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THE SILVER ORE-PROCESSING WORKSHOPS OF THE LAVRION REGION¹

THE production of silver and lead at Lavrion in Classical times was a difficult operation, employing a variety of methods, tools, and structures.² Because of the distinctiveness of the deposits and the mineralogy of the area,³ the practical process of production was separated into three interrelated stages: the first was the discovery and mining of the ore, the second its processing and cleaning of all constituents that were not silver-bearing lead, and the third, its smelting in order to produce the metals. Benefication, or separation of the gangue from the mined material, was necessary in order to achieve satisfactory and economical smelting. Each of the stages was carried out in a different place: in the depths of the earth for the first, at the processing *ergasteria* for the second, and in the smelting workshops⁴ for the third. A considerable number of both specialized and unspecialized workers was needed for these tasks. This article is concerned only with the processing *ergasteria*.

Many ores and non-metallic minerals are present in the Lavrion substratum, but not always in exploitable amounts. The commonest are those containing argentiferous lead (AgPb), and they are chiefly two: galena (PbS), an argentiferous lead sulphide ore, and cerussite (PbCO₃), an ore of the same kind, but a carbonate. Many of these ores are as a rule mixed together. Deposits of pure galena or cerussite exist, but are relatively rare and small. Galena or cerussite usually constitutes on an average 20% of the deposit; from this small percentage it can be seen that the deposits in the region had an essentially poor content of argentiferous lead.⁵

The degree to which the argentiferous deposits could be exploited was always commensurate with the level of technology possessed and applied by the ancient Lavrion metallurgists. When the ore was poor in galena or cerussite, it was difficult to smelt it profitably, since the smelting required a great deal of fuel, which was always a costly item, and during the smelting much of the argentiferous lead was lost because it was captured by the scoria that was produced.⁶ Owing to these serious problems, and until they learnt the methods and means for a full processing of the ore that were understood in Classical times, none of the deposits poor in argentiferous lead were utilizable in practice, as the metallurgists of the time were unable to remove the gangue. Only the richest ores could be used and so, understandably, the pre-Classical miners only mined the pure galena or cerussite or an ore rich in these minerals, which they found in the deposits when they opened their underground galleries. None of the ores that were poor in silver would have been mined, since they could not be utilized.

¹ The following special abbreviation has been used: Konophagos = K. Konophagos, *Τὸ ἀρχαῖο Λαύριο καὶ ἡ ἑλληνικὴ τεχνικὴ παραγωγὴ τοῦ ἀργύρου* (Athens, 1980).

² Konophagos 155 f.

³ G. P. Marinos and W. E. Petrascheck, *Λαύριον, (Ἰνστιτούτο Γεωλογίας καὶ Ἑρευνῶν Ὑπεδάφους, Γεωλογικαὶ καὶ Γεωφυσικαὶ Μελέται, iv, 1; Athens, 1956), 151.*

⁴ The *ergasteria* for smelting the silver ore, like those for cleaning it, were private enterprises and comprised special types of buildings (E. C. Kakavoyannis, *Τα ἀρχαῖα μεταλλεία τῆς Λαυρεωτικῆς* (Athens, 1988), 30 f., fig. 16.

⁵ Konophagos 21.

⁶ Marinos and Petrascheck (n. 3), 12; Konophagos 274 f.

Their technological incompetence would also have determined the methods they followed. From the Final Neolithic period, during which the exploitation of the Lavrion region apparently began,⁷ until the end of the sixth century BC, the process of producing silver and lead had only two stages: discovering and mining the ore, and smelting it. The stage of processing and cleaning it, as we find it in the Classical period,⁸ does not seem to have existed yet. This appears from the fact that so far no remains of relevant installations, nor the products or byproducts (e.g. tailings, scoriae), have been found in Attic silver mines datable to the pre-Classical period. Everything that has survived, and it is considerable, belongs only to the period from the end of the sixth century BC and after.

The absence of relevant remains leads to the following conclusion: the pre-Classical miners, who were at the same time metallurgists, built a furnace close to the mine and in it they slowly smelted all the material they had dug out. Pre-Classical galleries have been found in different parts of the Lavrion region⁹ and are readily distinguished, since they are small and chiefly extend along the First Contact¹⁰ of the metalliferous zone of the substratum, that is, the one near the surface of the ground. Their furnaces, on the other hand, have not survived and we can only infer their existence from the fortuitously preserved effects of the high temperature on the rocks where they happened to have been constructed in contact with different rock masses.

The pre-Classical furnaces disappeared almost completely, but for another reason: smelting technology, as we have seen, was very inadequate, with the result that they produced scoria that were rich in argentiferous lead; the Classical and post-Classical metallurgists at Lavrion, who possessed a superior technology to their predecessors, systematically sought out these scoriae to smelt them and obtain the argentiferous lead they contained.¹¹ There is a revealing testimony to this in Strabo (ix. 1. 23), who is certainly writing of his own period: ‘. . . the silver mines in Attica were originally valuable but now have failed. Moreover, those who worked them, when the mining yielded only meagre returns, melted again the old refuse, or dross, and were still able to extract from it pure silver, since the workmen of earlier times had been unskilful in heating the ore in furnaces’ (translation Loeb Classical Library). Just the same practice was followed by the mining companies of modern Lavrion,¹² who looked for and destroyed all the surviving remains of furnaces to obtain the scoria that existed not only in heaps around them, but inside them as well.

The fact that the process of silver production in pre-Classical times had only two stages surely indicates also that there were only two kinds of establishments, the mine itself and the smelting workshop. According to this theory, the pre-Classical workshop was located close to the mine and consisted of only one or more furnaces for smelting the ore and nothing else.

This practice appears to have lasted until about the end of the sixth century BC, at which time a great technological invention was developed in the Lavrion area, whose subsequent

⁷ J. Bourhis, C. Conophagos, and N. Lambert, ‘Les métaux trouvés à Kitsos’, in N. Lambert, *La Grotte préhistorique de Kitsos (Attique)*, i (Recherches sur les grands civilisations, Synthèse 7; Paris, 1981), 421 f.; P. Spitaels, ‘Final Neolithic pottery from Thorikos’, *Miscellanea Graeca*, 5 (Ghent, 1982), 9–44; V. McGeehan-Liritzis, *The Role and Development of Metallurgy in the Late Neolithic and Early Bronze Age of Greece* (SIMA pocketbook 122; Jonsered, 1996), 83, 176.

⁸ Konophagos, 212 f.

⁹ P. Spitaels, ‘The Early Helladic period in Mine No. 3 (Theatre Sector)’, *Thorikos*, 8 (1972–6), 151 f.; E. Ardaillon,

Les Mines du Laurium dans l'antiquité (BEFAR 77; Paris, 1897), 131; H. Lohmann, *Atene*, 1 (Köln, 1993), 87 f., 243 f., pls. 128–9.

¹⁰ Marinos and Petrascheck (n. 2), 83 f. and inserted Μεταλλευτικός χάρτης τῆς Λαυρεωτικής.

¹¹ *Ibid.* 133; Konophagos, 139.

¹² A. Kordellas, ‘Ἡ βιομηχανία τῆς Ἐταιρείας τῶν Μεταλλουργείων Λαυρίου καὶ τα μεταλλευτικὰ καὶ μεταλλουργικὰ αὐτῆς προϊόντα ἐν τῇ, Δ’ Ὀλυμπιακῇ Ἐκθέσει (Athens, 1888), 26 f.

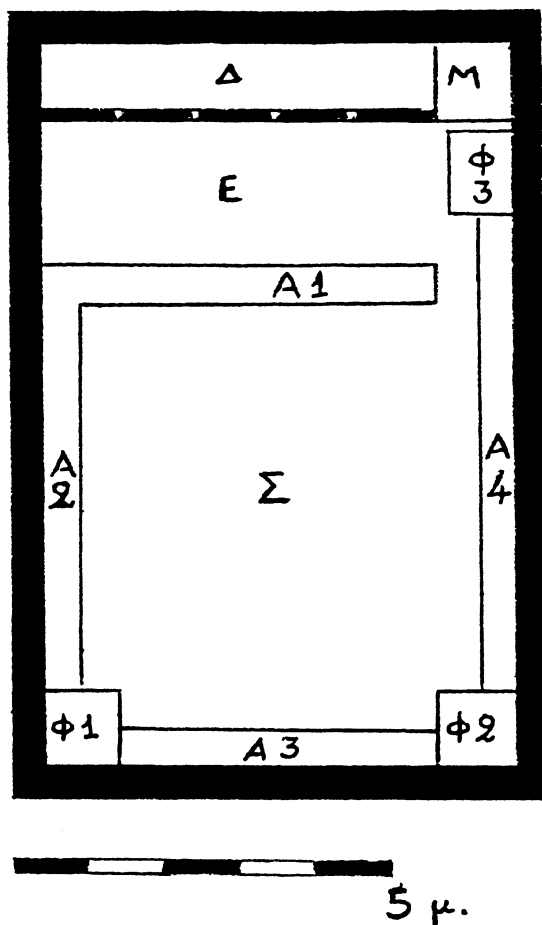


FIG. 1. Schematic section of a rectangular washery of Type I.

application completely changed the effectiveness of its mines and greatly helped the Athenian economy, with all its obvious consequences. This invention was a simple fixed structure, built on or cut into the rock, which the Athenians called a καθαριστήριο,¹³ and metallurgists of today a washery. In this structure the metallurgists, using relatively large amounts of water, were able to clean the mined ore of all its useless constituents—all that could be removed by mechanical means—and to keep only the pure galena or cerussite it contained.

I shall not attempt to describe the form and function of the washeries, since they are well-known in general (FIG. 1),¹⁴ but it may be useful to recall the basic principles: the processing of the ore in a washery was based on the fact that argentiferous lead, whether galena or cerussite, has a greater specific gravity than the gangue. To obtain the argentiferous lead, the workers crushed the ore into small pieces, and then ground it in special trachyte mills until it became 'flour', with grains about 1 mm in diameter. The ground material was next taken to the washery and washed

¹³ Harpocraton, *Λέξεις ρητορικά*, s.v. Κεργρεών.

¹⁴ Konophagos, 233 f., fig. 10. 16–22.

in clay basins,¹⁵ where the force of the moving water carried away the remaining lighter elements, leaving only the pure grains of galena or cerussite because they were heavier.

The water used for washing the ore did not go to waste; after passing through some 25 m of channels and settling tanks, in which it was alternately moving and stationary, all the material carried away by the water settled at the bottom of the channels and tanks and the water returned to its starting-point clear and ready to be reused. This recycling of the used water was the principal purpose of the washery and was especially important because the Lavrion region was, and still is, almost waterless. The invention of the washery was undoubtedly the metallurgists' answer to the aridity of the region, since with it they were able to use the same amount of water many times over for cleaning the ore with only a slight loss.

The discovery of the ore-washery was, in my opinion, a great landmark in the mining history of the Lavrion area, for it made it possible to exploit all the argentiferous deposits without exception, even the poorest ones. The region, as we have seen, contained mainly poor lodes, and the ore-washery, therefore, essentially multiplied the exploitable wealth of the Lavrion area, and thus in effect the Athenians' mineral resources.¹⁶ After it appeared, the exploitation of this resource, which had previously only been possible in certain parts, now spread to the whole of the region. The use of the washery created a new stage in the practical process of producing silver and lead, in which the ore was processed with the aid of water. It called for installations quite different from those used in the other stages, and it created a new kind of workshop: the ore-processing ergasterion. This discovery travelled far afield and became so widespread that among the numerous ruins of ore-workshops of the Classical period that have survived in the Lavrion area and are plainly visible on the surface, not one does not possess an ore-washery.

Since from the evidence of the surviving ruins all the ore-processing ergasteria were clearly self-contained production units, we wondered about the course of their development from their first appearance until their ultimate full operation.¹⁷ On the basis of previous evidence it was not possible to hazard even a rudimentary picture of this development, so in order to study the question more closely, Olga Kakavoyannis and I carried out a systematic surface survey of the Lavrion region some time ago with the aim of discovering any chance surviving pre-Classical installations for processing and cleaning ore.¹⁸ Our basic thought was that since the new

¹⁵ E. Kakavoyannis, 'Μια νέα άποψη για την λειτουργία των πλυντηρίων μεταλλεύματος της Λαυρεωτικής κατά τους κλασσικούς χρόνους', *Πρακτικά Α' Συμποσίου Αρχαιομετρίας της Ελληνικής Αρχαιομετρικής Εταιρείας*, 4, *Σύνδεση Αρχαιομετρίας και Αρχαιολογίας* (Athens, 1992), 79–93. C. Domergue comments on my opinion about the cleaning of the ore by the use of clay basins in his article, 'Remarques sur le fonctionnement des laveries planes du Laurium', *Αργυρίτις γη (Χαριστήριον στον Κωνσταντίνο Η. Κονοφάγο)* (Athens, 1998), 39. The writer does not judge the soundness or otherwise of my opinion as regards the metallurgy, but maintains that the find is limited and that such a quantity of pottery perhaps indicates a depository. My reply to his comment is this: (1) as I mention in my paper (p. 86), fragments of clay basins came to light not only in one, but in all the metallurgical workshops I investigated in the Haghia Triadha valley at Souriza; (2) fragments of basins are visible on the surface in nearly all the ruins of the hitherto unexcavated metallurgical workshops in the Lavrion region during the Classical period; and (3) fragments of basins have been found

in all the excavations of workshops of this period carried out by Greek and foreign archaeologists over the last decades. Today these fragments, together with the other finds, are in the Lavrion Archaeological Museum. For a reconstruction of the method of cleaning the ore using clay basins, see E. C. Kakavoyannis, 'Η εξέλιξη του ορθογωνίου πλυντηρίου μεταλλεύματος Τύπου Ι της Λαυρεωτικής', in *Πρακτικά Α' Διεθνούς Συνεδρίου Αρχαίας Ελληνικής Τεχνολογίας* (Θεσσαλονίκη 4–7 Σεπτεμβρίου, 1997), 88, fig. 2.

¹⁶ Aesch., *Persians* 237–8.

¹⁷ K. Konophagos, 'Η εξέλιξη της αρχαίας ελληνικής τεχνικής εμπλουτισμού των μεταλλευμάτων στο Λαύριο', in *Πρακτικά του Πρώτου Σεμιναρίου Αρχαιομετρίας 'Σκωρίες της Αρχαίας Ελληνικής Μεταλλουργίας'* (Ινστιτούτον Γεωλογικών και Μεταλλευτικών Ερευνών; Athens, 1985), 21 f.

¹⁸ E. C. Kakavoyannis, 'Αρχαιολογικές έρευνες στην Λαυρεωτική για την ανακάλυψη μεταλλευτικών έργων και μεταλλουργικών εγκαταστάσεων των προ-κλασσικών χρόνων', *ΑΔΑ* 22 (1989), 71–88.

technological invention was directly linked to the use of abundant water, in the beginning the ore cleaning would surely have been carried out where there was plenty of water: beside a spring, rivulet or stream, or even a copious well. Since the Lavrion region is virtually waterless and wells with water were rare, the likely localities were relatively few. We therefore began by investigating the large valleys in the region, which according to clear geological indications, even in their present-day condition, once probably possessed considerable water.¹⁹ In a very short time our survey produced scarcely hoped-for results, which were briefly as follows:

From the southern edge of the commune of Kamariza or Ayios Konstantinos a small valley runs in the direction of Megala Pevka (FIG. 2). This is the Bertseko Valley, which has rocky sides and is traversed during the winter months by a small rivulet, giving it thick vegetation (FIG. 3). On examining it, we could see along its margins some curious cuttings and hollows (FIG. 4), which certainly did not belong to quarries. To understand better what it was about, we cleaned some of them and to our great surprise found that they belonged to ore-washeries (FIGS. 5–6), which were in fact earlier than any we had hitherto come across in the Lavrion region. Their chief features were:

- (i) They were all entirely cut into the rock and not built.
- (ii) Their surfaces did not as a rule possess a facing of hydraulic plaster, like those of the Classical period, nor any other kind.
- (iii) Their channels and settling tanks had no definite number or particular positions in the body of the washery.²⁰ They were all rather irregular (FIGS. 7–8) and clearly showed that their constructors were still at the stage of searching and experimentation, obviously in order to find the best shape and operating method for the construction, elements we see already existing in washeries of the Classical period.

Because of their shape, I think there is no doubt that the Bertseko Valley washeries were forerunners of the Classical washeries. Our excavation was of course very limited in extent, but from the poor pottery fragments recovered and other indications, these washeries appear to belong to the end of the sixth or beginning of the fifth century BC.

Also striking is the number of the washeries. The Bertseko Valley is over 1 km in length. As the numerous cuttings along both its margins show, the washeries were densely packed, in many cases less than 1 m apart (FIG. 9); and when there was no more room, the washeries extended in two and sometimes three rows parallel to the edge, so that it is easy to calculate their total number. Here we find preserved unquestionably one of the largest ore-processing workshop sites of the Athenians. Since there are no open-air or underground water cisterns in the surrounding area,²¹ as there are in the rest of the Lavrion region, it is clear that the owners of the washeries procured the water necessary for their operation from the rivulet flowing beside them in the valley. In many cases there was a well 2–3 m deep, and thus a little deeper than the valley floor (FIG. 6), between two or three adjacent washeries in the upper row, or one beside each of them. These wells penetrated the subterranean aquifers of the valley and enabled the metallurgists to draw the necessary water from them and thus avoid carrying it up from the valley bottom to each of the washeries.

¹⁹ The existence in the Lavrion region of geological folds in which there was permanent flowing water is also indirectly attested by what are called Poletai Inscriptions. They contain lists of mines, which the Demos leased out to entrepreneurs to exploit, and in one of them the boundary of

the mine being leased is given as ‘. . . the flume flowing from Nape . . .’ (see M. L. Langdon, ‘Poletai records’, in *The Athenian Agora*, xix (Princeton, NJ, 1991), 123, no. P29, line 10.

²⁰ Kakavoyannis (n. 15), 89 f., figs. 3–8.

²¹ Konophagos, 252 f.

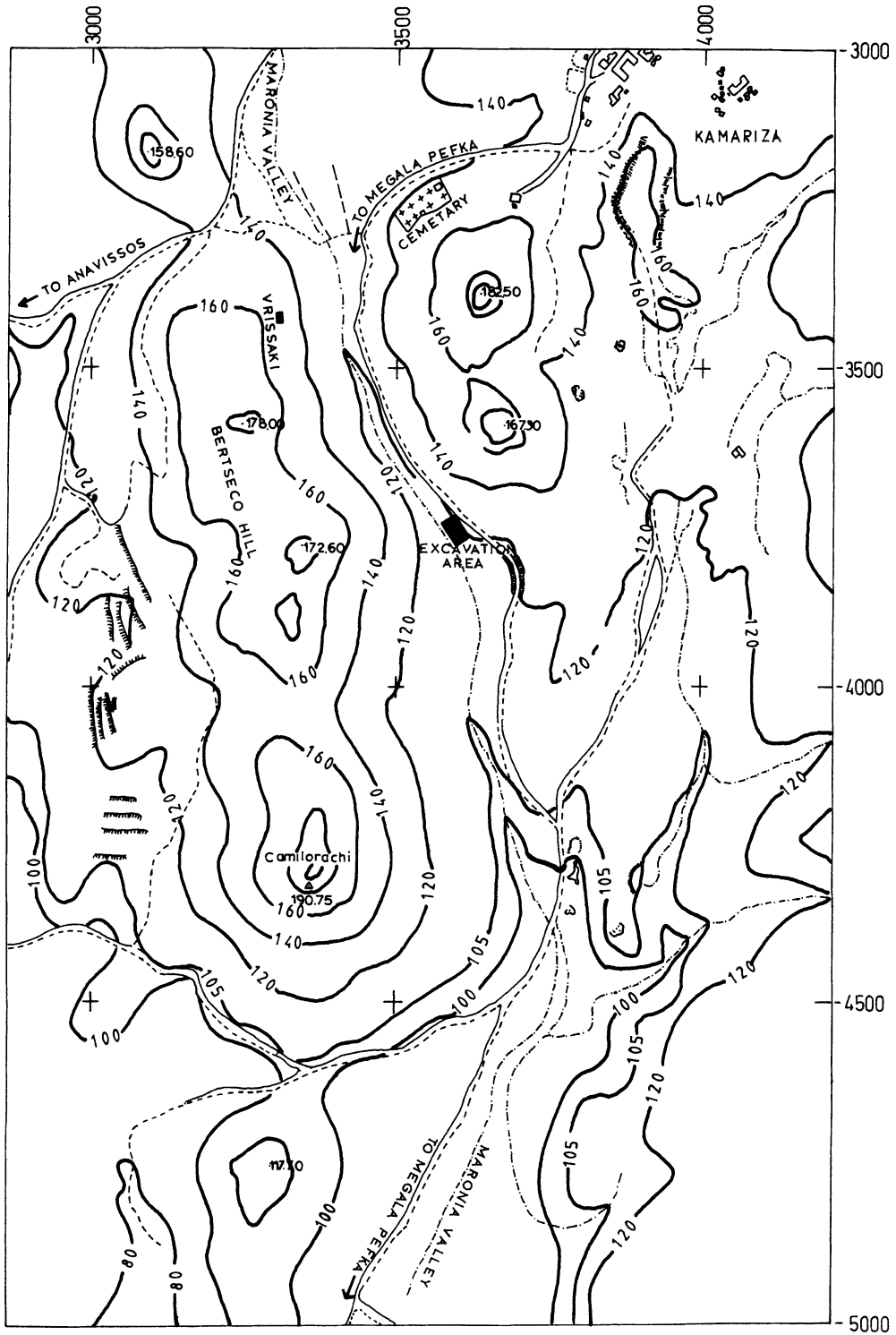


FIG. 2. Section of a map of the Lavrion region with the Bertseko Valley and adjacent district. The black rectangle indicates the site of the excavation.



FIG. 3. Part of the Bertseko valley. View from south.



FIG. 4. Cuttings in the east side of the Bertseko Valley belonging to an ore washery.



FIG. 5. Washery cut into the rock on the east side of the Bertseko Valley (washery no. 7). View from north.



FIG. 6. Washery cut into the rock on the east side of the Bertseko Valley (washery no. 9). View from east.

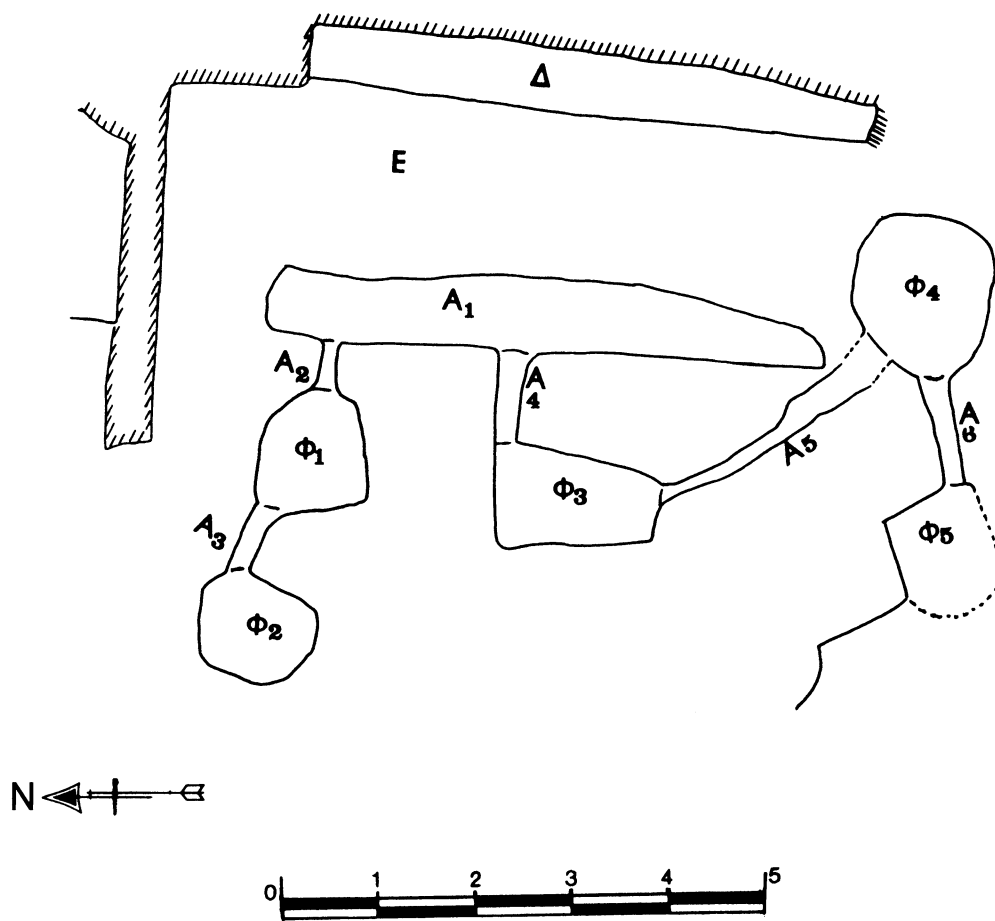


FIG. 7. Plan of the washery in FIG. 5.

In spite of their limited scope to date, the excavations in the Bertseko Valley allow of certain provisional but nevertheless trustworthy conclusions:

- (i) Washeries had begun to be used in the Lavrion area by at least the beginning of the fifth century BC, if not a little earlier, which meant that to the two production stages in the processing of silver and lead another was added, that of processing and cleaning the ore by the use of water. This stage had not existed previously.
- (ii) Because of the new technology, all the people occupied with the production of silver in the region established themselves beside this natural source of water to process their ores. Similar installations probably existed in other parts of the Lavrion area, for example at Thorikos²² and Demoliaki,²³ where there were probably also rivulets or streams.

²² R. Paepe, 'Geomorphic surfaces and quaternary deposits of the Adami area (S.-E. Attica)', *Thorikos*, 4 (1966-7), 7 f.

²³ H. Mussche and C. Conophagos, 'Ore-washing establishment and furnaces at Megala Pevka and Demoliaki', *Thorikos*, 6 (1969), 61 f.

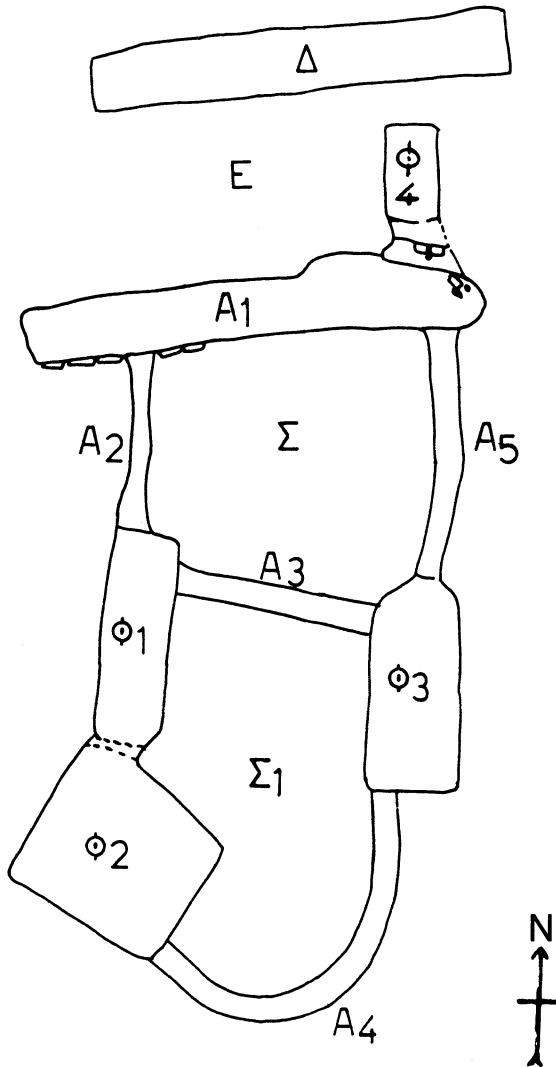


FIG. 8. Plan of the washery in FIG. 6.

(iii) The installations in the Bertseko Valley were surely the first forms of the fine Classical ore-processing *ergasteria* that we encounter later on throughout the Lavrion region. The washery was the chief feature of the latter, but how did the change from the one to the other come about?

The ore-washeries, as we have seen, multiplied the number of exploitable deposits in the Lavrion area from as soon as they first appeared. In particular, after the organization of the

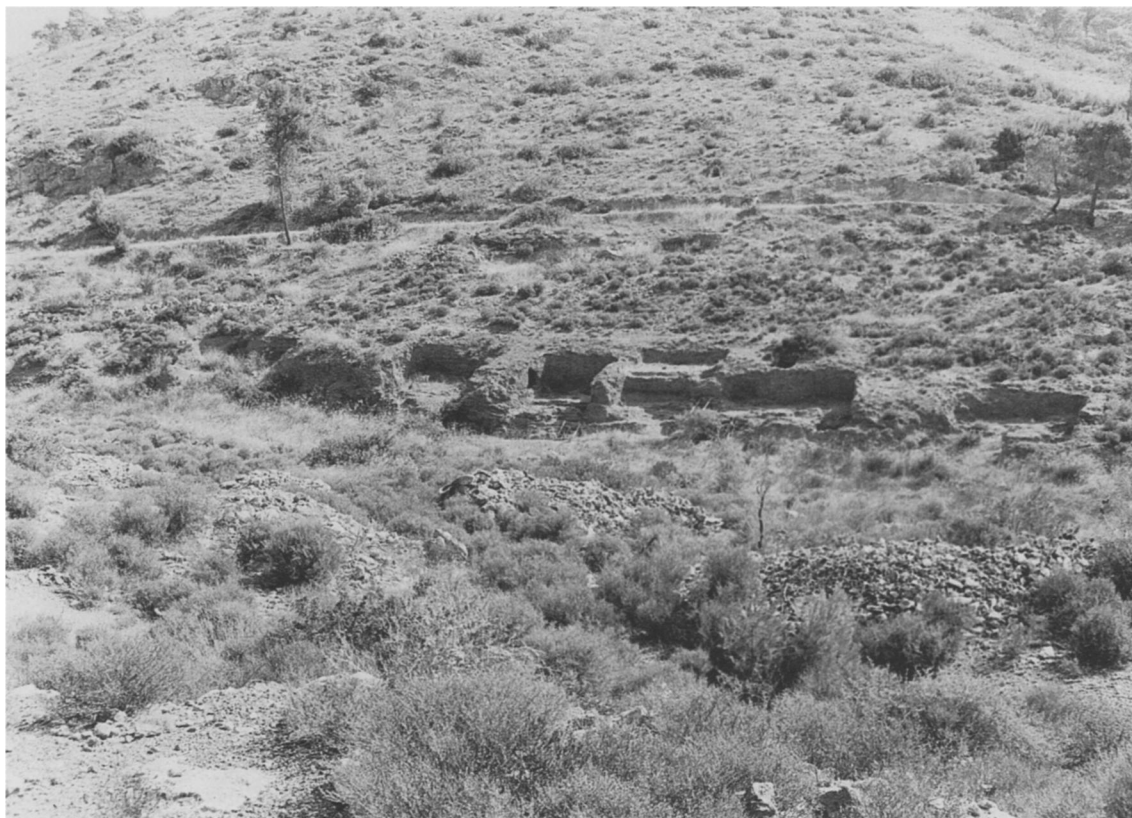


FIG. 9. Washeries cut into the rock along the east bank of the Bertseko Valley. View from west.

exploitation of the Attic silver mines implemented by the Athenian democracy,²⁴ many Athenians became engaged in silver production, for the discovery of exploitable argentiferous deposits was no longer difficult and offered the possibility of large profits. The great increase in the number of miners attested by the concentration of washeries in the Bertseko Valley posed a serious problem due to the fact that there were so many washeries and the water in the rivulet was no longer sufficient for their needs. The same thing must have occurred wherever there were similar concentrations of ore-washeries. To cope with the shortage of water, the miners conceived of a new, equally important device, which made it possible for the washeries to function irrespective of the existence or not of nearby streams, wells, etc. Thenceforth, instead of setting up their workshops beside natural sources of water, which were in any case few and poor, they now built them wherever they wanted, with the difference that at each of them they constructed a usually large, and sometimes huge, open-air water cistern in which they collected rainwater for use in supplying the washery throughout the year. As a rule the washery and large cistern were constructed beside each other.

²⁴ E. C. Kakavoyannis, *Μέταλλα συγκεχωρημένα: η οργάνωση της εκμετάλλευσης του ορυκτού πλούτου της*

Λαυρεωτικής από την Αθηναϊκή Δημοκρατία (doctoral thesis, in press).

This elimination of the need for springs or natural flows of water had a beneficial effect on production. The mines were located in different localities in the Lavrion region, and to clean the ore the miners had previously to transport it from the mine to where there was water over distances that were sometimes considerable. After the new invention they could build their workshops almost beside the mine, thus freeing themselves from the labour, time and cost of transporting the mined material long distances.

The addition of a large open-air cistern for rainwater beside the washery made the rapid development of the ore-processing *ergasterion* possible. From then on it was able to evolve in complete freedom of space and to acquire in time all the means and structures necessary for its operation, such as tables for crushing the ore, mills for grinding it, buildings for storing the products, places for dumping the waste material, dwellings for the permanent housing of the personnel and also sometimes of the owner,²⁵ underground cisterns for drinking water²⁶ and much else. As a result the ore-processing *ergasterion* now became the administrative centre of every mining enterprise, since for obvious reasons those in charge of the mining operations lived there and it provided lodging for the slaves who worked in the mines as well as their tools. The *ergasterion* also served to house the mining personnel. Further, it made no sense for the slaves to stay for long periods in the underground mines of the Lavrion region, for this would have meant their rapid demise and thus caused the enterprise considerable economic loss.

The archaeological finds show that women and children, whole families in fact, also lived at the *ergasteria*,²⁷ and it is apparent that these came to form small households. The inhabitants of each of them, among other things, probably practised agriculture and animal husbandry in the surrounding area, for this would have helped to feed them; and they would also have bred the pack animals they used to transport the ore and for their own needs, as well as for moving people over long distances. In time a cemetery grew up at each *ergasterion*, usually comprising a *peribolos*,²⁸ evidently for the burial of members of the owner's family, and scattered graves around the *peribolos*, belonging to members of the blue-collar personnel of the enterprise.²⁹

In districts where many mines were in operation due to the presence of important deposits, many ore-processing *ergasteria* grew up at the same time; they often bounded on each other.³⁰ The co-existence of many *ergasteria* in one place essentially created a considerable habitation centre in the Lavrion region; similar centres, to judge by the surviving surface ruins, seem to have grown up at Aghia Triadha, Agrileza, Megala Pevka, Demoliaki and elsewhere. Each *ergasterion* was always associated with a mine, but as a rule the first one had a much longer life than the second. We know that the mines were leased for a term of only three or seven years, according to their category.³¹ At the end of the three or seven years the lessee could

²⁵ I. Tsaimou, 'Ο ανδρώνας του "πλυντηρίου του Σίμου" στην Σούριζα της Λαυρεωτικής', *AAA* 12 (1979), 15 f.

²⁶ A. Liagouras and E. Kakavoyannis, 'Ευρήματα Λαυρεωτικής', *AAA* 9 (1976), 27 f., figs. 2–4, drawing 3; Konophagos, 386 f.; J. Ellis Jones, 'Laurion: Agrileza 1977–1983: excavations at a silver mine site', *AR* (1984–5; no. 31), 120, fig. 34.

²⁷ Their permanent presence at the *ergasteria* is confirmed by excavations, which have revealed pyxides, childrens' toys, and other things. There are also women's graves in the cemeteries that were close to the *ergasteria* and clearly belonged to them.

²⁸ On burial enclosures evidently associated with the mines and metallurgical workshops, see R. Garland, 'A first

catalogue of Attic *peribolos* tombs', *BSA* 77 (1982), 125 f.; O. Kakavoyanni, 'Σούνιο: θέση Πύργος της Βασιλοπούλας', *A. Delt.* 44 (1989), Chr. 83 f.; E. C. Kakavoyannis, *A. Delt.* 38 (1983), Chr., 55, pls. 26 g, 27 a–b.

²⁹ Kakavoyannis, *ibid.* 55.

³⁰ M. Petropoulakou and E. Pentazos, 'Αττική: οικιστικά στοιχεία—πρώτη έκθεση ("Εκδοση: Ἀθηναϊκός Τεχνολογικός Ὀμιλος—Ἀθηναϊκὸ Κέντρο Οἰκιστικῆς Ἀρχαίης Ἑλληνικῆς Πόλις, 21; Athens, 1973), addendum 1, fig. 30.

³¹ M. Crosby, 'The leases of the Laureion mines', *Hesp.* 19 (1950), 196 f.

³² Konophagos, 389, no. 2.

renew the lease, if the price set by the state suited him. Sooner or later, however, the mine would cease to operate after the deposits, which were not unlimited, were exhausted. When the particular mine closed, the entrepreneur did not abandon his ergasterion, since it represented a large financial investment and was a fully operational production unit. He made sure to lease in time another mine in the same or a different locality and to continue his enterprise, since it was not easy to set up another ergasterion at any time or place simply at will. In this way each ergasterion, although originally attached to a mine close by, later came to serve mines much further away.

In many instances an ergasterion might continue to operate without being attached to a particular mine. When, for instance, its owner no longer found enough ore in his mine, he could interrupt his mine leasing and confine himself to his ergasterion, where for a fee he cleaned the ores of others. The latter were small businessmen who did not have their own ergasterion and whom it did not pay to build one owing to their small production. There were considerable numbers of these, and we are told by an inscription that the fee they paid to the ergasterion owner for this work was called ἀπέργαστρα.³² In this way certain ergasteria developed into specialized units which afforded many people the possibility of engaging in a mining business even though they did not have large financial means to start with. That the ergasteria were able to operate independently of any particular mine is clear from the fact that their owners sometimes mortgaged them together with their blue-collar personnel in order to take out a loan. Inscriptions detailing the terms of the mortgage of an 'ergasterion and its slaves' have been found in considerable numbers in the Lavrion region.³³

On the basis of what we have said we can now, I think, form a rough idea of the origin and basic evolution of the ore-processing ergasteria for the argentiferous ore in the Lavrion region in Classical times, and also evaluate the great importance their study offers for an understanding of their operation and of the metal production of the Attic silver mines. The ergasteria, which differed greatly in size, were scattered throughout the Lavrion region, chiefly in localities where the substratum contained considerable argentiferous deposits and mines were opened up. Their number is striking and leads us to valid hypotheses about both the extent and organisation of the mining and metallurgical work of the Classical Athenians and the volume of the relevant production.

In spite of their manifold scientific value, excavations of metal-workshops are still at an early stage. Some, like those by the Belgian Archaeological School in what is called the Thorikos Industrial Quarter,³⁴ by P. Zoridis in Koilada Potami,³⁵ by K. Konophagos at Souriza,³⁶ and by the author³⁷ at Haghia Triadha, the Greek Arms Factory, and Spitharopousi, have produced very interesting finds, but the most important to date is that of Mr Ellis Jones at Agrileza.³⁸ This is a fine example of an ore-processing ergasterion (FIG. 10), the study of which has much to teach us. Jones, in a recent article,³⁹ has also produced a study of the types of ergasteria as well as what is found in them.

³² *IG* ii². 2747, 2748; cf. J. Ellis Jones and S. D. Lambert, 'Two security horoi from an ore-washery at Agrileza, southern Attica', *ZPE* 125 (1999), 131 f.

³⁴ H. Mussche, *Thorikos: eine Führung durch die Ausgrabungen* (Ghent and Nürnberg, 1978), 57 f.

³⁵ P. Zoridis, 'Εργαστήριο εμπλουτισμοῦ μεταλλεύματος στὸ Θορικὸ', *Arch. Eph.* 1980, 75 f.

³⁶ Konophagos, 375 f.

³⁷ E. C. Kakavoyannis, 'Ἀκυρωτική', *A. Delt* 38 (1983), Chr. 54–7 and 39 (1984), Chr. 49–55.

³⁸ Ellis Jones (n. 26), 106 f.

³⁹ J. Ellis Jones, 'The planning and construction of Attic ergasteria', *Bautechnik der Antike: Internationales Kolloquium in Berlin vom 15–17. Februar 1990 veranstaltet vom Architekturreferat des DAI in Zusammenarbeit mit dem Seminar für klassische Archäologie der Freien Universität Berlin* (Mainz am Rhein, 1991), 107 f.

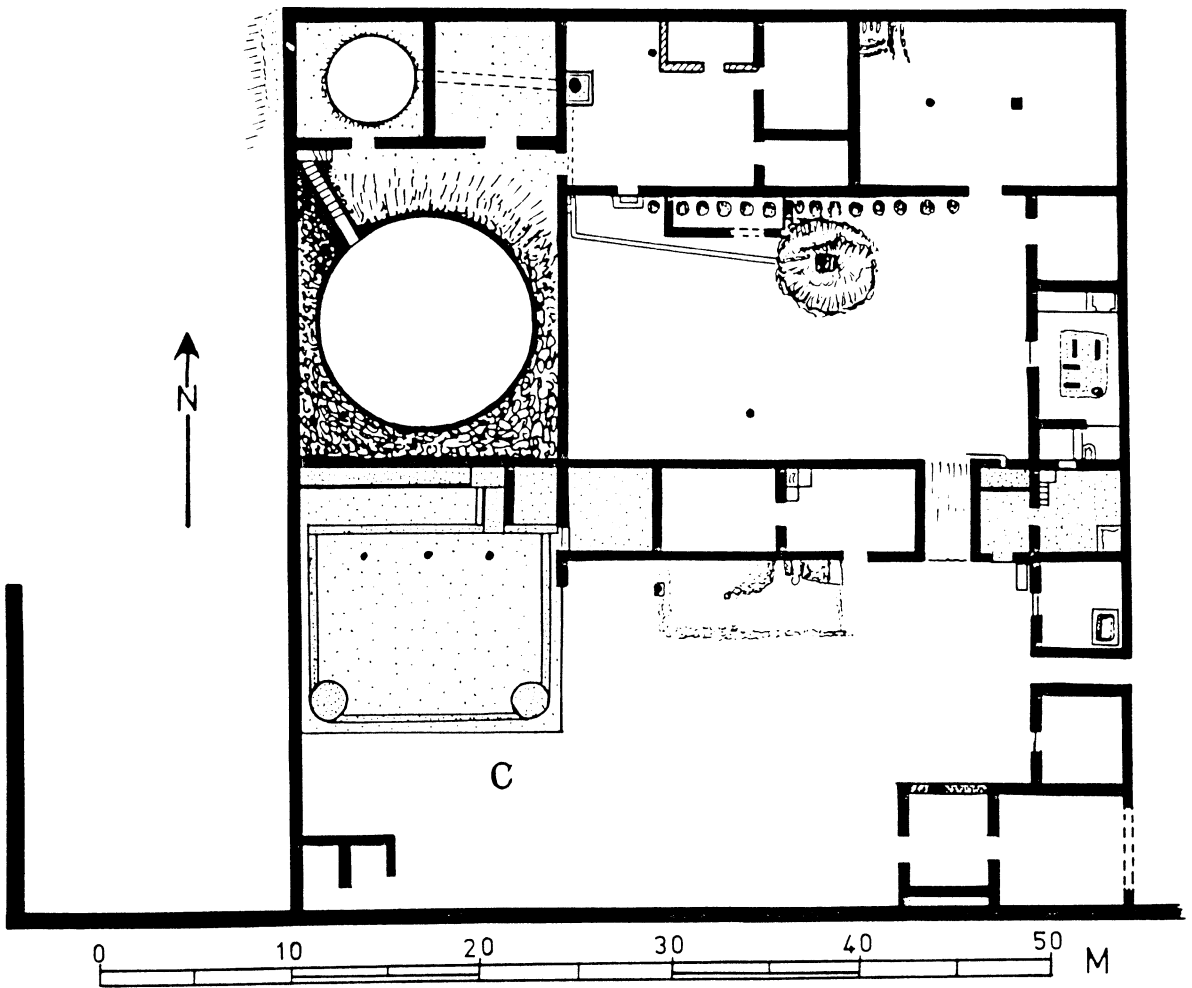


FIG. 10. Plan of the ore-processing ergasterion at Vouno Michali at Agrileza.

A few years ago we discovered and began a careful excavation of another, very large, similar ergasterion,⁴⁰ virtually matching that of Agrileza. It is located on the west side of the same valley and roughly opposite the latter; to distinguish it from the others, we named it the Kordellas Ergasterion, in honour of the pioneer investigator of the ancient mines of the Lavrion region, Andreas Kordellas.⁴¹ The Kordellas ergasterion has a fine open-air cistern with internal steps (FIG. 11), a large tank in front, also with internal steps, a rectangular washery of Type II,⁴² and special places for crushing and grinding the ore. It is divided into

⁴⁰ E. C. Kakavoyannis, 'Λαυρεωτική: το αρχαίο μεταλλουργικό εργαστήριο Α στο Σπιθαροπούσι', *A. Delt.* 50 (1955), Chr. 61 f., pl. 26 b-d.

⁴¹ K. Vovolinis, *Μέγα Ελληνικὸν Βιογραφικὸν Λεξικόν*

(Athens, 1958), ii. 44, s.n.: Κορδέλλας Ανδρέας.

⁴² E. C. Kakavoyannis, 'Περὶ τοῦ "Τύπου II" των αρχαίων ορθογωνίων πλυντηρίων των μεταλλευμάτων της Λαυρεωτικής', *A. Delt.* 44-6 (1989-91), Mel. 1 f.



FIG. 11. East side of the large cistern of the Kordellas Ergasterion. View from west.



FIG. 12. Ruins of the west wing of the Kordellas Ergasterion at Spitharopousi, right after the deforestation of the terrain from east.

two parts, of which the eastern contains the work places and the western living quarters (FIG. 12). The finds point to a date in the fourth century BC, but it clearly had preceding phases.

Research into ore-processing *ergasteria* is of great wider importance. They were the principal means of exploiting the resources of the Lavrion region. In organizing their exploitation the Classical Athenians endeavoured to develop this natural resource to the fullest extent for the enrichment of their homeland and in this, as we know, they succeeded admirably. The investigation of these ore-working installations will without doubt help us to a better understanding not only of the operation of the Attic silver mines, but also of the economy, technology, society and history of the great Athenian democracy.

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