Bồng Miêu Gold Mine: Technological evolution and colonial adaptation in Southeast Asia

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The Bồng Miêu gold mine in Quảng Nam province, central Vietnam, provides a rare case study of the long-term history of gold exploitation in mainland Southeast Asia. Archaeological and historical evidence suggest that extraction began during the Protohistoric period through alluvial panning, later expanding to small-scale underground mining. These practices likely continued under the kingdom of Champā and the Empire of Annam, highlighting the enduring economic and political significance of gold in the region.

In the late 19th century, Bồng Miêu became the first modern gold mine in French Indochina. Established in 1896, it incorporated advanced infrastructure, including an aerial cable system, and cyanidation processing facilities. Between 1900 and 1918, over 250,000 tons of ore were extracted, yielding more than one ton of gold, though recovery rates remained limited. A major modernization program in the early 1930s improved recovery efficiency from 60% to 90%, with peak annual production reaching 258kg in 1935.

This paper examines how the Bồng Miêu gold mine reflects the evolution and local adaptation of mining and metallurgical practices in a colonial context, marked by a long sequence of occupation and a shift from local exploitation to industrial activity.

Weapons, Rituals, and the Making of a Warrior Society? A Use-Wear Assessment of Swords and Associated Artefacts with Weapon Function and Social Identity of Sinauli

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Keywords: Ancient Indian metallurgy, use-wear analysis, Copper Hoard culture, Sinauli excavation, ritual and warfare, Ocher Coloured Pottery (OCP)

The recent excavations at Sinauli, Uttar Pradesh, have provided significant insights into the cultural and technological development of the late Protohistoric period in the Indian subcontinent. Among the most remarkable discoveries are the copper-decorated chariots and an assemblage of copper weapons found alongside Ocher Coloured Pottery (OCP). These finds invite renewed attention to the long-debated Copper Hoard tradition, whose artefacts are often discovered as isolated chance finds with little contextual information.

This study analyses the material culture of Sinauli through a detailed examination of weapon morphology and surface wear patterns, supported by preliminary metallurgical and elemental observations. By exploring the physical traces of use and the contextual associations of these artefacts, the research aims to better understand their technological sophistication and potential social meanings. The work also considers the broader implications of such evidence for interpreting martial identities, ritual practices, and social organisation within early metal-using communities.

Metallurgy and Firepower: A Technological Overvie of Iron Cannonry in Medieval Bengal

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Keywords: artillery technology, iron cannonry, Medieval Bengal, metallurgy

The iron cannonry of medieval Bengal marked a transformative phase in regional military and technological history. With some specific examples of iron cannon, this paper offers a technological overview of iron cannonry within broader contexts of metallurgy, warfare, and regional innovation. Cannons such as the Jahankosha of Murshidabad, the Bachhawali of Hazarduari, and Dal Mardan of Bishnupur illustrate the mastery of forge-welding techniques. These cannons were made by hammering and welding multiple iron blooms and reinforced with concentric rings to create massive yet resilient artillery pieces. Archaeometric examination of the Dal Mardan through SEM and XRD has brought to light slag inclusions, fayalite phases, and traces of high phosphorus. These features point towards a direct-reduction process of sponge iron and, at the same time, explain the cannon's unusual resistance to corrosion. Other examples, like the Kale Khan/Kale Jamjam and the Bibi Mariam of Dhaka, attributed to the famed Janardan Karmakar under Mughal patronage, demonstrate the ability of Bengal's workshops to produce artillery on an extraordinary scale. However, the comparatively smaller-sized, forge-welded guns now displayed in the Tripura State Museum offer a different perspective tailored for mobility and riverine warfare, reflecting local needs and contexts.

British Gunfounding after the Weald

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Keywords: ordnance, gunfounding, Weald, coke blast furnaces

Until the 1750s, almost all cannon made in Britian were cast from charcoal blast furnaces in the Weald in southeast England. During the Seven Years' War and after, coke blast furnaces began to be used, but guns made by the Carron Company in Scotland were so prone to bursting that they were withdrawn from service. In 1774, Anthony Bacon on behalf of John Wilkinson proposed casting cannon solid and boring them, rather than casting them with a core. Tests found that cannon cast solid were better, so that the Ordnance Board ordered all cannon to be cast solid. Wealden ironmasters were apparently unwilling to invest in the boring mills needed for this, so that Wealden gunfounding largely ceased. After the War of American Independence, Samuel Walker & Co of Rotherham became the Board's sole supplier, in part recycling old cannon. They were joined in the 1790s by other suppliers, including the Carron Company, Clyde Ironworks, and Alexander Brodie of Calcutts in Shropshire. However, Gordon and Stanley, probably representing John Wilkinson's Bradley Works had many guns failing proof and gave the business up. Unfortunately, after 1797 the surviving records are less penetrable.

On the constructional detail of the type 2 mediaeval anchor from Ladby, Denmark

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Keywords: anchor, early-medieval, archaeometallurgy, industry, iron working, forge, longship, seafaring

The type 2 early Medieval anchor from Ladby, Denmark, was discovered as part of an elaborate ship burial dated to the 10th century. Standing at 1.2 metres tall and 0.8 metres wide, analysis of the constructional detail of the anchor reveals a composite object of complex fabrication, built from no fewer than 60 separate parts. Furthermore, a laminate construction suggests a sophisticated understanding of the mechanical properties and limitations of the available ferrous materials of the period.

Exploring Ancient Indian Panchadhatu and Ashtadhatu-Making Traditions as Prototypes of Modern High Entropy Alloys

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Keywords: Panchadhathu, Ashtadhathu, high entropy alloys, multi-component alloys

This study revolves around understanding the ancient metallurgy of Panchadhathu (five metal alloy)/ ashtadhathu (eight metal alloy) alloy making which was prevalent in ancient India, especially in its southern counterparts. This work is trying to locate these technological achievements as a prototype of modern High Entropy Alloys (HEAs) by examining the metallurgical practices, cultural contexts and technological sophistication. Even before formal codification of metallurgical practices, ancient blacksmiths showcased remarkable progress in this field and especially they understood core alloying principles like entropy stabilization, corrosion resistance, and mechanical strength. Preliminary studies show the importance of multi-component alloys in Ancient India and its potential to offer insights in to resource optimization and sustainable practices as well.

This project aims to bridge the gap between traditional metallurgical knowledge system with modern sustainable engineering practices through an interdisciplinary approach where archaeology, materials science and heritage studies are intertwined. Through experimenting with different compositions and combinations, this study aims to integrate past understanding of the technique of alloying with the contemporary advanced technologies thereby creating a sustainable and futuristic methodology for the production and utilization of metals.

Investigating Failure Mechanisms in Archaeological and Modern Wrought Irons

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Keywords: wrought iron, Salisbury Cathedral, Blenheim Palace, acoustic emission, tensile testing, digital image correlation

Architectural wrought irons from the 14th (Salisbury Cathedral), 18th (Blenheim Palace), and 21st (Topp & Co.) centuries are subject to optical, chemical, and mechanical characterisation. To investigate micro-mechanical failure mechanisms, tensile testing is undertaken in tandem to acoustic emission (AE) monitoring and digital image correlation measurements. The modern specimen exhibited expected ductile failure, with post-yield behaviour characterised by plastic deformations and uniform strain distributions. In contrast, the archaeological irons exhibited a defect-driven failure, evidenced by the emergence of multiple surface cracks, often on one face of the sample, and a high number of post-yield AE hits. Multivariate analysis and clustering of the AE signals using principal component analysis and DBSCAN identified three major failure mechanisms, differentiated by the signal's peak frequency. These are the plastic deformation of iron, debonding between iron and slag and within different phases and microstructures of the iron matrix, and inclusion cracking. The latter two were supported by observations from fractography. A small number of high frequency events are identified and provisionally attributed to iron matrix cracking. This research ultimately provides deeper insight into the micro-mechanical failure mechanisms in wrought irons.

Iranian Copper Alloys Archaeometallurgy, Corrosion, and Cultural Heritage Management

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Keywords: Iran, archaeometallurgy, copper alloys, corrosion, cultural heritage management

Corrosion of archaeological metals may be complex owing to the varying influences of the burial environments, alloy compositions, and microstructures, and internal (residual) and external (burial) stresses imposed on artifacts. This book surveys the corrosion-related metallurgy and long-term corrosion of archaeological copper alloy artifacts excavated from aerobic soil environments in Iran, and also the remedial and restoration issues, including conservation, as contributions to the cultural heritage of Iran. The final step is cultural heritage management (CHM), whose main objectives are the classification and understanding of deterioration risks, i.e., further corrosion, and avoiding them. The risks include excavation and displacement from the original burial sites and insufficiently controlled display and storage environments. In addition, the book discusses the scientific methods employed in corrosion assessment and diagnosis, such as metallography, surface analysis, and corrosion product characterization. The interdisciplinary approach adopted offers insights valuable not only for archaeologists but also for conservation scientists and materials engineers.

Metallographic and Neutron Analysis of EBA metalworking traditions

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Keywords: metallography, neutron diffraction

Technological choice, decision making, and craft traditions have been well documented by analysing prehistoric metalwork using metallography, and more recently Neutron probing. My current research aims to incorporate the scientific data obtained from studying Chalcolithic and Early Bronze Age axes and halberds using metallography and Neutron analysis into a theoretical craft-focused perspective. Reflexive experimental bronze smithing will be used to try and replicate data from artefacts, and thereby reproduce a non-scientific, inductive chaine operatoire based on sense experience. It is hoped that this can understand the cognitive and embodied elements of metalworking skill and variation within the archaeological record.

The preservation and conservation of Phopo hill, an archaeometallurgical site in Rumphi, Malawi

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Keywords: conservation, preservation

Phopo Hill is a significant archaeometallurgical site associated with Early Stone Age societies, containing a rich material record that includes artifacts, metals, iron slag, and pottery. However, the preservation of this important cultural heritage is under severe threat. The site is increasingly vulnerable to the damaging effects of climate change and accelerated erosion. These environmental challenges are actively degrading the archaeological deposits, risking the irreversible loss of invaluable data concerning early human technological and cultural development. Therefore, conservation and preservation strategies need to be employed to mitigate these impacts and ensure the long-term protection and study of the Phopo Hill site.

First insights into the origin of iron in eastern Cilicia during the Iron Age, using osmium isotope and trace element analysis

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Keywords: osmium isotopes, Kinet Höyük, Iron Age, Anatolia

The study focuses on the provenance investigation of several iron smithing slag and iron ores samples from the Iron Age phases (c. 750–575 BC) at Kinet Höyük, a major trading port on the coast of eastern Cilicia (Turkiye). Additionally, we analyse 18 ore samples from major iron deposits in the eastern Taurus region. The applied techniques include optical microscopy, XRD, XRF, analyses of siderophile and chalcophile elements by (ICP-MS), and Os-Re isotopy. The results allow the exclusion of the analysed iron ore samples from central Anatolia as a source of the iron processed at Kinet Höyük. The archaeological samples of slags and one of the archaeological ore samples fragments are characterised by low radiogenic 187Os/188Os ratios, high Os concentrations (411–15057 pg/g), elevated contents of Ni, Cr, As, and low contents of Co, V, Sb, and W. This suggests a local origin for the forged iron, the source of which should be sought in a geological environment associated with ultrabasic rocks in the ophiolitic suture zones. From the methodological perspective, the results allow stressing the usefulness of investigation of iron smithing remains by osmium isotopes for drawing connections blacksmithing and iron smelting workshops.

The Spatial Distribution of Iron slag Evidence Sites in Northern Ethiopia (Tigray)

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Keywords: Ethno history, rock-hewn churches, metallurgy, iron production

Archaeometallurigical investigations on the sites of Tigray with the evidences of iron slags made possible in reconstructing evidence of iron smelting societies. The central aim of this paper is to explore and locate the ancient metallurgical sites and to synthesize the tradition of iron smelting in the region. It is a recent phenomenon and iron smelting in Tigray is currently unrecognizable but, to profuse the tradition of the past community locating the distribution of the evidence of slag sites is the primary task. Thus, ethno historic interviews, field survey and oral traditions were used to interpret the data qualitatively in a descriptive way. Survey and preliminary geological investigation indicates that the ores in the nearby areas of the sites may have been the sources for ancient iron productions. Preliminary analysis of potsherds and radiocarbon dating (in some sites) indicated that the sites were possibly settlement sites. The region particularly Eastern part of Tigray has significant metallurgical sites history which is supported by the presence of many rock hewn churches which could indicate the beginning of iron ore production was mainly during the Aksumite times.

Potential of Technical Ceramics for Studying the Iron Metallurgical Chaîne Opératoire: Selected Medieval Case Studies from Southern Czech Republic

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Keywords: technical ceramics, iron, archaeometallurgy, Medieval, tuyeres, iron smelting, blacksmithing

In Pre- and Protohistory, the selection and use of technical ceramics were mandatory for the success of all pyrometallurgical processes connected with iron and were therefore not arbitrary. Drawing on selected Medieval case from the southern Czech Republic covering different production contexts (rural and proto-urban), we show that interdisciplinary analyses (macroscopic, pXRF, ED-XRF, XRD, SEM-EDS) of ceramic debris such as tuyeres, furnace parts, and hearth fragments in relation with associated pyrometallurgical features and slags yield crucial insights into workshop organization and resource-distribution networks. In doing so, we address the entire metallurgical chain, from iron smelting to subsequent processing of iron (blacksmithing).

The Archaeology of Ironworking Landscape: The Case Study of Brdy Mountains, the Czech Republic

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Keywords: landscape archaeology, mining, charcoal burning, ironworks

Historical ironworking played a crucial role in the history of the Brdy region, which is located on the border of central and western Bohemia, the Czech Republic. Iron production has a long tradition in the area, spanning from the Middle Ages up until the 19th century, during which it was the main Bohemian ironworking region. The contribution summarises the current results of a landscape archaeology oriented research of the northwestern part of Brdy region. Using common methods of non-destructive archaeology, such as LiDAR data prospection, a great number of ironworking-related sites were identified. These include a great number of charcoal-burning platforms and mining sites.

Metal production in the 2nd millennium BC Eurasian Steppe: An update of research

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Keywords: Eurasian Steppe, Bronze Age, metal production, smelting recipes

During the 2nd millennium BC, the Eurasian Steppe witnessed profound transformations in metal production and circulation, reflecting the rise of socio-economic networks and technological specialisation among semi-pastoralist communities. While the movement of copper alloys and finished artefacts across this region is well documented, growing attention is now directed towards the choices underpinning primary production and the organisation of metallurgical practices.

We present new data from key metalmaking contexts spanning the Late to Final Bronze Age in Central and East Kazakhstan. Each site offers distinct perspectives on metallurgical traditions and production modes, highlighting both shared technologies and regional variation in smelting recipes and alloying strategies. Communities of metalsmiths processed similar ores but developed different approaches shaped by local resources, cultural preferences, and shifting exchange networks.

Archaeometallurgical analyses of ores, slags, and technical ceramics reveal how knowledge was created, adapted, and transmitted across the Eurasian Steppe, underscoring it as a dynamic arena of innovation during the Bronze Age.

The ERC DREAM aims to advance the current understanding of metalmaking technology in the Eurasian Steppe, and to situate the region as a central hub of technological and social transformation during the Bronze Age.

Paths of Production: Spatial and Experimental Investigations of Native Copper Working In North America's Native Copper Industry

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Keywords: native copper, Great Lakes, Archaic, production

This presentation explores native copper production in North America's Native Copper Industry, with a focus on the Archaic period (ca. 6000–1000 BCE) and the copper-rich region of Isle Royale. Drawing on both archaeological evidence and experimental archaeology, the research aims to reconstruct stages of copper production—from raw material acquisition to artifact manufacture. Fieldwork includes analysis of copper artifacts, hammerstones, and production debris from multiple Archaic sites at varying distances from copper lodes. These data are compared to results from experimental replication of traditional cold-hammering, annealing, and shaping techniques using native copper sourced from the region. Patterns observed suggest a spatial relationship between site function and proximity to copper sources, indicating that copper was often worked near its source, with finished or partially finished tools transported to distant habitation sites. This integrated approach provides new insights into the organization of early metallurgical practices in the Great Lakes region and enhances understanding of the social and technological complexity of pre-contact Indigenous copper use. The findings also contribute to broader discussions of early metalworking in Hunter-Gather societies and demonstrate the value of combining experimental archaeology with regional artifact analysis.