

Bronze Age Mining Round the Aegean*

By O. DAVIES

DURING the bronze age, Greece was remarkably wealthy in gold; though the most sensational finds have been those of Mycenæ, there is little doubt from the amount that has been turned up elsewhere that the contents of the shaft-graves only represent a small portion of the gold that was at one time available. Homer still has many lines reminiscent of the riches of Mycenæ, but seems no longer to be living himself in times of such plenty, and thus many of the gold objects which he describes are said to have been of foreign workmanship. In the early iron age gold was even rarer, as is seen by the astonishment of the Greeks at the regal wealth of a man like Cræsus. One may therefore ask oneself what happened to all the gold, seeing that only some of it seems to have been laid in tombs, and it is not possible for it to be destroyed by rust. Some may have been carried off by pirates, but if we look to the history of the period of reconstruction at the beginning of the iron age, we find two figures noted for their wealth, Midas in Phrygia and Solomon in Palestine; to Solomon may have gone some of the Aegean gold, brought originally to the Levant by the sea-raiders of the twelfth century B.C. or by Phœnician traders; and it is not unlikely that Midas made a good profit by selling to the Greeks the new metal iron before they had learnt to produce it for themselves, though it is probable that he also had gold mines of his own.

It is more difficult to decide where the Aegean peoples obtained their gold. The test by chemical impurities is unsatisfactory owing to the fact that gold, unlike copper, does not have characteristic impurities which are found in one mine but not in others. All the Aegean gold which has been analysed contains a good deal of silver, in amounts varying from 8 to 25 per cent, which suggests the use of native electrum; though some of the early gold, as the early bronze age pieces from Mochlos and Leucas, is of very good colour, there is no record of pure gold having been found in analysis, and in Egypt at least it is certain that the knowledge of purifying gold did not come in until later, probably at the time of the Persian invasion, while Cræsus probably started it in Lydia. On the whole, the late bronze age gold from the Aegean varies in colour, the more massive pieces being yellower than the leaf, which suggests that some method of faking the surface by dissolving the silver was already known, though it was not practicable for thin leaf.

As to mines, Macedonia seems to have been working a little stream gold from early times, as is seen by gold slags found on various sites. Herodotus¹ mentions the gold and silver mines of Siphnos in the seventh century, which were probably at H. Sosti; I have been told that two

golden eggs were found here, ready to be sent as an offering to Delphi, but as they have now been lost this story must be considered doubtful. At any rate, stone hammers have been found in and above the mine, and I found a sherd which seemed to belong to some local sixth century ware, and a number of crucibles. Bronze age sherds, however, have not been found, and there are not many relics of the later bronze age on the island, so that it is probable that gold was not worked here until the iron age and that we shall not find here the source of the gold of Crete and Mycenæ.

To some extent probably local sources, which have since been exhausted, were used in the bronze age; for example, some gold objects have been found in Arcadia, not far from the placer of Doliana. Egypt produced much gold early, and, as there was frequent contact between it and the Aegean, gold may have been one of the articles of commerce. The placers of west Anatolia, especially Lydia, were probably not tapped much before the iron age, considering their wealth and reputation in later times. It may even be that the Danube valley was supplying Greece so early; it has been claimed that some gold found in Egypt came from Transylvania owing to the presence of tellurium*; and though the inference is not certain, since telluride of gold is reported from Andros, yet as there was for a long time a trade route from Egypt and Syria to the Danube, such a source is by no means unlikely.

The early bronze age objects of silver from Amorgos which have been analysed contain much gold and more copper than should remain in the metal after cupelling; they are probably therefore derived from native silver or a silver mineral. But a bar from Troy II and a vase from Mycenæ shaft-graves with a good deal of copper and some lead may have been cupelled badly or debased after cupellation.† The lead found is remarkably pure and almost free of silver, which makes it likely that it is derived from a mineral containing very little silver.

The Laurium mines perhaps were not opened before the seventh or sixth century; nor did they become prosperous until the discovery of the rich lower zone of mineralisation at the beginning of the fifth.² On Mytilene, at Argeno 1½ hours east of Molyvo, are old silver workings in which I found pieces of a black bucchero pot of the seventh or sixth century, now in the Ashmolean Museum. On Kuphonisia have been found some ancient mines for argentiferous lead with stone tools,

* The antimony in this gold which was held to prove the presence of tellurium may be an early and sporadic instance of the use of stibnite for de-silvering, a technique otherwise thought to be medieval.

† The presence of a little lead in silver is no convincing proof that cupellation had been practised; cf. Friend and Thorneycroft, *J. Inst. Metals*, 41, 105, 1929, who do not believe that cupelling was known in Greece so late as the seventh century; only the knowledge of cupellation must precede that of liquation, which probably accounts for the large quantities of lead found in the iron age *aes rude* in Italy.

* From a paper read before Section H (Anthropology) of the British Association on Sept. 7.

which may therefore be quite early, though the use of stone hammers is not confined to the bronze age.³

Other early silver mines are not known in the Aegean⁴ nor is silver common early in Egypt, but there is much in Anatolia. The date of the old mines near Hector's grave in the Trojan Plain⁵ is exceedingly doubtful. Balia was perhaps working early, but the mention in an alchemical author of silver from Adramyttium suggests rather a late date. Silver mines are known at Myndus, but classical writers are silent about them, and the modern name Gümüşlü suggests that they are Byzantine or medieval.⁶

Farther east, there is certainly very early silver mining in Taurus at either Bulgar or Bereketli Ma'den; the Kara Öyük tablets mention the export of silver from this region in the third millennium. In Homer⁷ we read of Halybe as the birthplace of silver; this seems to be located on the eastward land route from Troy along the southern shore of the Black Sea. Such data as we have would point either to the Taurus mines, reached by a road which followed the coast to perhaps the Halys mouth and then turned inland, or to the mines of argentiferous copper behind Tireboli, which are certainly Greek though it is not known how much earlier they go. Again, the story of the golden fleece⁸ in Colchis suggests early mining activity in the south-eastern corner of the Black Sea.

The copper of the early bronze age in Crete and the Cyclades seems to be almost entirely free of nickel but usually contains small quantities of lead, arsenic and antimony, while arsenic is sometimes added to colour the surface. These characteristics remain, on the whole, constant throughout the bronze age in Crete, but so far as one can judge from the scanty analyses of mainland objects, the metal contains only lead, arsenic and antimony being rare impurities.

Of the ores which have been analysed, that from Chrysokamino near Pachiammo was not tested for impurities, while that from Gavdos is incomplete but seems to contain about the right amount of antimony and arsenic. The Othrys ores have no nickel and contain little if any antimony and arsenic, though most have a small quantity of lead.

If we compare Aegean copper with that of neighbouring regions in the bronze age, we find that the Italian and Anatolian seem to correspond most closely to it. Analyses of ores from these regions are rare; that from Boccheggiano seems to contain rather too much silver, bismuth and nickel but otherwise agrees fairly well. The ore from Sacili in Macedonia is very similar to Aegean copper, but the mine is small, and I do not think it possible that it can have supplied the whole Aegean for fifteen hundred years; Othrys might also suit. On the whole, the analyses seem to show a constant source for copper in Crete throughout the bronze age, though the mainland copper is more variable and occasionally contains nickel.

We shall see that it is probable that the mainlanders exploited a number of local mines of small importance, so that the compositions of their metal are likely to vary considerably.

To turn to the sites of mines known, I have found in the early bronze age stratum at Volo some copper slag, which I have described elsewhere. The numerous copper mines of Othrys were being worked in Hellenistic times, and for most of them there is no earlier evidence, while prehistoric sites in this area are infrequent; but some bronze double axes and celts were found in a mine at Gardiki⁹. Further, the hoard of ingots shipwrecked at Cyme might suggest the transport of copper from the mines of Othrys to southern Greece rather than the other way, it being by no means certain that these quadrangular ingots come from Cyprus. But it is difficult to say how important Othrys was in prehistoric times as a centre for copper production.

There is a persistent tradition in the ancient authors of a mine of copper and iron at Chalcis, and of an early metal industry there. One can scarcely believe that these stories are a mere invention due to the name of the town, though modern travellers have been unable to locate the mine. I have searched the territory of Chalcis thoroughly, without success; but the most likely locality is in the serpentine ridge just behind the town, which is now partly built over, and in which the mines would have soon been inundated if they had reached any depth. I have found stray pieces of copper slag to the south-east of the town; but the fact that no slag heaps of any size are known makes it probable that the mine was small and only working for a short period.

At Athens I have found pieces of copper slag on the slopes of the Acropolis, with a fragment of crucible which is perhaps early or middle bronze age. This probably comes from the working of some very small deposit; for example, malachite is reported at Colonus and on Ardetus, but the extent of the modern town makes adequate exploration of these sites now impossible.

At Mycenæ, apparently in late bronze age levels, copper slag has been found, and there is in the Athens Museum a tray of malachite galena and sulphur, which was found during Tsoundas' excavations here; unfortunately, it is not recorded where he found it. On both sides of the pass from Mycenæ to Phlius is a little copper ore; I could not find signs of ancient working, but a small opencast might easily be denuded completely or a shaft be filled in. Just above the deposit is a site with rough sherds which looked like early iron age ware. Other mines are reported behind Mycenæ; on the path to the Heraeum are several caves, one of which seemed to have been cut out with a pick, though whether as a mine or shelter I could not tell, while in another was a slight stain of malachite in the conglomerate. This information is at present unsatisfactory, but it is not unlikely that Mycenæ was an important centre of copper working during part of the bronze age.

On Seriphos there is much copper slag and a number of galleries in the iron mine which may have been seeking veins of copper; such rejection of the iron ore might point to early working, though there is some evidence that mining was being practised here in the later centuries B.C.

On Paros, copper slag was found in an early bronze age tomb at Abyssos. Near Naussa is a small mine of malachite, much overgrown, with a gallery leading off at each end; all the ore had been removed, as is usual in prehistoric mines; but otherwise the evidence for its early date is weak.

On the early bronze age acropolis of Syra a piece of copper slag was found.

The cave of Chrysokamino has yielded early and middle bronze age pottery, and was probably a copper mine, though all the ore has been extracted; slag, burnt clay and pieces of perforated crucible have been found outside. Gournia nearby was probably a manufacturing centre, considering how many moulds it contained, but Chrysokamino is too small to have supplied the whole of Crete with copper during the bronze age.

The copper mines of western Crete which are claimed as prehistoric were opened in Hellenistic times and continued until the Middle Ages. Much

copper ore is also reported from Gavdos, but there is no reliable information as to when it was worked.

As to more distant sources, the direct evidence for bronze age mining in Cyprus is not strong, and it must be considered doubtful if the island supplied copper to the Aegean so early. The mines of Sinai are doubtful, the ore being apparently always poor, and it is likely that such copper as was produced was largely absorbed by the Bedouins, save at the times of Egyptian expeditions. The Kara Öyük tablets mention copper as an object of trade, but it is not common in western Anatolia. Italy seems to have been working copper sporadically from early times, and the Homeric Temesa is probably to be sought in this direction, whether Etruscan or south Italian ores were used. Largely, however, the Greeks seem to have used small local deposits which they completely exhausted.

¹ Herodotus, 3, 57; cf. Bent, *J. Hellenic Studies*, 6, 195.

² Cf. Ardailon, "Le Laurium"; also Davies, *Mon.*, 6, 1931.

³ Stephanos, *Cong. int. Archéologie*, I, Athens, 216; 1905.

⁴ For Siphnos see above.

⁵ Freise, *Z. Berg. Hütten. und Salinenwesen im preuss. Staat*, 56, 347; 1908.

⁶ Paton and Myres, *Geog. J.*, 9, 38; 1897.

⁷ "Iliad", II, 856.

⁸ Bosanquet, *Rep. Brit. Ass. Adv. Sci.*, 722, 1904. Athens Nat. Mus., Inventory No. 12445.

Electrical and Magnetic Units

THE British Association has done a great service to the electrical industry by fostering the study of electrical standards and it was with considerable interest that Section A listened to two papers given by Sir Richard Glazebrook at the recent York meeting. Sir Richard has been an active member of the British Association committee on electrical standards which has laboured for a period of fifty years. In 1913 a single volume edited by Sir Frank Smith was published, giving the complete series of thirty-nine reports. Sir Richard was present at the York meeting in 1881 when Section A met at the same centre—St. Peter's School—and received the eighth interim report of the committee for constructing and issuing practical standards for use in electrical measurements. One of the papers* presented by him at the recent meeting showed the changes which have taken place in the British Association wire resistance coils over the period of half a century. The conclusion reached is that platinum is the most stable material to use for the construction of standard coils. This paper has already been referred to in NATURE (Oct. 22, 1932) and will be published in full in the Report of the British Association for 1932. The other paper† dealt with a topic which is still under discussion, namely, the definition of electric and magnetic units.

Sir Richard Glazebrook is president of the Com-

mission of the International Union of Pure and Applied Physics which was set up by the General Assembly at Brussels in 1931 to consider the symbols, units and nomenclature used in physics.

The Commission at its first meeting decided that the most urgent problem awaiting solution was the definition of electrical and magnetic magnitudes. The first step taken therefore was to prepare a questionnaire which was circulated to the national committees working under the auspices of the Union of Physics in various countries.

The principal issues raised by this questionnaire related to:

- (1) The basis on which a connected account of electromagnetic phenomena should rest. Should the starting point be Coulomb's law of force between magnetic poles or some other physical law?
- (2) Should μ (the permeability) be treated as a quantity having dimensions in length, mass and time, or as a pure number? In other words, are H , the strength of a magnetic field, and B , the magnetic induction, quantities having different dimensions or are they quantities of the same kind?

The British reply to this questionnaire was agreed to at a meeting held in the rooms of the Royal Society in May last, at which were present, besides the members of the National Committee for Physics, representatives of the British Association Committee dealing with Magnetic Units and British representatives of the International Electrotechnical Commission, which had also been dealing with this matter.

* Material Standards of Resistance: the British Association Coils, 1881-1932. By Sir Richard Glazebrook and Dr. L. Hartshorn.

† Electric and Magnetic Units. International Congress of Electricity, Paris, July, 1932. By Sir Richard Glazebrook and Dr. Ezer Griffiths.