Arsenical copper ore in the newly discovered Copper-Age mine ALS2 in Almeria, South-east Andalusia (Spain) – a correction

The discovery by our IAMS survey team in September 1988 of a prehistoric copper mine and smelter (ALS2 = Almeria Survey Site No. 2), probably related to nearby Los Millares, the important Copper-Age key site of the 'Millaran culture' and the beginnings of metallurgy in South Iberia, was an event of considerable interest to archaeo-metallurgy. As explained in our previous report (*Newsletter* No. 13), among the major objectives of our Almerian Archaeo-Metallurgical Survey is the solution of one of the basic problems of Millaran metallurgy: the appearance of arsenical copper as the copper alloy in common use already at this very early phase (late 4th-early 3rd millennium BC) of metalworking.

To emphasise the importance of the ores found at ALS2, and their correct identification, we re-state here the pertinent question: Was the arsenical copper, used by the early prehistoric metalworkers of Andalusia, the product of a metallurgical process involving the intentional addition of arsenic to copper to improve its metallurgical properties and applications, or was it an ingredient of the original copper ore as mined? In other words: was arsenical copper a 'natural alloy', the appearance of which in metal history is but a fortuitous 'accident' of mining history, or was arsenical ore brought to the copper-smelters or the workshops to be used as an intentional additive to the copper ore or the metallic copper in order to make 'arsenical bronze'? This question is of considerable importance for the understanding of prehistoric metalworking technology not only of Southern Iberia but also of the Near East and many other areas of the Old World where in prehistoric times arsenical copper was commonly used for the manufacture of working tools, weapons, jewellery and cult objects.

The problem of the early appearance of arsenical copper in Southern Iberia has been previously discussed in Beno Rothenberg, et al., *Studies in Ancient Mining and Metallurgy in South-West Spain* (Metal in History Vol. 1, 1981). Based on the mining situation in the Huelva Province it was suggested that the answer to the question of arsenical copper is to be found in the mines and not in the smelters, i.e. the arsenic was contained in the copper ore as mined in the secondary enrichment zone of the pyrite ore deposits of Southern Iberia and also in the ores from complex ore deposits which were also mined in prehistoric times. The fortuitous production of an alloy of such complexity seemed the only acceptable explanation considering the still rather primitive technological horizon of the Copper Age.

It must be mentioned here that recent investigations of arsenical copper smelting in Peru (John Merkel and Izumi Shimada, Arsenical Copper Smelting at Batan Grande, Peru, *IAMS Newsletter*, No. 12, 1988, 4–7), showed that arsenic-rich minerals were intentionally added to oxidised copper ore in order to produce arsenical copper. Although the smelting site in Peru is dated to the period between AD 900 and the Spanish Conquest, i.e. rather late for comparison with European and Near Eastern prehistoric metal production, it presents proof that the process of mixed ore smelting (oxidised copper ore together with arsenic-rich minerals) was indeed practised in societies functioning at a 'prehistoric' level. This evidence, though arriving from a very different archaeo-metallurgical time and space, has to be taken into consideration in any discussion of arsenical copper production and use. It will also be an important guideline for our future archaeo-metallurgical surveys.

Considering the previous conclusions of our surveys in the south-west of Andalusia, the identification of the copper ores found at the mine and with the ancient slag at site ALS2, (published in *IAMS Newsletter* No. 13, 1988), as chalcocite, chrysocolla as well as malachite and azurite, was rather disappointing. We had hoped that we would be able to establish a similar situation – arsenical copper ore in the original ore deposits – also for south-east Spain and in a Millaran context.

The evaluation of site ALS2 and its place in the metallurgy of Los Millares has now been radically changed through the recent re-identification of the ores and minerals collected there by our team. A small group of our samples was recently sent to Noel Gale, Oxford University, for lead isotope provenance studies and he identified the substantial presence of arsenical ores: 'Azurite and malachite are both present in these ores, but so apparently are fahlerz ores, probably mainly tennantite. There are certainly major amounts of arsenic present'. Gale also pointed out the presence of sulphur as a major component of most of the minerals (not azurite or malachite).

The precise and detailed identification of the minerals of site ALS2 must await XRD studies, but already at this preliminary stage of these investigations, the presence of arsenical ores as a major component of the mining geology of site ALS2 establishes the basic fact that the arsenical copper of Los Millares was apparently the result of the mining situation, just as the arsenical copper in the Huelva province.

The probable role of the fahl-type ores from ALS2 in Millaran metallurgy, especially in the metallurgical workshops uncovered at Los Millares by the Granada group, directed by Fernando Molina, is now being studied by members of the IAMS Iberian Archaeo-metallurgy Project.

Beno Rothenberg