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There is Evidence that Dry Silver Ore was Used a Lot in Early Islam, which has Implications for the History of Silver Metallurgy

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Abstract

Lead metallurgy has been closely associated with silver production for much of its history. It is generally accepted that galena, a lead sulfide, was the most common silver source in the early Middle Ages. Since galena can be associated with silver in the range of 0.1–0.5%, and rarely more, this indicates that tons of lead had to be laboriously processed in order to extract kilograms of silver. This study has found evidence that extremely rich silver ores must have played a key role in one of the major silver-using polities in the 8th and 9th centuries AD, despite the fact that all existing physical evidence from mines, slag, and the metal itself points to this being true: the early Caliphate of Islam. Metallic analysis of 26 coins revealed that Umayyad and Abbasid dirhams, renowned for their exceptionally pure silver, frequently contain matte inclusions (silver-copper sulfides). Silver cannot have been produced solely from lead ore or through the use of lead because the matte that was preserved in the coins could not withstand the highly oxidizing refining process required to separate lead from silver. For the understanding of early medieval extractive metallurgy, a new paradigm is required. The early Islamic silver supply greatly benefited from the processing of "dry" silver ore, which contained nearly pure silver minerals. The consequences of this study have major innovative and monetary ramifications and topple well established sees on the historical backdrop of silver metallurgy. Additionally, they have significant effects on the interpretation of elemental and lead isotope data and provenance studies.

Keywords: Archaeometallurgy; Metallic extraction; Mining; Economy during the middle ages; EDS; Silver; Cupellation

Introduction

Over a century ago, attempts were made to retrace the development of silver metallurgy. Because silver was primarily extracted from lead-based ore for the majority of its history, perspectives adapted from contemporary extractive metallurgy were essential to its development from the beginning. The research direction, which can be followed into the 21st century, was influenced by engineers and metallurgists like these. Research on the early Middle Ages, where it is generally accepted that galena, a lead sulfide that can be associated with silver typically in quantities of 0.1–0.5 percent, served as the primary ore basis for silver production, places a particular emphasis on lead-based silver ore [1]. The galena ore at Melle, the well-known mine in western France that has been linked to the Merovingians' adoption of the silver standard and the most prominent Carolingian silver mine, contains silver in this range. Based on Islamic silver's fundamental characteristics, including a sudden drop in gold content, it appears that silver ores based on galena have dominated since the middle of the 8th century [2]. Additionally, because richer ores had run out, it took significantly more labor to extract silver from poorer lead ores that were located further down in the earth. The way we understand how silver metallurgy developed over time has significant economic and technological implications for how we understand the ancient world. It is subsequently vital to assess fundamentally the suspicions and verifiable proof whereupon it is based.

The production of silver and lead are linked for three reasons: 1. Lead and silver minerals are frequently found together, During ore smelting, lead collects and safeguards the silver, and 3. Cupellation is a method for separating silver from lead. Critical is the cupellation procedure [3]. Through the particular oxidation of lead over 900 °C, two immiscible fluids structure: a metallic liquid containing silver and other oxidation-resistant metals as well as an oxide liquid (PbO). Silver can be recovered with minimal loss and refined to a very high purity using this method. However cupellation has its starting points in the far off past, by the Greco-Roman period at the most recent, the utilization of lead and cupellation is viewed as key in silver creation across the Old style World.

Two Islamic dirhams' anomalous nickel-rich compositions prompted a large-scale investigation into the elemental and lead isotope analysis of the 8th and 9th centuries. This provoked further examinations, which formed into a metallographic investigation of 26 dirhams. The purpose of the study is to provide answers to the inquiries "how" and "from what" silver was produced in the past. To answer these questions, it is necessary to carefully examine the cupellation process itself to determine which phases and elements, particularly sulfur, survive [4]. The outcomes challenge the laid out thought of silver creation essentially founded on lead metal and the comprehensiveness of cupellation and on second thought highlight the double-dealing of top-grade silver minerals without the utilization of lead. To examine this issue from a different perspective and to propose a new paradigm for comprehending the early medieval extractive metallurgy of silver, the present study combines metallography, quantitative elemental analysis, and experimentation.

Archaeological viewpoints on the historical backdrop of silver metallurgy

The historical backdrop of silver metallurgy is a developmental model that starts with the most extravagant and open types of silver [5].

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Technology and organization are adapted to extract silver profitably from increasingly lower-quality ore as rich ore becomes exhausted. One method used to classify ore types of archaeological silver from the early to later periods is elemental analysis, which focuses on the elements lead, copper, and gold. Native silver is extremely rich and "dry" silver ores like acanthite and cerargyrite can both be used to make silver. The term "dry" silver ore is used to distinguish lead-poor silver ores from argentiferous lead ores, which are naturally low in lead but high in a variety of rich silver sulfide and halide minerals. It is argued that the earliest uses of silver were made with native silver and "dry" silver ore. It is established that lead-based metallurgical processes were not utilized in the production of silver objects by the El-Argar culture of Spain in the Bronze Age. It is argued that the Moche in the Andes used "dry" silver ores like cerargyrite in the New World contends for the utilization of 'dry' metals at the origin of silver utilized in the Chalcolithic and Early Bronze Ages in Western and Focal Asia. Similar metallurgical procedures used to extract copper from ore, such as reduction or roast-reduction smelting, would have been used to treat these "dry" silver ores.

Cupellation was a significant technological advancement that was made in the Old World in the fourth millennium BC. According to, cupellation was developed to extract silver from abundant lead-free ore, but lead ores had become the basis for silver production by the third millennium BC [6]. Meyers confidently proposes a transition to silver production with a predominant lead-ore base in the third millennium, but this assumption has no clear foundation. It is essential to stretch that the utilization of cupellation doesn't demonstrate that silver was created from lead metals, and keeping in mind that there is significant proof for a long history of cupellation, the connection among cupellation and the extraction of silver from argentiferous lead minerals isn't immediate all of the time.

By the time of Classical Antiquity, it was almost universally agreed that the primary source of silver supply was lead-based ores like galena. Classical authors Pliny and Strabo provide evidence for the use of lead-based silver ore and for the use of lead in the extraction of silver from ore. After the Roman mining of silver in Spain stopped working, supplies had to come from production in the eastern Roman provinces and from the Persians in Late Antiquity. Since the Romans had a similar technological arsenal at the beginning of the Middle Ages, it stands to reason that when Roman mines ran out, medieval societies had no choice but to turn to ore sources that required more and more labor [7]. It is possible that subsequent mining resulted in ore deposits that were even poorer or more difficult to access because the Romans were mining silver from argentiferous galena. From this vantage point, the research narrative of silver metallurgy is consistent with the use of galena-based ores for silver production during the Early Islamic Caliphate and the early medieval Melle.

However, after the early Middle Ages, this conventional viewpoint ceases to be viable. In regards to Central Europe, texts from the late medieval and Renaissance periods categorically disprove that galena, which typically contains 0.1%–0.5% silver, was used to produce silver before explosives were used. This indicates that our understanding of earlier metallurgy may be skewed due to the fact that lead-based silver metallurgy leaves traces that archaeologists find, whereas processing of "dry" silver ores leaves almost no trace. This has implications for the wider history of silver. Bartels's argument goes back to early modern mineralogy and the Middle Ages, emphasizing the significance of a variety of high-grade silver minerals, secondary ore enrichment processes, and "bonanzas" for the silver industry. A divide exists between archaeology and early modern history because of the disparity between the two research cultures.

Islamic Dirhams: Historical context

Arabs began using silver coins in the middle of the 7th century when they conquered Sasanian Mesopotamia and Iran. The Umayyads, who ruled Mesopotamia from 661 to 750 AD, adopted the practice of minting silver, combining the three different metals that were used for money. Wasit, the most productive mint and chief garrison for Iraq and Iran, began to strike silver dirhams of exceptional purity around 100–104 A H (718–722 AD), a practice that spread throughout the Caliphate and remained roughly unchanged for two centuries. At first, the new dirhams adhered to the same alloy standards as previous Sasanian and Arab-Sasanian coinage [8]. The metal had to have been freshly produced or refined in order to attain the purity of the Early Islamic dirhams, which typically contained 97 percent silver by weight. This metal does not need to be mined recently; As long as the silver was refined to meet the exceptionally high purity standard, it could also come from recycled old metal; Despite this, there are reasons to oppose widespread recycling during this time. A thorough development in the result of high-virtue money, as seen particularly in the Early Abbasid period over the most recent thirty years of the eighth century Promotion, can occur with an extension of metal stockpile, which focuses to new mining and metal creation. In light of composed sources, proposes silver mining in the Bedouin Landmass and Focal Asia, yet this presently can't seem to be affirmed by logical strategies. Using historical sources, this thesis argues that changes in monetary policy and an increase in coinage availability fueled widespread economic expansion throughout much of the Islamic world.

Under the Abbasids in the second half of the 8th century, one of the greatest expansions of the Early Islamic dirham minting occurred. Dirhams were generally sent out and were key in the foundation of the trans-Eurasian silver exchange that associated the larger pieces of Eastern and Northern Europe to the Islamic World. This blast of dirham stamping, archeologically verified by ninth and tenth century dirham stores in Russia and the Baltic locale, is vital for the social and financial history of Eurasia.

To investigate the circumstances surrounding how and why this occurred, it is essential to comprehend the resource base that fueled this expansion. Getting back to the subject of Early Islamic mining, a lack of silver and a huge reduction in mineral quality depicted are certainly not the conditions one would anticipate regarding a development in silver stamping and send out. However, a second line of physical evidence has not yet been available to support or refute Meyer's theory.

Materials and Methods

Samples

26 dirhams deaccessioned from the Ashmolean Historical center, presently at the School of Oriental Examinations at the College of Oxford, structure the reason for this metallographic review. Six of these are Umayyad dirhams from Wasit (704–740 AD) and twenty are Abbasid dirhams from Baghdad (Madinat al-Salam), the most common Early Abbasid mint, from Iraq, Iran, and Central Asia [9]. The mints of al-Muhammadiya (Tehran, Iran), Zaranj (western Afghanistan), Balkh (northern Afghanistan), and Bukhara (Uzbekistan) mint the dirhams from the eastern Islamic territories. The dirhams were chosen to contrast the central (Iraq) and eastern (Iran and Central Asia) parts of the Abbasid caliphate spatially and to cross-cut the chronological divides between the Umayyad and early Abbasid dynasties that have been identified elsewhere.

Mass spectrometry

Abrasion was used to remove corrosion from the 10–20 mg of silver samples that were clipped from the coins. Portable X-ray fluorescence was used to analyze the silver samples, which were then divided into two ca. 5 to 10 mg chunks. After the silver was digested in the first batch with dilute nitric acid, it was dried and dissolved in a solution of 2% HNO3 to measure the silver and lead content. The subsequent group was processed in weaken HNO3 and dried; Aqua regia was mixed in a beaker that was airtight, heated to 105 °C for 12 hours, dried, and then redissolved in a solution containing 5% HCl [10]. The water regia assimilation was utilized to decide the centralization of the multitude of outstanding components estimated. Inductively coupled plasma quadrupole mass spectrometry (ICPQMS) was used to measure the elemental concentrations (NexION 2000 BTM ICP Mass Spectrometer, ESI prepFASTTM sample introduction system, School of Geography, University of Oxford). Multi-element standard solutions traceable to NIST SRMs (Merck, Darmstadt, Germany) were used to calibrate the instrument, and elemental silver reference materials MBH 133X-AGA1 and AGA3 were measured concurrently to demonstrate precision and accuracy. Internal detection limits and the absence of contamination were determined by repeating blank analyses. An error with the 100x dilution in the ESI prepFASTTM sample introduction system made it difficult to accurately measure silver, resulting in low sample recovery (often 40–80 percent). Silver was measured separately after the HNO3 solutions were manually diluted by one hundred times. A source of error was the 100-fold dilution, and it appears that there was a problem with settling, resulting in variable and occasionally low sample recovery. The measured analytical totals are provided, and the silver contents shown in Table S1 have been adjusted to show a total of 100 percent. With the exception of Cr, Fe, Se, and Pd, which exhibit greater variability, replicate analyses of multiple digestions of reference materials AGA1 and AGA3 varied typically less than 15% (2RSD) for the majority of elements. For most elements, the Oxford ICPQMS analyses are within 15% of the MBH reference values, and for gold and copper, they are within 5% or better.

Metallography

The dirhams were once more sampled for metallographic analysis by removing a 3–5 mm-long slice that was mounted cross-sectionally in epoxy resin [11]. The mounted examples were then cleaned to the micron level. At magnifications between 20 and 40, optical microscopy was carried out with a Zeiss Axiophot and a Brunel SP-400. After that, carbon was applied to the samples, and scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDS) was used to examine them. A Zeiss Gemini SEM with a Thermo UltraDry Silicon Float X-beam Finder was utilized with a functioning distance of 10 mm, an energy of 20 kV, and dead times in the scope of 20-35%. The Nora System Seven software with standard calibration was used to perform the semi-quantitative quantification of the elemental spectra. After that, 10 milliliters of deionized water, 3 milliliters of 30% hydrogen peroxide solution, and 17 milliliters of concentrated ammonium hydroxide were used to clean and etch 17 of the 26 sections. By immersion, the sections were etched.

Experiment with cupellation

Using conventional lead-based metallurgical methods, silver was extracted from silver-bearing sulfide ore. The experiments were designed to investigate the persistence of sulfur and other easily oxidizing elements following the final cupellation of sulfidic ore metal. Three samples of argentiferous galena and a fourth ore, a lead-poor sample made up of argento-tetrahedrite, acanthite, and quartz from the same location, served as the basis for the first set of experiments [12]. After the final cupellation, all of these ore samples produced metallic silver.

An agate ball mill was used to crush and then pulverize the ore. In ceramic trays, the batches of pulverized ore were roasted for 24 hours in an electric oven at 725 °C. The roasted ores based on galena gained approximately 5% mass because of the development of lead sulfates. To deliver lead from cooked galena, the broiled metal was squashed and charged in 20 g bunches into hot graphite cauldrons with covers and refined for 20 min at 1100 °C. The lead was turned into an ingot by casting. The roasted tetrahedrite-acanthite was combined with assayer's lead in a ratio of 2.8 grams of roasted ore to 17.5 grams of lead and 0.5 grams of borax, scorified for ten minutes in an oxidizing atmosphere at 980 degrees Celsius, and then cast into an iron ingot. An electric furnace set to 950 °C, below the melting point of pure silver, was used to cupel the argentiferous lead in batches of 15–25 g in magnesite cups to help ensure the survival of small amounts of lead. Following the silver's solidification, the cupels were removed from the furnace within 15 to 20 minutes. The silver was permitted to cool. Lead, silver, and ore (about 20 mg samples) from these experiments were analyzed using the outlined procedures by solution-based single collector ICPMS. Copper, lead, and sulfur were among the measured substances.

More material was needed to produce enough silver for metallography. Silver was made by cupelling argentiferous lead, which was made by following the same processes as before. In a closed graphite crucible, once at 1080 °C, the silver was poured into hot water; The silver bead weighed 1 gram. A gram-sized silver bead was made by cupping and combining batches of galena-based ore with 7000 ppm silver. After being sectioned and polished for microscopy, the two silver beads were analyzed by ICPQMS at the University of Oxford using the same techniques as the dirhams in this study to determine their elemental compositions.

Results

The ore type is the focus of this study's analytical and metallographic findings, which also look into aspects of source and technology. Essential examination is significant not just in light of conversations of basic markers related with cupellation or specific mineral sorts, yet it can likewise give source-related data [13-17]. The extensive number of silver matte inclusions is the most significant metallographic feature. The primary focus of the research question is the survival of sulfur during silver extraction from sulfide ore using lead-based metallurgy, as well as the microscopic examination of matte inclusions and an understanding of the nature of the nickel found in two Abbasid dirhams. In separate sections (Supplementary Appendix), the manufacturing process and the widespread presence of mercury amalgams on the surfaces of the studied dirhams are discussed.

Conclusion

The presence of matte considerations in Early Islamic silver is a broad peculiarity that can't be made sense of utilizing the current perspectives on the improvement of silver metallurgy. A sign that silver was frequently extracted from ore without the use of metallic lead or cupellation is the persistence of sulfides in numerous dirhams. Native silver, cerargyrite, and acanthite-rich silver ore must have been available in sufficient quantities during the study period to warrant its own, previously unknown, extractive metallurgical treatment, which contributed significantly to the overall supply of silver. Although the conventional narrative of the history of silver metallurgy is a necessary oversimplification, it skews and narrows the spectrum of ores toward poor ores, in part due to the invisibility of rich ore and the (over) abundance of waste associated with the lowest ore grades and the strong influence of particular views in the early 20th century. The way the study of silver is approached and the questions that are considered worthy of investigation are controlled by the current paradigm of the universality of cupellation and silver production based on lead ore. In any case, it can likewise be seen as a block to advance, forestalling new and less noticeable viewpoints to be perceived. A change in outlook is required that empowers the basic assessment of the suppositions and genuine reason for existing hypotheses and pursues a bound together history of silver that spans the scholarly practices that partition the Medieval times.

The organization of minting throughout the Islamic world is impacted in a number of significant ways by the findings of this study. The fact that silver was not routinely cupelled at the mints is one of the most important factors. This means that the majority of mints were consistently supplied with imported silver that was extremely pure. According to the study, silver stocks are limited geographically and chronologically. This means that the stock used by the Umayyads at Wasit can be distinguished from the stock used by Abbasid Baghdad, and the stock used in Baghdad is not the same as the stock used in Iran and Central Asia. For lead isotope and elemental analysis-based provenance studies, these findings are encouraging.

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Conflict of Interest

None

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