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Sophisticated Roman Recovery Techniques for Gold

In his *Naturalis Historia*, Pliny the Elder has told us much about the state of science and technology at his time, i.e. the first century AD. The industrious author was well aware of the writings of his contemporaries, though he very rarely acknowledged them. For the wealth of material he wanted to communicate, he not only had access to what can only be termed a data base in the form of elaborately filed notes and quotations, but also to scores of scribes to whom he could dictate his books. Translations of Pliny's *Naturalis Historia* are numerous. However, some sentences are difficult to understand, others are even unintelligible. Therefore, a study group in Germany, consisting of linguists, scientists, technicians and historians has been engaged for more than 15 years in retranslating and reinterpreting Pliny's texts on metals.

When Pliny wrote about gold mining and beneficiation, he wrote with some authority. After all, he was procurator in Hispania Tarraconensis from AD 72 to 74. Iberia was once one of the main sources of gold for the Roman Empire, though not the only one. Bird (1984) discusses references which Pliny made to several gold mining and extraction techniques. These techniques include hushing, sluicing and the unique 'arrugia'-practice which is the systematic preparation of whole mountains by tunnelling for subsequent erosion by man-made floods from gigantic water reservoirs. Not mentioned by Bird (ibid) are Pliny's remarks that, for purification purposes, gold has to be 'cooked' (i.e. smelted) with lead. According to H. Rackham, this passage (*Nat. Hist.* XXXV, 60) is translated in English as '. . . for the purpose of purifying it is roasted with lead'. Furthermore, some gold ores have to be crushed and washed, as well as roasted and the smelting of the ore with lead produces a silver-colour alloy. This alloy would be considered a lead bullion in modern terminology. According to Pliny, the slag has to be crushed and returned (recycled) to the furnace. Using the Rackham translation again, this passage (*Nat. Hist.* XXXV, 69) is extremely interesting:

'The substance dug out is crushed, washed, fired and ground to a soft powder. The powder from the mortar is called the "scudes" and the silver that comes out from the furnace is the "sweat"; the dirt thrown out of the smelting furnace in the case of every metal is called "scoria", slag. In the case of gold the scoria is pounded and fired a second time; the crucibles for this are made of "tasconium", which is a white earth resembling clay. No other earth can stand the blast of air, the fire, or the intensely hot material.

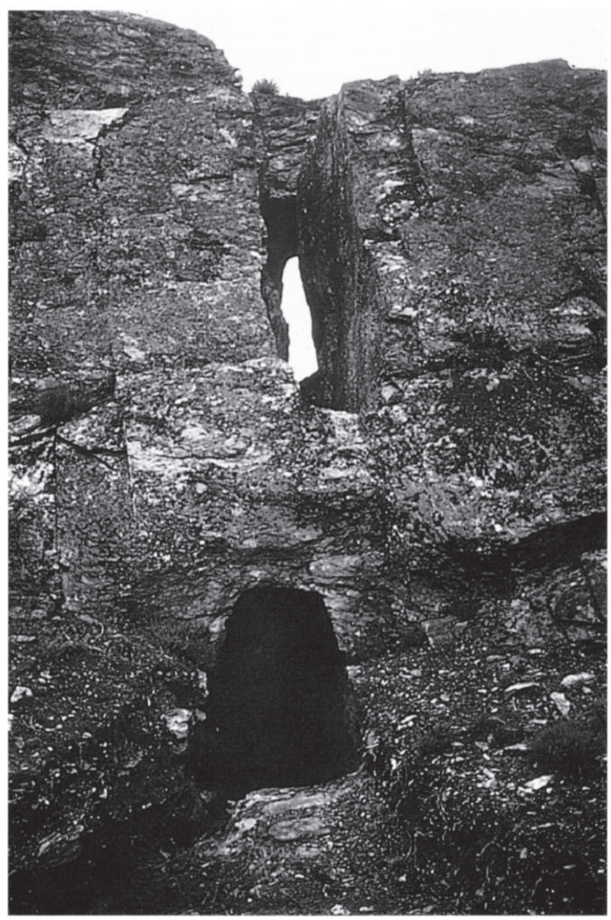

Fig. 1. Adits to Roman open cast gold mine: Três Minas, Portugal.

Surely these procedures do not apply to free or native gold from alluvial deposits, but point to hard-rock polymetallic gold ores in which at least part of the precious metal is associated with a variety of base metals and other elements, like sulphur, arsenic, etc., defying the simple process of 'panning', i.e. gravity separation.

Actively involved in the Pliny Study Group, I was invited to visit the unique Roman open-cast gold mines called 'Três Minas' located in the county of Trás-os-Montes in Northern Portugal (Fig. 1). These mines have been known for a long time, but only fairly recently have they attracted the devoted attention of the German archaeologist J. Wahl (1988). He became intrigued by finds pointing to a process technology hitherto unknown in the many Roman gold mines in the Iberian peninsula, and asked for scientific support and advice. Wahl found hundreds of prismatic stone slabs with cup-shaped depressions on all four sides (Fig. 2). These proved to be discarded crushing stones of Roman stamp mills. They are preserved in the modern villages, serving as construction material for gates and foundations. Circular millstones, also discovered in the vicinity, point to the next step of Roman gold ore treatment: grinding after crushing (Fig. 3). The existence of slag heaps near the mining area was at first not seen as something bearing any immediate relation to the metallurgy of precious metals but, after analysis, these slags were identified as waste typical of a smelting process in which lead acted as collector for precious metals. Already Harrison (1931) had noticed the slag heaps near Três Minas. He came to the conclusion that the slag had something to do with Roman gold metallurgy. He wrote of a 'lithargine process' in which litharge (lead oxide) had played a part in gold recovery and which apparently was practised here during Roman times. The process of smelting with lead can be carried out either with metallic lead or lead oxide.

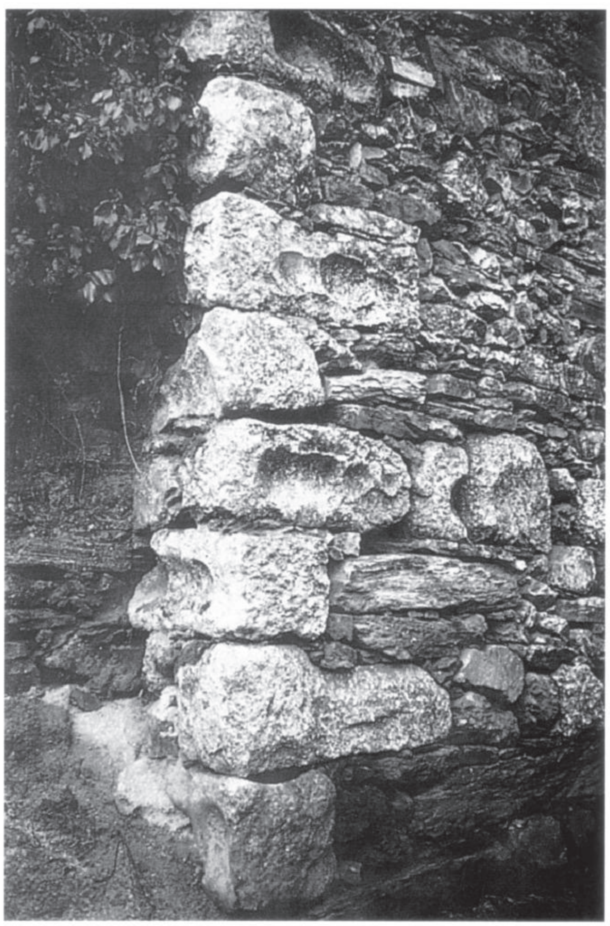

Fig. 2. Reused crushing stones from Roman stamp mills: Três Minas.

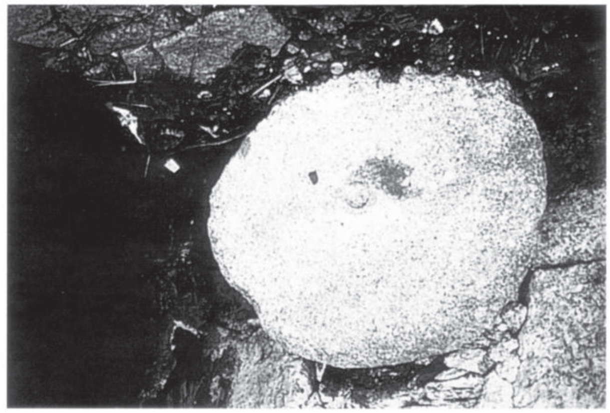

Fig. 3. Roman mill stone from ore/slag processing at Três Minas.

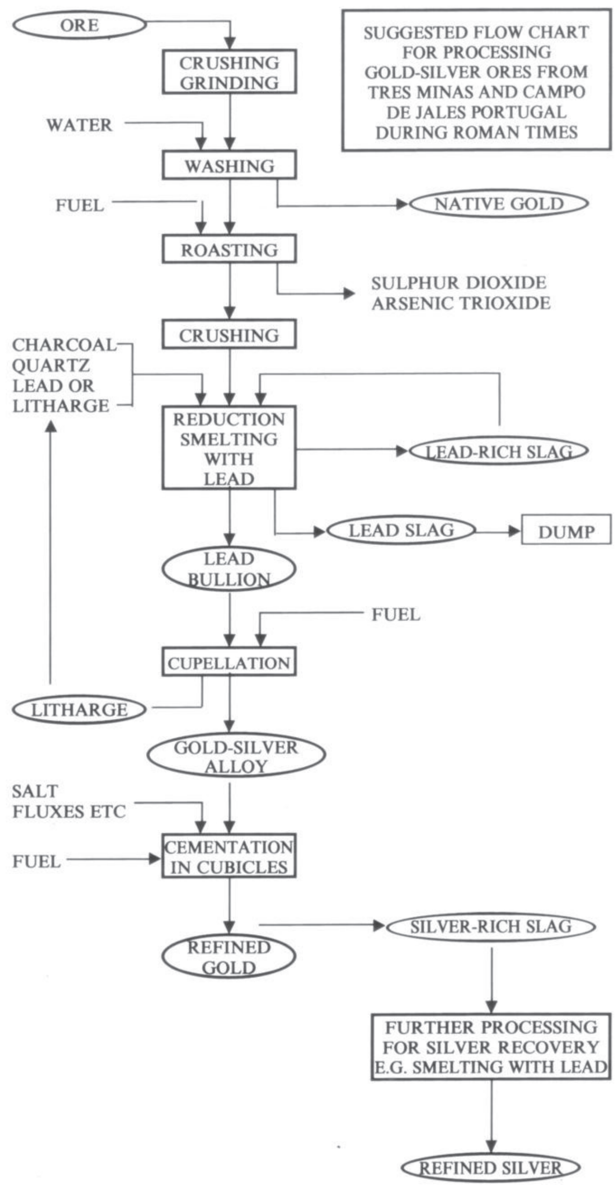

Fig. 4. Schematic flow sheet for gold ore processing at Três Minas.

The reducing atmosphere in the furnace will in either case provide lead metal as collector for the precious metals.

Though the Roman mines have been completely exhausted, we do have a reliable indication of the types of ores mined in antiquity. A modern, small gold mine nearby – perhaps the last one in Portugal – had been in operation until quite recently. The type of ore mined here was a mixture of arsenopyrite, pyrite and galena, with some sphalerite, stibnite, etc. and quartz as the main gangue mineral. Gold was present either as native gold or intimately intergrown with other minerals, notably arsenopyrite. The gold concentrations varied between 5 and 25 grams/ton. Silver content from silver-rich galena as well as from alloys with gold could reach 200 grams/ton and more. We have good reason to assume that the ore mined during Roman times was similar in composition and precious metal content.

Taking Pliny's remarks at face value, Roman gold ore beneficiation from Três Minas could have been carried out in a sequence of steps illustrated in the flow chart (Fig. 4). This schematic diagram leaves an option for the recovery of native gold prior to the treatment of the gold-containing complex ore. As the deposit is rich in silver as well, the separation of the precious metals, after cupellation, was probably the final metallurgical step, either performed on site or in a special refinery. Refined gold (*aurum obricium*) was mandatory for the minting of Roman gold coins.

Contrasting the ancient descriptions of Pliny along with modern principles of process metallurgy serves to understand better an ancient, technologically-advanced metallurgical process for the recovery of precious metals. The metallurgical flow chart will assist as a model for further archaeological excavations of the various industrial, gold-processing sites at Três Minas. It is ample proof of the interdisciplinary nature of archaeometallurgical research.

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Romano-British coins from Richborough, Kent

During the excavation of the Roman Saxon Shore Fort at Richborough in Kent, a small hoard of coins (Fig. 1) was discovered which were thoroughly corroded together. The find was published in the coin report for Richborough (Reece, 1968) where a date of the second quarter of the fourth century AD was suggested. The only visible feature on any of the legible coins on the surface of the hoard was a PROVIDENTIAE AVGG reverse type of Constantine I (AD 306–337) which would have been issued between 324 and 326.

This group offered a rare chance to investigate a hoard of coins where the individual coins are still stacked in original positions. The idea was to see if the compositions of the coins change relative to their position and degree of corrosion within a hoard. This project was part of my doctoral research, supervised by Drs Richard Reece and John Merkel, at the Institute of Archaeology, University College London. Usually, the degree of corrosion on coins from the exterior of a hoard is worse than in the centre. It was decided to investigate the range of compositional variation between apparently identical coins in relation to the position of each coin within the Richborough hoard. This information would also be used in conjunction with the analyses of numismatically comparable issues discovered at Tingrith (Deacon, 1990). Using the same issue of coins practically as test blanks of the same composition buried in different environments, enables the post-depositional modification suffered by these coins to be assessed over a period of some 1,668 years.

In order to accomplish this task, it was first necessary to record accurately the relative position of each coin within the corroded hoard in three dimensions. Various possible methods of doing this were considered, ranging in complexity from simple cardboard models up to sophisticated photogrammetric imaging techniques. It was eventually decided to use a computer-aided design (CAD) programme called Microstation (Intergraph Corporation, 1991). This was chosen mainly because of its ability to interface directly with database programmes as well as for its relatively user-friendly interface.

Although primarily intended as a design programme for architects and engineers, Microstation also has the ability to draw simple standard shapes from sets of Cartesian co-ordinates. In this case it was necessary to reduce each coin in the hoard to a set of three co-ordinates relating to three arbitrarily selected points along the edge of each coin. This was done using a Reflex Metrograph in the Department of Photogrammetry,

Fig. 1. The small hoard of corroded coins dated to the second quarter of the fourth century AD discovered at Richborough.