More about the Silver-rich Lead of Ancient Laurion

J. Kepper recently published two articles in the periodical *Historical Metallurgy* devoted to the problems connected with the extraction and concentration of silver-rich lead minerals in the Laurion region[1]. Regrettably, once more, it must be noted that all discussions concerning such problems have been carried out by metallurgists, geologists, or chemists. In general they tend to ignore or neglect the archaeological evidence, showing little interest for the historical background and concerning themselves solely with the geological, chemical or technical aspects. On the other hand, the contributions by archaeologists lacking the relevant technical training, for instance without metallurgical experience, are limited, and the results often deceiving.

First of all, I am surprised that Kepper omits to mention a number of major publications such as those by W. Krysko, R. Hopper, M. Crosby, the important work by S. Lauffer, and the excavation reports by V. Kakavoyannis and the reports of Thorikos[2]. Had he included such research in his work, Kepper might have reached more accurate historical and even technical conclusions. For example, the history of metal extraction at the Laurion comprises 35 centuries, not just the 8 mentioned by Kepper: the exploitation of the silver-rich lead begins towards the end of the Neolithic-Early Bronze Age, around 2900 B.C. and ends sometime in the 6th century A.D. Kepper makes no mention of the 2500 years preceding the 5th century B.C. One important question arises: how did men, 2900 years before Christ, manage to develop metal-working techniques at the Laurion? We logically presume that two conditions had been present: open-cast mining combined with highly rich mineral. The situation existing at Mine no. 3 at Thorikos comes to mind[3]. However, the vein was completely exhausted already in antiquity; therefore nothing remains of it to allow the identification of the exact nature of the mineral and its silver content. As

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[1] J. KEPPER, "A hindered-settling model applied to the flat-washing platforms at Laurium, Greece", *Historical Metallurgy* 38 (2004), p. 75-83; J. KEPPER, "Third Contact ore mineralogy at Laurium, Greece", *Historical Metallurgy* 39 (2005), p. l-11.

[2] W. KRYSKO, "Archaologisch-anthropologische Daten zur Frühgeschichte der Metallurgy", *Erzmetall* 32 (1979), p. 499-500; W. KRYSKO, "Beitrag zur Klarung von Aufbereitungsproblemen der klassischen Periode Griechenlands am Beispiel Lavrion", *Erzmetall* 40 (1987), p. 209-211; ID., "Die Bleihütte Port Pirie der *The Broken Hill Associated Smelters Pty. Ltd.* in Port Pirie South Australia", *Erzmetall* 35 (1982), p. 202-207; R.J. HOPPER, "The Attic Silver Mines in the Fourth Century BC", *BSA* 48 (1953), p. 200-254; R.J. HOPPER, "The Laurion Mines: A Reconsideration", *BSA* 63 (1968), p. 293-326; M. CROSBY, "The Leases of the Laurion Mines", *Hesperia* 10 (1941), p. 189-312; S. LAUFFER, *Die Bergwerksklaven von Laureion*, Wiesbaden, 1979²; V. KAKAVOYANNIS, "The Silver Ore-processing Workshops of the Lavrion Region", *BSA* 96 (1996), p. 365-380; *Fouilles de Thorikos*, 9 *Preliminary Reports*, 3 *Final Reports*, Brussel/Gent, 1967-2006.

[3] *Fouilles de Thorikos, Preliminary Report* 8, Gent, 1984, p. 151.

L'Antiquité Classique 75 (2006),
p. 225-230.

Krysko correctly observes, we can imagine a situation in Thorikos similar to that of 19th century Australia, in the Long Reef region, where a mineral with ca. 60% silver content was found in the surface in the "Day Dream" and "Maybell" mines. The mines were small, but extremely rich; in the following years, deeper drilling produced poorer minerals. A mining expansion could compensate for quality loss[4]. The prospecting of the ancient mining galleries at the Laurion reveals little: nothing remains but a slight trace of the early exploitation. In general the situation on the ground is rather complex: metallurgic residues are rare and difficult, if not impossible, to date. In order to draw reliable historical conclusions it is indispensable to retrieve such residues within sealed and undisturbed contexts, including sufficient datable archaeological material. The region has been overturned, reworked and remodeled in the course of two millenniums. The final calamity took place during the 19th and 20th centuries with the re-opening by the French Mining Company of the Laurion; no ancient gallery has been left untouched, all have been re-worked by modern miners. Furthermore, it must be said that systematic excavation in the region is still very inadequate.

Next, Kepper writes about "the ancient hand-sorting and washing operations of the 5th century B.C."[5], whereas we have known since long that the ancient washing tables date only as far back as the last years of the 5th century B.C. and that 95% of these installations date to the 4th century B.C. All one has to do is to refer to the work by M. Crosby published in 1941. It is precisely thanks to those leases that we are so well informed regarding the situation in the 4th century B.C.

In the same article, Kepper states (p. 9): "Closure of the mines after the end of the first century B.C..." The statement would imply that mining activities continued throughout the Hellenistic period. However, throughout the Laurion region Hellenistic lamps are almost absent, Hellenistic pottery is extremely rare and the same goes for structural remains. It is reasonable to argue that mining activity ceased after the conquest of Athens by Demetrius Poliorketes in 295 B.C., which clearly does not exclude the possibility of continuing, but much reduced, activity by squatters reworking the metal slag and, maybe, the *ekvolades* discarded by their predecessors. On the other hand, Kepper devotes not a single word to the hundreds of 5th-6th centuries A.D. pre-Byzantine miner's lamps found in the outbuildings and in the mine galleries, clearly pointing to resumption of activity, due to an increased demand in the Eastern Empire during the reigns of Theodosius and Marcianus[6].

The contribution by J. Kepper does include some interesting geological observations, but it is useless from an historical point of view, regrettably so since the study itself deals with historical metallurgy.

Other observations concern the functioning of the washing tables. Firstly, we have the more traditional interpretation, according to which the minerals were poured into wooden sluices suspended by ropes from the roofing over that part of the washery and placed in front of the outlets of the stand tank. The system would allow

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4 KRYSKO, *op. cit.* (n. 2).

5 KEPPER, *op. cit.* (n. 1), p. 76.

6 O. DAVIES, *Roman Mines in Europe*, Oxford, 1935, p. 251.

an inclination of the sluices adapted to the quality of the ore. This interpretation was developed in detail by Conophagos in the 1980s; Krysko and Tsaimou carried out trial tests with good results.

For some inexplicable reason some authors (Kakavoyannis, Domergue, Kepper) replaced this perfectly logical interpretation, that accounts for all observations on the ground, by two other hypotheses:

1) The ore was poured either into containers or mortars (flat dishes or shallow ceramic bowls), in which the concentrate was obtained by vanning, or into *lekanai* placed in front of outlets, with the ore concentrate obtained by panning.

2) The ore was thrown into the stand tank where it was stirred with water dripping from the outlets. Afterwards the concentrate was scooped up.

Let us consider the two alternatives of the first hypothesis. Various authors[7] are influenced by the idea that mortars, or *lekanai*, were present "in large number" in the washeries[8]. Conophagos writes "in the nearest room we found, next to washery Pa (of Simos), a large number of dishes"[9], but he does not specify how many. According to photo 10.23, they are mortars, but Conophagos states that they were found "next to the washery", which means in the labourer's living quarter. Furthermore, he asserts that the mortars were used only for sampling. We may, then, wonder about the precise meaning of "large number"; and why were the exact terms mortar and *lekanai* not used?

The appraisal of the material retrieved at Thorikos, a site archetypal for the Laurion – 11 identified washing tables, 4 of which excavated, cisterns, mines, dwellings etc. – presents a totally different picture. Of the 9.000 inventory numbers (from a total of *ca* 13.000) 95% of which are artifacts excavated within the recorded stratigraphy of an approximately 10.000 m² site, exactly 19 are mortars, just 0.2 % of the total, not one from the washeries. The number of lekanai is 360, 4.1 % of the total, but only 4 fragments, i.e. 0.06 %, were retrieved from the washeries. These data clearly contradict the assertion "found in abundance near the workshops", as J. Kepper writes[10]. The real situation, as presented on the site, is that mortars are rare, although they were also used in the household. The number of *lekanai* is equally surprisingly low considering their frequent everyday use: "it is a common item of domestic equipment"[11].

Another point at issue is whether these two types of pots were adapted for use in metallurgy. Let us consider first the mortars. "Among kitchen implements in constant and continuing use, the grinding bowl, θυεία (?) or ἴγδις (?), holds the first, the most ancient place"[12]. They are solid basins usually made of tile-fabric, on average 0.36 m in diameter and 5.375 kilos in weight. A more lavish, unusual, version

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[7] KEPPER, *op.cit.* (n. 1), p. 76.

[8] KAKAVOYANNIS a.o.: "large number of fragments of shallow ceramic bowls".

[9] C. CONOPHAGOS, *Le Laurium Antique*, Athènes, 1980, p. 245.

[10] KEPPER, *op. cit.* (n. 1), p. 76.

[11] B.A. SPARKES, L. TALCOTT, *The Athenian Agora XII Black and Plain Pottery*, Princeton, 1970, p. 211.

[12] *Ibid.*, p. 221.

in sandy class ware weighs 2.760 kilos. It is virtually impossible that the labourers could shake, all day long, such heavy bowls weighed with wet lead ore. The work efficiency would have been minimal and we may reasonably wonder why then the washing tables were built. In this case, the viewpoint of Conophagos and Kepper[13], according to whom they were used "to sample", is theoretically acceptable, although it is reasonable to speculate if a well-tested method needed such a large and heavy basin and such an amount of ore in order to establish the quality of the concentrate. To solve this problem a smaller dish would have been easier and more manageable, and it must be noted that the washing boards reproduced in Conophagos, fig. 10.23, are 30 to 50 % smaller than the mortars.

Let us then consider the *lekanai* and their use. By and large they were pots of medium size holding two gallons of liquid, or slightly more, measuring approximately 0.30 / 0.40 m. in diameter. They were employed for numerous tasks in the household: "an open basin usually provided with a pair of handles and made of household ware"[14]. Most of the lekanai recovered in Attica are of local manufacture, a few were imported from Corinth. G. Lüdorf, in her detailed study of lekanai, writes[15]: "da die Lekane auch für Flüssigkeiten verwendet wurde, war es notwendig, den porösen Ton vor dem Brand mit einer wasserdichten Schicht zu überziehen... die Lekanen wurden jedoch aus dekorativen Gründen auch an anderen Stellen gefirniszt".

We may wonder why containers of a fragile and porous nature would be utilized for such an industrial function, particularly pots that had to be made waterproof by the application of a thin, flimsy layer of black varnish. There can be little doubt that the layer of black varnish would wear out after just a few hours of use: hard mineral ore had a truly abrasive effect. Finally, there is no relationship between the flow of the outlets: 45 liters per minute dropping at a speed of 2.8 meter per second, and the capacity of the lekanai: 9.08 to 13.62 liters. Another solution could have been, for example, to use larger metal containers. However, they would have been too costly and no trace of any such vessel has been found. It is my opinion that the hypothesis according to which the ore concentrate was collected in ceramic pots, cannot be maintained. There is no archaeological evidence to support it and their daily use would have been neither practical nor economical.

We must consider now the second system suggested for collecting the concentrate: the grinded mineral ore is thrown into the stand tank filled with water, the mixture is then stirred; subsequently the dirty water runs out via the outlets. Next, it was necessary to empty the stand tank and deposit the concentrate on the drying floor.

At this stage, a number of questions need to be answered: why 3, sometimes 5, outlets were used and why at a height that always allowed approximately 0.50 meter of water to stagnate in the stand tank? Why was the washing table so large (c. 2 m) that the transfer of the concentrate to the drying floor was rendered more difficult? Why are there no traces of wear in the stand tank and why have traces of metal never

[13] KEPPER, *op. cit.* (n. 1), p. 78.

[14] G. LÜDORF, *Die Lekane, Rahden*, Westfalen, 2000, p. 35.

[15] *Ibidem.*

been retrieved from it? (All the tailings found by T. Rehren[16] were on the washing tables, never in the stand tanks). What is the purpose of a feeding floor in every washery, on which a workman poured the water that was filled in the last tank of the decantation circuit so that it would flow in the stand tank without stirring? Astonishing is also Kepper's assertion that "operation of the washing workshops was seasonal, because water was largely collected during the winter months"[17], referring to Conophagos[18]. In Conophagos' text, however, this is not mentioned. On the contrary, in the passage referred to C. Conophagos demonstrates that the numerous large cisterns in the Laurion were essential precisely to allow continuous work throughout the year. We may wonder if Kepper has fully understood the French text.

In conclusion, it must be noted that the hypotheses elaborated for the two new systems of concentration are unsupported by archaeological evidence or by any other historical validation.

Let us return to the traditional interpretation. It is absolutely certain that the sluice was known in the Laurion and there are indications pointing to its existence already in the 5th century B.C.: the helicoidally shaped washeries[19]. The system functioned faultlessly, the quality of the ore concentrate was flawless, but the revenue was inadequate. The washeries must have been very costly, both to build (the transportation of large blocks, the meticulous cutting out of the circuit) and to run (the amount of concentrate obtained is always minimal, it had to be gathered up each time by hand, the cleaning of the circuit was required after two or three usages and had to be done cupula after cupula). This situation must certainly be the reason why only three complete examples of the type (and one unfinished) have been found so far. The principle was, nevertheless, known and the washing table can be considered its improved, financially viable outcome. With 3-5 outlets it was possible to work in a continuous, regular manner: one man could add sufficient water to the stand tank to keep the adequate pressure necessary to feed an outlet while another tank was emptied and a third was filled. On the washery there was enough place to move about, the sluices with the concentrate were easily tipped on the central drying table. The decantation circuit could also be cleaned while the concentration process was carried out.

Leaving aside the technical and archaeological aspects, the economic consideration remains. If we take into account the silver-rich lead metallurgy of the Laurion on the whole, we notice that the Athenians had accumulated a considerable know how, no doubt acquired partly thanks to the expensive, specialized *technites* imported from Asia Minor or Pontus Euxine[20].To try to recreate the authenticity of historical complexity merely on the basis of geological and chemical elements, disregarding the

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[16] T. REHREN, D. VANHOVE, H. MUSSCHE, "Ores from the Ore Washeries in the Lavriotiki", *Metalla Bochum* (2002) p. 27.

[17] KEPPER, *op. cit.* (n. 1), p. 82.

[18] C. CONOPHAGOS, *op. cit.* (n. 9), p. 254.

[19] *The Helicoidal Washeries*, Archaeology International, University College London, 2000/2001, p. 40-43.

[20] S. LAUFFER, *op. cit.* (n. 2), p. 60.

archaeological, epigraphic and historical facts is utterly faulty. We may conclude that the description of the process by Conophagos, with the additional information presented by Papadimitriou and Tsaimou, appears to be the more realistic one. Conophagos had the advantage of having been an engineer who had worked all his life in the mines of this region, he knew very well its ancient remains and, most importantly: he had put to the test all his interpretations.

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