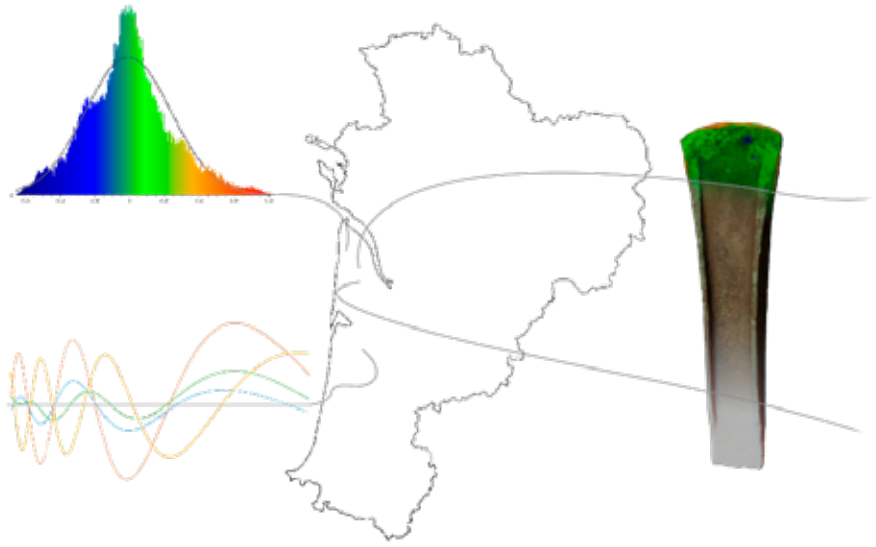
Such a hypothesis is a persistent theme in the reconstruction of Bronze Age societies and their economies since the end of the 19th century. Nevertheless, there is still very few in-depth analyses of the metrological features of the metallic artefacts to highlight whether the archaeological data is consistent with it. In the few cases that allow a validation of the hypothesis, the frame of use of the standardisation and its purposes remain limited.

With this presentation we want to provide an overview of the state of the art on the topic as well as the models dealing with the metrology of metallic objects. From this baseline, we then question them through several examples and case studies. In particular, we will focus on the study of a series of axes found in southwestern France and dated to the Middle Bronze Age: the so-called *Médoc* axes.

That research relies on the analysis of some 350 axes from the Middle Bronze Age southwestern coast of France. They will be first analysed from a metrological point of view questioning the metrological standardisation of these objects. Through different analysis, we will determine if their dimensions, volumes and masses can correspond to the application of metrological principles, and what characterise them.

Then, we will focus on the features that highlight their production. We will particularly deal with the types and number of moulds used, specifically inside same hoards, through the application of 3D acquisition and modelling protocols. We will also compare the results of several composition and isotopic analysis to talk about the alloys involved in their manufacture and the provenance of the metal.

Our objective is to question the place of the metrology in the manufacture of metallic goods. Often considered only for its possible economic outcomes, the application of metrological standards shows a deep entanglement with the manu-



facturing process themselves. That lead to consider the metrology as an integral part of the *chaîne opératoire* to produce metallic objects. The comprehension of degrees of accuracy of the metrological aspects and their insertion inside the manufacturing processes can shed new light on the standardisation and its functions.

Thibaud Poigt
post-doc UMR 5607 Ausonius, Bordeaux
& UMR 5608 TRACES, Toulouse, France
thibaud.poigt@gmail.com

Nicolas Frerebeau
CNRS, UMR 6034 Archéosciences, Bordeaux

Alexis Gorgues
Université Bordeaux Montaigne
UMR 5607 Ausonius, Bordeaux, France
alexis.gorgues@u-bordeaux-montaigne.fr

Thibault Picard
Master université Bordeaux Montaigne, France

The Bronze Age metal of Gegharot: culture, society and technology

Ruben Badalyan, Khachatur Meliksetian & Adam T. Smith

This report presents the main features of the socio-cultural processes and technological innovations that shaped the field of bronze casting in Armenia and the South Caucasus during the Bronze Age. The primary objects of study come from the excavations of Project ArAGATS at the multi-component site of Gegharot which produced a significant corpus of metals from both Early and Late Bronze Age layers. These data will be contextualized in reference to metallurgical analyses undertaken on recently excavated materials from the sites of Karnut, Shahumyan, and others.

The site of Gegharot is located on the northeastern border of the Tsaghkahovit plain on the southern slopes of the Pambak ridge, at an altitude of 2150 m above sea level. The location of the site made it possible to control the passes that connected the Ararat valley and adjacent regions with the Alaverdi-Vanadzor group of copper deposits, Bolnisi (Southern Georgia) and the Gedabek (Western Azerbaijan) copper ore regions. Gegharot is a settlement site that includes layers of the Early and Late Bronze Age as well as a Late Bronze kurgan cemetery at its base. The excavations of the site revealed a wide range of finished products (including imported weapons in elite Late Bronze complexes) attesting to various steps in the bronze casting process (molds, crucibles, tuyeres, stone weights).

Compositional analysis of metal artifacts from Gegharot, Karnut and Shahumyan reveal the presence of distinct geochemical groups of metals, particularly copper-arsenic alloys, pure copper, lead-arsenic-copper alloys for Early Bronze Age objects and tin bronzes, antimony bronzes and other alloys for Late Bronze Age artifacts. Lead isotope analysis of artifacts and comparison with ores allows us to approximate the origin of metals for production of copper and copper alloys. Some of the artifacts, particularly an Early Bronze age necklace from Gegharot contained high arsenic alloys (~20% As), indicating quite advanced metallurgical technologies.

This report summarizes both the results of a contextual analysis of the metallurgical assemblage and details attributes of bronze foundry production, their cultural and chronological attribution, and the results of Project ArAGATS's archaeometallurgical studies.

Ruben Badalyan,
Institute of Archaeology and Ethnograph
National Academy of Sciences, Armenia
r.badalyan@yahoo.com

Khachatur Meliksetian
Institute of Geological Sciences
National Academy of Sciences, Armenia

Adam T. Smith
Department of Anthropology Cornell University, USA

Gold from the desert: Artefact production at Saruq al-Hadid

Kristina A. Franke, Lloyd Weeks & Zuzanna Wygnańska

Saruq al-Hadid, (Dubai, UAE) is probably one the most outstanding and enigmatic archaeological sites in south-eastern Arabia. It is characterised by an incredible quantity and also diversity of deposited artefacts. Of particular note are copper-base, iron and precious metal artefacts that are accompanied with their working debris. The site was occupied at least from the 3rd millennium BC up through to the Iron Age and later in the Late pre-Islamic and early Islamic periods. However, the majority of artefacts can be attributed to the Iron age and its extensive trade networks. The material is buried within dunes up to 6m deep and spread across an area of about 1 km2. Hence, it is often difficult (archaeologically) to establish a relationship between finished artefacts and working debris. Consequently, analytical studies were employed to discuss the potential of on-site workshops and the relation between finished and half-finished artefacts and working debris in addition to studies on composition and working techniques and the provenance of raw materials. This paper focuses on precious metal artefacts and the potential of on-site workshops for their production. We will discuss a variety of production techniques, the provenance of the metal, and possible colour preferences. The range of artefacts poses the question of the sites specialisation and the importance of Saruq al-Hadid within Iron Age trading networks.

Kristina A. Franke
Ruhr University, Bochum, Germany
kristina.franke@ruhr-uni-bochum.de

Lloyd Weeks
University of New England, Australia

Zuzanna Wygnańska
Polish Academy of Sciences, Poland

Metalwork Wear Analysis: A patinated history

Andrea Dolfini

The paper presents results of fifteen year's sustained research on the social and functional histories of Chalcolithic and Bronze Age metal objects led by the author and his team, through the application of Metalwork Wear Analysis and experimental archaeology. Metalwork Wear Analysis (MWA) is the study of the manufacturing, use, and post-depositional traces observed on ancient and historic copper-alloy artefacts. Developed in the last two decades from the cross-fertilisation of microwear studies and archaeometallurgy, this field of research has generated a wealth of fresh data and perspectives on the social lives of metal tools and weapons from late prehistoric Europe. The paper discusses these data and perspective, with a focus on early axes, daggers, and swords, showing how MWA has changed and enriched our understanding of these objects – at times dramatically so. The paper also showcases recent groundbreaking developments in metalwork residue extraction and functional experiments with replica metals, which complement MWA data. A brief critical overview of where this field of research is heading, and what challenges lie ahead, concludes the paper.

Andrea Dolfini
Professor , chair of Archaeology, School of History, Classics and Archaeology,
Armstrong Building, Newcastle University,
Newcastle upon Tyne NE1 7RU - UK
andrea.dolfini@ncl.ac.uk

Producing, using and hoarding in Late Bronze Age: multi-elemental analyses, 3D morphometric and techno-functional approach of the Late Bronze Age 3 axe blades from Auvergne (France)

Théo Enudde & Pierre-Yves Milcent

Studying Late Bronze Age metal production in Western Europe is problematic because it is documented by finished objects rather than by workshops. Moreover, these products appear mainly in hoards, outside their primary context of production and use. Characterising the supply of metal, its places of transformation and production, and the ways of use of the objects therefore implies working backwards, starting from the places of final hoarding of finished objects. Among the latter, axe blades appear to be the most suitable medium for study: they are sufficiently frequent and numerous to be able to work on coherent series. Nevertheless, the winged blades of the Late Bronze Age have not been the subject of a specific study until now. The interest of this type of object is all the more pronounced in the case of the continental Europe in the Late Bronze Age 3 (950-800 BC), as almost no production site could be clearly identified.

The recent discovery of a large number of axe blades in hoards studied in exceptional conditions on a fortified settlement in the south of the Allier department (Auvergne region) has allowed us to establish a corpus that is particularly well suited to addressing these different issues. The majority of these are sub-terminal winged axe blades, common in France and western Germany. The corpus is completed by a few socketed axe blades, some of Atlantic and others of Continental types.

The method used combines several approaches. Firstly, the techno-functional study of the objects aims above all to provide information on the stages at the end of the operating chain, and the characteristics inherent in the life of the object. In this case, it consists of post-foundry shaping operations, finishing, maintenance and wear of the objects. This approach makes it possible to distinguish the parts of the blade that are transformed during its life from those that remain identical to the object removed from its mould. This aspect, which is a prerequisite, is completed by a 3D morphometric approach. This method, which is not yet widely used in the study of metal objects, makes it possible to discern groups of similar blades, including those produced from the same mould. This allows to address issues of standardisation and variability of production. Finally, a series of multi-element analysis could be carried out in collaboration with the C2RMF. This last approach makes it possible to address alloying types and supply network. The combination of these different methods allows to better comprehend the organisation of the production of bronze objects. It also provides new keys to understanding the relationships between producers and consumers of metal objects, and ultimately to a better understanding of metal hoarding practices at a crucial time in western Europe protohistory.

This presentation will focus mainly on methodological aspects and the integration of approaches, as this research is beginning, and will present the first results obtained within the framework of the Projet Collectif de Recherche “Le Pays de Gannat, de la Protohistoire à l’Antiquité” (see : https://pcrbj.hypotheses.org/)

Théo Enudde
PhD student, université Toulouse-Jean Jaurès, UMR 5608 TRACES, Toulouse, France
theo.enudde@etu.univ-tlse2.fr

Pierre-Yves Milcent
Professor, Université Toulouse-Jean Jaurès, UMR 5608 TRACES, Toulouse, France
pierre-yves.milcent@univ-tlse2.fr

Isotopical and elemental chemical analyses of french metal Bronze age hoards

Cécile Le Carlier de Veslud

Bronze Age in Western Europe is characterised by a very numerous and various composition terrestrial metal deposits, composed by few whole or fragmented objects to several thousand. In the northwest of France, this phenomenon is particularly impressive. Thus, It is possible to carry out a wide-ranging elemental chemical composition study of objects, in relation to the chronology, location and typology. Analyses are made by ICP-OES, a technique that allows, on the one hand, a precise determination of trace element content with a very low detection limit, and on the other hand, to carry out representative analyses of artefact’s bulk composition. These elemental analyses are classical. The originality of this project is represented by the statistical approach. Thus, several hoards from each period are taken into account. If possible, the entire hoard is analysed, avoiding too great an impact on the integrity of the objects. For largest deposits, over 200 objects, a reasoned and

representative sampling is carried out, lied to functional categories and typology of artefacts. This approach leads to identify chemical signatures included local signature *i.e.* the signature of metal worked in the area of the hoard. For Brittany, it's correspond to atlantic type composition. For this purpose, objects with a «local» typology must be analysed, as well as foundry wastes that is probably not intended to travel and must have been deposited at a «moderate» distance from the workshops and/or hoard. This identification is fondamental to discuss long-distance material exchange issues. We have also to analyse all the fragments of copper ingots in order to assess the diversity of chemical compositions of the raw material worked in the area. The comparison of the chemical compositions of the objects described as «exogenous» then makes it possible to know whether they really have a remote origin or whether they are copies. Lead isotopical analyses (LIA) correspond to the only analyses allow us to propose copper origins. The choice of objects for these analyses is made on the basis of elemental chemical compositions in connection with typological attributions.

Currently, more than 2300 objects have been analysed, mainly in the north-west, but also in the centre-east, south-west, south and south-east of France. This statistical approach makes it possible to identify different and characteristic chemical signatures of the major Bronze Age and Early Iron Age periods for several regions. For north-western France, this suggests that recycling of metal from one Bronze Age period to another is not a major phenomenon, and that much new metal must have been regularly consumed and imported, as the region does not have large enough copper deposits for such production. A first hypothesis of the origin of the copper can be formulated for BMa1, the copper would come from the Great Orme mine. . It remains to be determined how far this metal could have spread on the continent. In contrast, the objects in BM2, which have a fairly clear elemental signature, seem to be produced by mixing copper from at least two sources, possibly copper from the provinces of Huelva and Jaen in Spain on the one hand, and the mines of Mitterberg on the other. In the same time, elementary analyses seems to highlight a possible used of BMa1, the previous period metal type. New metal or recycling ? We can't conclude by the only chemical based study. In the Late Bronze Age, first LIA results seem to show a widening range of copper sources, with metal perhaps coming from Central Europe or even Eastern Europe or Cyprus, but also, perhaps, closer to home, from southern France. These hypotheses need to be amply confirmed, by new analyses but also by the typological study of the ingots. Indeed, the shape of ingots is often quite characteristic of the periods and areas of production.

Nevertheless, these initial analytical results show that north-western France participated fully in Bronze Age trade with the whole of the European continent. The region's richness in tin may have contributed greatly to this.

Cécile Le Carlier de Veslud
UMR 6566 CReAAH Laboratoire Archéosciences, CNRS, Université de Rennes
cecile.lecarlier@univ-rennes1.fr