

The iron and copper slags at Baratti, Populonia, Italy

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Abstract

It has been calculated that the slags at Baratti represent a total iron production, between 600 and 100 BC, of up to half a million tonnes. The evidence on which this calculation is based is re-examined. A number of alternative interpretations are put forward, in particular that a significant proportion of the slags are from copper smelting.

Introduction

The Gulf of Baratti, beneath the famous Etruscan town of Populonia, is well known for its remarkable deposits of slag. Some of these slags, in the San Cerbone area, are visible as a series of stratified deposits in an almost vertical cliff up to 3.5m high and extending for some 100m. The beach below the cliff is littered with a large quantity of Elban haematite, slags and other materials eroded from the cliff. Populonia was clearly an important metal production centre during Etruscan and Roman times. There are a number of references to iron-working at Populonia by the Classical writers¹ and the site has long been accepted as one of the most important early iron-production centres in Europe.

At the 1983 conference of the Comité pour la Sidérurgie Ancienne, held at Populonia and Piombino, Olfert Voss presented a paper on the Baratti slags, with a quantification of the iron production they represent and details of earlier reports on these slags (Voss 1988). In 1858 a French mine engineer, L. Simonin, described "a mountain of slags with an average height of 2 metres over a distance of 600 metres along the beach". In the 1920's work by Dompé, Fossa-Mancini and d'Archiardi resulted in an estimate that an area of some 200,000 square metres, 20 hectares, was covered with slag. In places the slag reached a thickness of more than 2m and the total weight of material was estimated to be about 2 million tonnes.

Voss also reports that for many years the slags had been used for roads in the community of Piombino and that from 1915, for a period of some 50 years, the slags were removed for re-smelting in the blast furnaces in Piombino, Portoferraio on Elba, Follonica and as far away as Germany. Slags were also apparently shipped to Belgium and England (Maréchal 1988). Thus, although there is some doubt about the estimate of 2 millions tons, it is no longer possible to check this quantity.

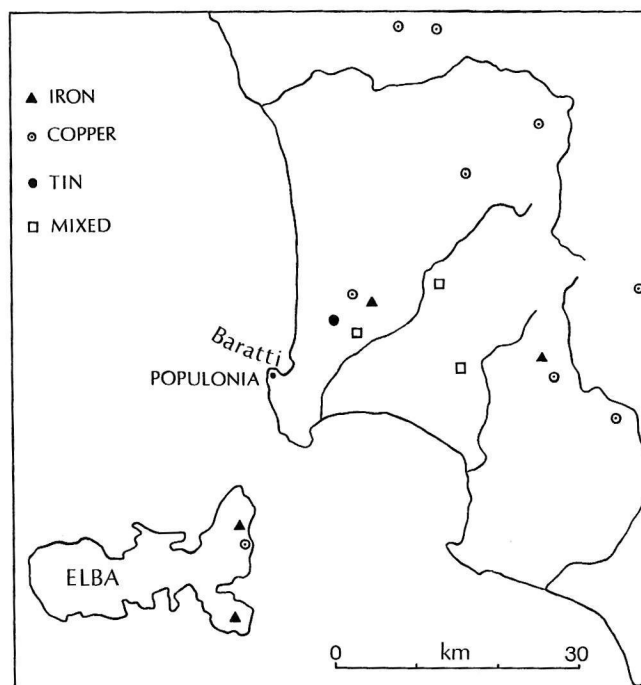


Fig 1: Location map of Populonia, Baratti and Elba, after Sestini 1981.

During regular visits to the Baratti beach Voss has studied these slags and he describes two types. The first type consists of small pieces of slag, normally less than 5cm, which occur in the lower horizons of the cliff and which are now cemented together in layers up to 1.50m in total thickness. These layers also contain charcoal, burnt clay and amounts of iron ore. The second type consists of larger fragments and cakes of tap slag, which occur both in the upper part of the cliff and as stray finds on the beach. It is these slags which appear to have been sorted for the blast furnaces.

Two important radiocarbon dates are also reported. The first is 465 ± 100 BC (K-1409) from charcoal in the basal layer of the type 1 slags. The second date is 170 ± 100 BC (K-4406) from a furnace in the upper layers of the cliff, above the type 1 slags. Both of these dates are calibrated. A convenient sketch of the section and the furnace is published in Tylecote 1987, fig. 5.11.

Slag weight and iron production

Using the 1920's estimate of 2 million tonnes of slag

Voss calculated that this represents a total production of between 300,000 and 500,000 tonnes of sponge iron. By taking the radiocarbon dates at face value, to indicate activity over a 500 year period, the production was calculated to be between 1.5 and 3 tonnes of iron per day.

The original calculations are based on the area of 200,000 square metres being covered in slag to an average depth of 2m, with a mean density of 5 g/cc. Voss applied a coefficient of 0.8, to allow for the stone and burnt clay in the deposits, reducing the slag weight to 1.6 million tonnes. Using the data from Tylecote's 1971 experiments and Danish data from 2nd to 3rd century AD furnaces, slag to iron ratios of 3.2:1 and 5.3:1 were used to calculate the sponge iron production. Voss also calculated that between 2 and 3 million tonnes of charcoal would have been used, requiring between 2 and 6 square km of trees per year. Even allowing for a 60 year cycle of regeneration, over 100 square km would have been affected (Voss 1988, 98).

These estimates for the iron production and its environmental impact are quite remarkable and, despite the limitations of the data available, they deserve further consideration. Voss' argument is based on three main elements; the weight of the slags, the radiocarbon dates and the assumption that the slags are all a result of iron-working. Each of these elements will be examined and number of alternative interpretations and quantifications will be proposed.

Comparative data

There have been only a few attempts to quantify the production from major early iron-working centres and it is perhaps useful at this point to put the Baratti estimates into a wider context. In Sweden, Magnusson (1986, 272–280) has made careful and perhaps conservative estimates for the important prehistoric iron production from Jämtland and Dalarna, giving totals of 3,400 and 2,100 tonnes respectively. These are both very large regions, with abundant resources of both bog iron ore and timber, and with well preserved and well studied iron-working sites.

In Poland, Bielinin (1978, 38) has calculated the total iron production from the large number of Roman period sites in the Holy Cross Mountains to be about 5,400 tonnes. This region was clearly one of Europe's most important early iron-working centres, with some 500,000 slag-pit furnaces and a very well developed technology, smelting high quality haematite ores.

In Britain, Cleere (1976) has estimated the Roman iron production from six of the most important sites in the Weald to be about 89,500 tonnes. The most extensively researched of these sites is the 3 hectare complex at Bardown, which had an estimated total iron production of 4,500 tonnes. The total quantity of slags from all six sites is estimated at some 250,000 tons and the iron

production was arrived at using a slag to metal ratio of 3:1. As will be argued below, this is rather optimistic and a more conservative estimate of the smithed bloom production would be around 40,000 tonnes. This amount of iron was produced over a period of some 200 years and is argued to have required a total of 300 square kilometres of forest, or 1.5 square km per year.

Compared to these regional production figures, the Baratti estimate of up to 500,000 tonnes of iron, from what is essentially a single site, however important, seems too large. At the proposed scale of production and timber use, surely the iron-working would have been broken up into smaller production units and spread over a much wider area with more easily accessible timber resources.

The calculations

The calculations can be refined in a number of ways. The mean density of 5 g/cc, used by the 1920's workers, is too high. A part-smithed iron bloom only has a density of about 5 to 6 g/cc. It is difficult to give an accurate figure for a tap slag, as this depends very much on the porosity of the slag. Generally it varies between about 3 and 4 g/cc and a more acceptable mean density would be 3.5 g/cc (Sperl 1980, 13).

The slag coefficient of 0.8 is also too high. Although it might apply to some of the lower parts of the existing section, the deposits are not consistently slag-rich. Overall probably only about 40% of the cliff deposit is actually slag; the rest being iron ore, charcoal, furnace lining material, large stone from the furnace structures, other settlement debris and a large quantity of earth and small stone.

Finally, the use of the slag weight to calculate sponge iron production is rather misleading, since it is unlikely that sponge iron would have been taken elsewhere for further processing without, at least, some preliminary smithing. If it is assumed that only primary smithing was carried out, this process could account for about 20% of the slags and the resulting part-smithed bloom weight would be about 50% of the raw bloom (Crew 1991, Tables 3, 4). This would give a net iron yield some 60% less than that used by Voss.

Taking these three factors together, the estimated total iron production could be reduced by a factor of 10 to about 50,000 tons. This is, however, still a remarkable quantity of iron from a single site when compared to the regional production figures given above.

The area covered by slags

It is possible that the estimate of 400,000 cubic metres of slag is simply too large. This is an enormous quantity of material, which is rather difficult to visualise. As an illustration, it would mean that a 450

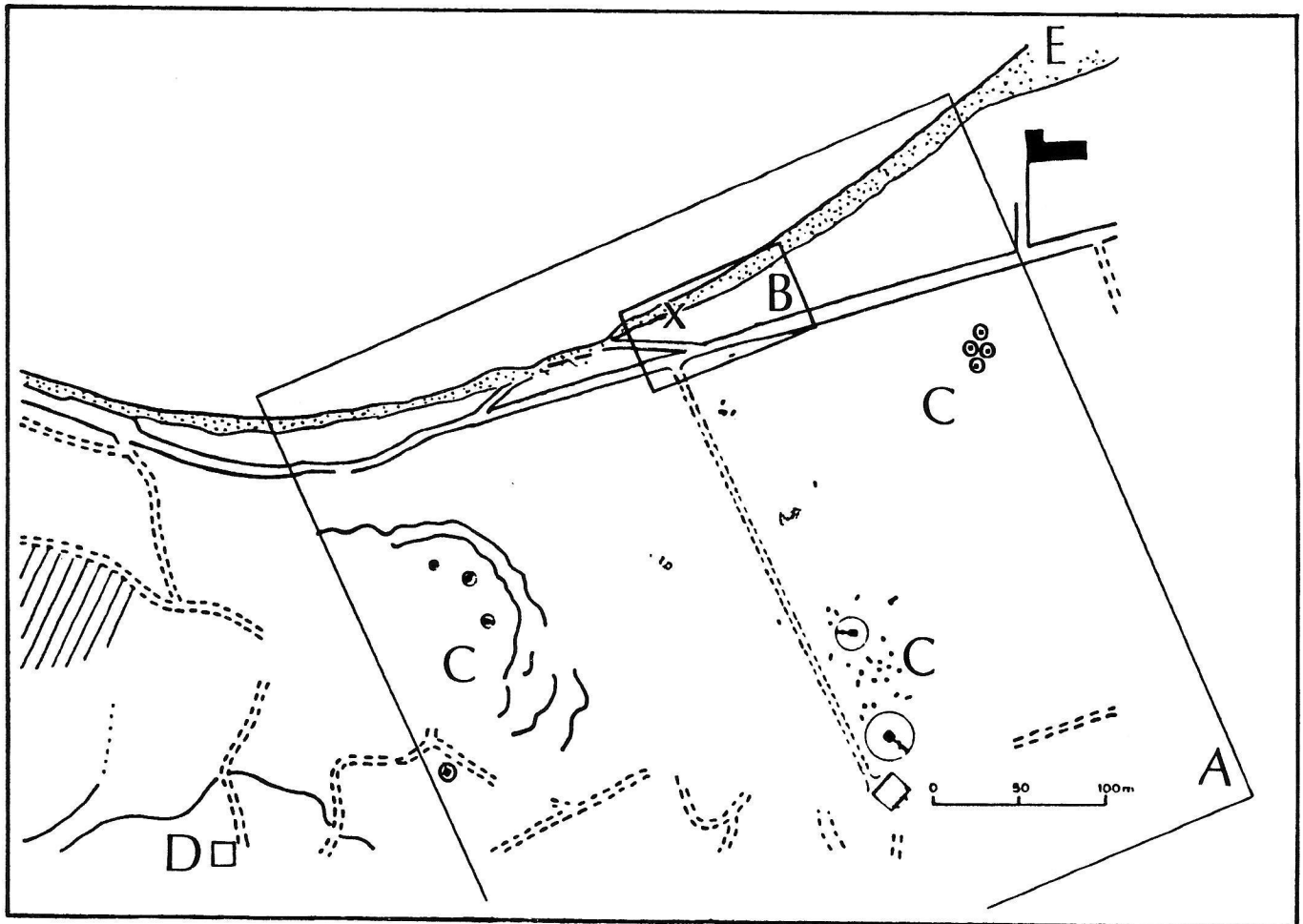


Fig 2: The Gulf of Baratti, after Voss 1988 and Sperl 1981. X marks the 1984 furnace. A is 447 metre square, representing the 20 hectares reputed to be covered in slag in the 1920's. B is 100 by 50 metres, representing a conservative estimate for the area of the San Cerbone beach deposit covered by Etruscan slags. C indicates the location of the Etruscan cemeteries, D the 1981 excavations at Poggio Porcareccia and E the Baratti/Casone deposit sampled by Sperl in 1977.

metre square, approximately that of the whole of the location plan published by Voss, was covered in an average 2m depth of slag (Fig. 2). This is rather difficult to believe, even allowing for the large quantity of slags removed for re-smelting in the blast furnaces.

Voss admits that the 1920's estimates are rather unreliable and suggests various ways in which the figure might be confirmed, including archival research. Work of this kind has been carried out for the Forest of Dean, which gives a particularly relevant comparison to the Baratti calculations because of the weight of slags involved. The Forest of Dean is an area of some 400 square kilometers, which had an ample resource of high quality limonite and haematite and a large number of iron-working sites. During the 17th and 18th century an estimated 2 million tons of bloomery slag were removed for re-smelting (Bick 1989). The weight of slag was calculated from good quality historical records, which also indicated that these slags were used to supply 20 blast furnaces for an average of 78 years! It is likely that most of the Dean slag was in fact medieval, with only a relatively small proportion deriving from prehistoric or Roman deposits.

Sperl has also published sketch plans of the Baratti area (1980, Fig. 4; 1981, Fig. 6). These show the locations of various slag deposits sampled by him in 1976 and 1977, including some on the beach near Casone, to the east of the deposits mentioned above, some from near the San Cerbone tombs, and some from further south in the Fossa dello Fociarelle and Fosso della Fredda areas. Sperl's plan also indicates the area with ancient slags as about 1 km square, or 100 hectares, which also includes a large number of tombs of various dates grouped in cemeteries (Cristofani 1981, fig. 3). The implication of this, as might be expected, is that the metal-working took place in discrete areas, perhaps representing different processes or even different dates of working. Only one focus of Etruscan settlement and iron-working, in the Poggio della Porcareccia area, seems to have been identified by excavation (Martelli 1981).

Calculating the volume of scattered slag deposits over such a large area would be an extremely difficult task even using modern surveying methods. One possibility is that the 1920's estimate is wrong by a factor of 10. It is very easy to lose or gain zero's in calculations with numbers this large! This would give a slag volume of

40,000 cubic metres and, applying the corrected factors mentioned above, this would give a total smithed bloom production of some 5,500 tonnes. This is about one hundred times less than that proposed by Voss, but still a very large quantity of iron.

numbers of iron-working sites, many of which can be dated to the 12th and 14th century AD. This is a period when Pisan ironworkers came seasonally to this area, to exploit the Elba ores, and their bloomeries are spread over a large area, presumably to take advantage



Fig 3: The Baratti/San Cerbone beach deposit, September 1991. This shows the remains of the Voss furnace (arrowed) and several of the stone-built furnaces, overlying the type 1 slags. Scale 1.5m!

The dating of the slags

Perhaps the most uncertain element in Voss' argument is the dating of the slags. The two radiocarbon dates from the San Cerbone beach slags give an important indication of the date range for the lower part of this particular deposit, but this does not necessarily mean that the whole of the 2 million tonnes of slag (or whatever the weight) was produced during the same period. Voss himself argues (1988, 96–97) that the type 2 slag cakes were the product of Roman slag-tapping furnaces and that the slags which had been sorted for the blast furnaces were those of Roman date, from the upper part of the cliff. These slags cannot, therefore, be included in the weight estimates of early slag production.

One aspect not explored is the possibility that a significant proportion of the slags used for re-smelting in the blast furnaces may have been from a medieval phase of production, as in the Forest of Dean. For instance, recent systematic fieldwork on Elba and in the coastal region of Tuscany (Coretti 1991, Frankovich 1990) has resulted in the discovery of large

of the available timber resources. It does not seem unreasonable to suggest that it was the Gulf of Baratti to where the Elba ores were initially shipped and that some of the iron may have been smelted there.

It is worth stressing at this point that most of the surviving slags in the Baratti beach cliff are still in stratified deposits. The furnace dated by Voss is clearly later than the type 1 slags and is itself sealed by an old ground surface, above which are further deposits. Some of these appear to have been disturbed, presumably to remove slag for the blast furnaces, but some of the deposit is still stratified and in 1991 at least one stone-built furnace was visible just below the top of the cliff. The type 1 slags are therefore the only ones which fall into the date range used by Voss for his calculations. As these slags have been crushed to a small size and are now very firmly cemented together, they would not have been in any case particularly easy to recover for resmelting.

As the Etruscan slags are undisturbed, at least in the San Cerbone beach deposit, it is possible to make an approximate calculation of their weight. Allowing for

coastal erosion, the general topography of the surviving deposit and the location of the nearby Etruscan tombs, a conservative estimate of the area covered would be about 100 by 50m (Fig. 2). The probable nature of this deposit is that of a dump of slags on the Etruscan shore line, of increasing depth on the seaward side. The earlier furnaces would have been on the foreshore, with later furnaces like the example dated by Voss built nearer the sea on top of the earlier slags. Taking this area to have an average depth of 1m of Etruscan slags, this would give a total weight of 4,400 tonnes. If this quantity is doubled, to allow for slags in the Casone area and elsewhere on the beach, we arrive at a figure of about 9000 tonnes.

Using the same calculations as before this would give a smithed bloom production of about 1400 tonnes, or about 3 tonnes a year for the proposed period of 500 years. Although about 400 times less than the original estimate, this is still a very large quantity of iron from an early context.

Copper slags

As mentioned in the introduction, it seems generally to have been assumed that the slags at Baratti are only from iron production. This is perhaps not surprising, as one of the dominant features of the beach is the large quantity of Elban haematite, both in large blocks and as fine sand. There are also the well-known references to iron-working at Populonia by Strabo and Livy and, of course, the later removal of the slags for the blast furnaces.

On the other hand, there is ample evidence for copper production from this area of Tuscany. From Populonia itself there are a number of Villanovan or early Etruscan copper cakes (Sperl 1981, 30–34, Plate 1) and, as will be argued below, there is evidence for both Etruscan and Roman copper production. There are also large quantities of copper slags from Madonna di Fucinaia, near Campiglia, radiocarbon dated to the 12th/13th century (Voss 1988, 97), and from Francovich's excavations at Rocca San Silvestro. This raises the possibility of some of the Baratti slags being from medieval copper smelting, but there is no direct evidence for this.

The difficulty of distinguishing between slags from iron and copper working is well known (Tylecote 1987, 300). A good indication of the latter is if there are visible external copper corrosion products or if the sectioned slags show prills of copper or copper oxides/sulphides, though these are sometimes difficult to detect even under the microscope. If the copper smelting has been efficient, then iron silicate slags may be produced which are devoid of copper products and the only way of demonstrating their origin would be their archaeological context.

The type 2 Roman tap slags in the San Cerbone beach deposit appear at first sight to be normal iron silicate



Fig 4: Detail of the central part of Fig. 3, showing the type 1 slags and a pair of stone-lined furnaces (internal diameter 35cm). Above and to the right of the furnaces is a stone mortar, in the deposits which have been sorted for slag.

slags. However, on careful inspection a large proportion of them do have clearly visible external copper corrosion products and in section the slags have very frequent small prills of copper oxy-sulphides. The type 1 slags, in the lower Etruscan layers of the cliff, are small angular pieces generally less than 5cm, which is consistent with their having been carefully crushed to recover copper prills.

Also relevant here are the important results of Sperl's 1976/77 fieldwork. Of 18 samples from the Baratti/Casone deposit, 11 were clearly from copper smelting (Sperl 1980, Table 10; 1981, Table 5). Three of the analysed samples which are argued to be from iron production have an unusually high FeO content (between 72% and 86%). Sperl interprets these as Roman tap-slugs, from inefficient iron-smelting, but it also seems possible that they could be from either iron-smithing or, possibly, from copper smelting. Bachmann has examined slags from the smelting of chalcopyrite in Cyprus, which also have a high iron content. In contrast, the slags from the Fossa dello Fociarelle and Fossa della Fredda deposits all appear to be normal iron-working slags.

On a visit to the San Cerbone area of the beach in September 1991, one corner of a sub-rectangular stone dish was found, which was heavily burned on its inner face. It is possible that this may have been used for casting copper ingots, but at the time the potential importance of the find was not appreciated and it was not collected. Several examples of stone mortars, with their distinctive working hollows, were also noticed, and several stones which may have been used as hammers. These types of artefact are generally found in Europe on early copper mining and working sites, for the preparation of the ores, rather than on iron-working sites.

On the basis of a brief visit it is, of course, impossible to make a valid assessment of the proportion of slags which might have derived from copper working. However, a few final observations may suggest that a large proportion, if not the majority, of the Baratti beach slags were indeed from copper smelting.

First of all, with ores of the quality of the Elban haematite, it would hardly have been necessary to adopt an iron smelting technology requiring the tapping of slag in the Etruscan period. The furnace dated and published by Voss, which was still partly visible in 1991, was interpreted as a non-tapping low shaft furnace. There were, also, several other furnaces of a different design in similar stratigraphic contexts in the cliff face. These are square section stone-lined furnaces, some set side by side, which are heavily slagged and vitrified and more typical of a slag-tapping furnace. These are remarkably similar in form and layout to the Mitterberg furnaces (Eibner 1982) and also to the medieval copper smelting furnaces excavated at nearby Rocca San Silvestro, which produced iron silicate slags with copper oxy-sulphide prills identical in character to those from Baratti.

Secondly, if iron had been produced, even on the minimum estimated figures set out above, then there should be abundant surviving examples of the characteristic plano-convex smithing hearth bottoms. These were specifically looked for on the 1991 visit and none was found. The Livy reference to the refining of iron at Populonia makes it clear that a large quantity of iron was smelted somewhere nearby and the excavations in the Porcareccia area (Martelli 1981) indicates that the foci of iron-working were perhaps concentrated elsewhere at Baratti.

It seems clear then that there is a good case for arguing that the slags of both Etruscan and Roman date in the Baratti beach deposits represent mainly the production of copper, rather than of iron. If this is the case, what of the large quantities of un-roasted, un-smelted haematite to be found on the beach? All the slags are good quality iron-rich, low melting point silicate slags and it seems more than probable that some of the iron ore was brought over from Elba to be used as a flux, for what must have been a rather siliceous copper ore. The occurrence of ore in the Etruscan levels and the

large quantity of later copper tap-slugs imply that this fluxing may have been carried out throughout the history of the site.

To complete the sequence of increasingly unreliable quantifications, it is of some interest to speculate on the potential output of copper represented by the most conservative estimate for the weight of Etruscan slags in the beach deposits. If it is assumed, for the sake of argument, that one-third of the slags are indeed from iron-working, and two-thirds from copper working, then the total production of smithed blooms could have been 470 tonnes and the total production of copper could have been about 600 tonnes². These are still significant amounts, representing about 1 tonne of each metal per year, for the proposed 500 year period of operations. If all of the slags are from copper working, which seems more likely, then the total production of copper could have been over 800 tonnes.

As a final comment, it is worth noting that the nearby hills on the edge of the polymetallic Colline Metallifere have sources of both copper and tin. The tin deposit is at Monte Valerio, which traditionally has been mined since Roman times, though there is no direct evidence that this source was exploited by the Etruscans (Dunning 1989, Sestini 1981). An alternative source of tin could have been Sardinia. At least in an Etruscan context, the production of bronze would have been as important as that of iron and it would be of some interest to compare the putative copper production figure above to an estimate of the weight of bronze likely to have been used by the Etruscans.

Concluding remarks

Much of this note is clearly speculative, being based on very uncertain evidence and making many assumptions. Even using the most conservative of the estimates, there is no doubt that Baratti was a major metal production centre and that it would have made an important contribution to the economy of Populonia in both the Etruscan and Roman periods. Beyond saying this, however, the inadequacy of the evidence makes impossible further speculation of the potential quantity of metal produced.

Many unresolved questions remain. Some of the uncertainties about the beach deposit could be clarified by a relatively short programme of systematic recording, dating, sampling and analysis. Because of the quality of the stratification and of the surviving furnaces, excavation on an adequate scale could produce some of the most important information yet on early iron and copper smelting. Resolution of the broader questions relating to the full extent and dating of the Baratti slag deposits, and the identification of the early iron-working locations, will require a major programme of geophysical surveying and long term excavations.

Acknowledgements

The unusual nature of the slags at Baratti was noticed by my wife. I should like to thank both Susan and Eva Hjärthener-Holdar for encouraging me to prepare this note for publication. I am grateful to Chris Salter, Gerhard Sperl and Bob Young for advice on specific points and to Justine Bayley for her comments on an early draft.

Notes

1) Strabo v, 2, 6 says that Populonia was the most important iron-working centre until the early Empire and that it imported its ore from Elba. Livy xxviii, 45 tells us that the Elban mines provided iron for Scipio's expedition to Africa in the Second Punic War, and that the people of Populonia provided the refined product. (Healy 1978, 63, 184–5).

2) For the purpose of this calculation the copper slag to metal ratio is taken as 10:1. This is an approximate figure only, as there is little reliable data and much depends on both the quality of the ore and the efficiency of the smelting.

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Note

Since this article was completed there has been the opportunity to read the important papers by G D'Achiardi (L'Industria Metallurgica a Populonia, *Studi Etruschi* 3, 1929, 397–404) and A Minto (L'Antica Industria Mineraria in Etruria ed il porto di Populonia, *Studi Etruschi* 23, 1954, 219–319). D'Achiardi records the occurrence of copper slags in the Poggio della Porcareccia area, the working of copper ores in a number of areas and the possibility of some tin slags. Several tons of litharge had also been found. He suggests that there may have been discrete zones for the working of different metals, but accepts that the evidence is too fragmentary and unreliable to support this idea.

Minto recognises that there was an early phase of copper/bronze production, but argues that this was superseded by iron working after the fifth century. He also publishes some remarkable photographs (figs 10–14), including two from the air, showing both the extent of the slag deposits in the San Cerbone/Casone areas and the scale of their extraction with mechanical shovels. Electro-magnetic separators were used because of the variability of the deposits. Both authors stress that the slags buried, and thereby protected, a number of the Villanovan and Etruscan tombs, indicating that a significant proportion of the slags were from a relatively late period of metal working.