GREEK LEAD

Ingots from a Shipwreck Raise Questions about Metal Trade in Classical Times

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Metals and metallurgy are of great interest to archaeologists, and much has been written in these pages and elsewhere recently about copper, tin, and gold. The question of the time and place of the origin of bronze has sent archaeologists stalking the elusive tin and documenting better-known copper sources. Gold has always been held in awe—treasures from the tomb of Tutankhamen recently exhibited in the United States and Canada exemplify man's fascination with it. Silver has taken fourth place, perhaps because of its limited technical uses, although no one would deny its great intrinsic value nor its usefulness for coinage.

But mention the word lead, and you are met with polite amusement, this despite the facts that lead has been in use since the 4th millennium B.C., lead sources were widely known, it is relatively simple to mine, and had a broad range of uses in antiquity. The problem with lead is that for 20th century folk it is not exotic. We may speak of a Bronze Age culture, or the golden or silver ages of Latin literature, but the only metaphorical use of lead that comes to mind is the proverbial lead balloon.

But if there is glamor to gold and mystery to tin, there is a feature of lead which appeals to the detective in students of ancient metallurgy: it leaves fingerprints. Lead has four stable isotopes, designated as Pb^{204}, Pb^{206}, Pb^{207}, and Pb^{208}. In any given sample of lead, the proportion of these isotopes can be determined by mass spectrometry and varies depending on the geographical source of the lead. In this respect, lead differs from other metals. The isotope composition, which is generally expressed as a ratio, in a sample of lead ore from a particular geographical area is different from the isotopic composition of a lead ore from another area. Consequently, if the isotopic composition (the "fingerprint") of a lead artifact can be determined and can be compared with the fingerprint of an ore sample, some knowledge can be gained about the possible sources of lead exploited in antiquity.

One of the advantages to this kind of analysis is that it requires a very small sample which need not be a pure metal. Another is that isotopic composition of a sample is not affected by its chemical history; in other words, smelting, melting, casting, and corrosion do not change the isotopic composition. Limitations, however, include the possibility that leads from different sources could be and were melted together and reused, resulting in isotope ratios somewhere between those of the original metals. Another limitation is that each lead source does not necessarily have a unique isotope make-up. Some leads from far distant sources are very similar. As a result, in some instances we can determine only where a lead sample did *not* originate. But as the body of data grows and improved accuracy in testing methods is coupled with chemical determinations, this last problem seems to diminish.

The most prominent lead sources are in naturally occurring galena ores (lead sulfide), which are very common. Most galenas are silver-bearing, and although the proportion of silver to lead is generally so low as to be expressed in ounces of silver per ton of lead, in antiquity galena was worked primarily for silver, lead being simply a by-product. Lead was so mundane a commodity in antiquity and so few writers ever bothered to mention it that we are hard pressed to gain much insight into lead mining from the texts. But this cloud has its silver lining. Because lead and silver were recovered from common ores, what we know from ancient writers about the location and exploitation of silver mines can be extended to lead mining. Silver was more widely used for coinage in antiquity than any other metal, and it was a subject of considerable interest to ancient writers.

The study of lead—its sources and commerce in antiquity—has enjoyed some popularity in the past twenty years. It received its impetus from Robert H. Brill at the Corning Museum of Glass, who became interested in sources of leads found in lead-containing ancient glasses and glazes. The success of Brill's work attracted the attention of others, and scientists and archaeologists are now joining forces to study lead found in silver, gold, and bronze coins, bronze statues and implements, white lead pigments and kohl. At the same time, ores from mines, leads from ancient ingots, and lead objects from closely dated archaeological contexts have been sampled, and a large body of data is now available as a basis for further study. The earliest work of Brill and his colleagues identified isotope ratios for leads from Laurion in Attica (Group L), southern Spain (Group S), and Roman Britain (Group E). More recently, studies at the Max Planck Institute for Nuclear Physics in Heidelberg and at Oxford University have given us data which help to distinguish leads from Laurion, Thasos, and Siphnos, three important sources of lead and silver for Classical Greece.

I became interested in lead studies when I began examining material excavated by a University Museum team from a shipwreck found near the village of Porticello in southern Italy. The ship was carrying a mixed cargo of wine, salt fish, monumental bronze sculpture, ink, and lead in ingot form. Although the site was discovered and heavily plundered by local treasure hunters before archaeologists learned of its existence, enough remained of the cargo and some of the vessel's fittings to add to our knowledge of maritime trade around the year 400 B.C., when the ship sank.

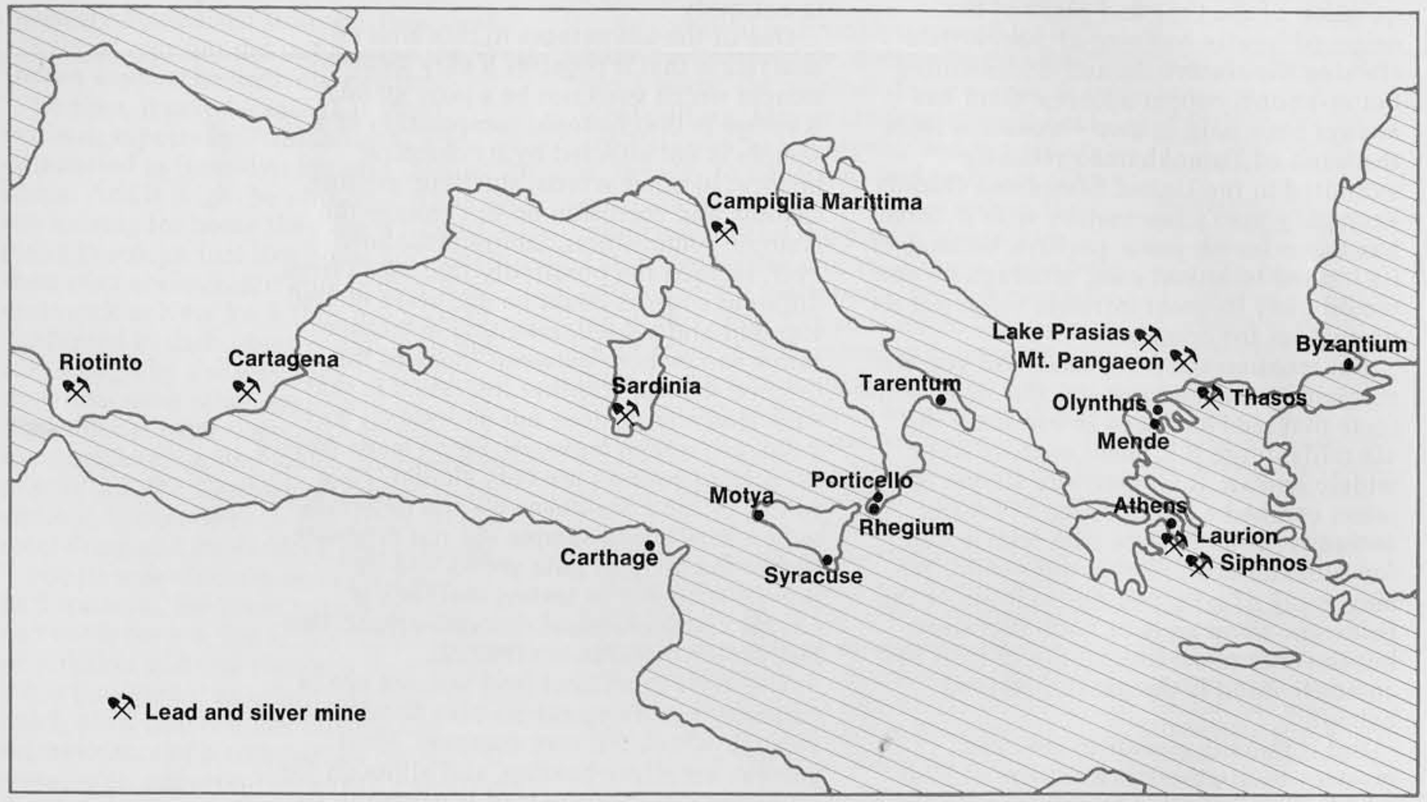
She was carrying some twenty or more lead ingots, and all but two of these were sold by the looters for scrap. Other lead items recovered included pieces of lead sheeting used to protect the outer hull surface from shipworms, portions of lead anchor stocks, and a handful of metallic nuggets which turned out to be silver and lead.

Isotopic analyses made on samples from these objects indicate that lead in the ingots, sheathing, and nuggets all came from the well-known mines at Laurion in Attica. The anchor stock, however, belongs to a rather mysterious group sometimes known as Group X, to which we shall return shortly.

Lead ingots of Roman date recovered by archaeologists working on land or in the sea now number in the hundreds, but ingots of Greek origin are quite rare. One, similar in shape to the whole ingot from Porticello, was found in the 19th century by French miners re-working the old mines at Kamareza in Laurion, but it cannot be dated by context or other means. Several long, slender rods or bars of lead recovered at the northern Greek site of Olynthus might be ingots, and these have been dated to 348 B.C., the year of that city's destruction. There are no other examples of Greek lead ingots known to me; so there is no way of knowing how typical the Porticello examples are.

Even without the evidence of isotope analysis, we might have guessed a Greek origin for one of our ingots, because one bears a stamp on its curved surface, in Greek letters. It is not possible to tell whether the stamp was made in the mould when the ingot was cast (a primary stamp) or whether it was impressed afterwards (a secondary stamp). Later Roman ingots have both kinds.

It is also not possible to determine the meaning of the stamp, although a number of possibilities suggest themselves: the



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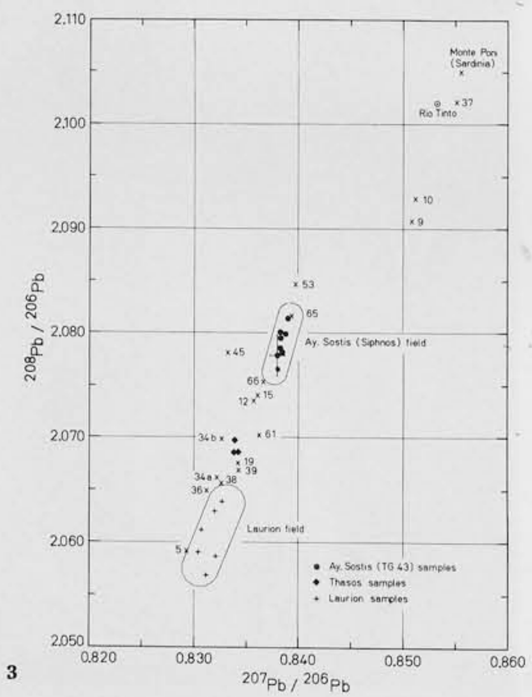
1
The Porticello ship was carrying wine from Byzantium and Mende, lead from Laurion, and salt fish from Motya. Because treasure hunters destroyed evidence of the cargo's lading, it is not possible now to determine whether the ship actually visited all those ports, picking up cargo along the way, or was a local, western ship which took on all the cargo at a major western port such as Syracuse, Rhegium, or Tarentum.

2
A partial lead ingot recovered by archaeologists from the cargo area of the Porticello shipwreck. Length 27 cm.



3
Lead isotope diagram of ores and slags from the Aegean region. Well-defined fields are Laurion and Siphnos. Three samples from Thasos also cluster together. Note that Spanish and Sardinian ores plot far outside these fields in the upper right corner. (Reprinted from *Naturwissenschaften* 65:6, June 1978.)

4
A whole lead ingot, believed to have come from the Porticello shipwreck and confiscated by Italian antiquities authorities from treasure hunters who looted the site. A stamp was impressed in six places along its curved, or back, surface. Length 52 cm.

5
Two pieces of lead sheathing from the shipwreck's hull. These provide the earliest evidence of this practice on vessels built in the Mediterranean, which is widely documented in Roman times. Strips of lead were attached to the hull by small nails or tacks. On the left piece (L. 31 cm.) nail holes are preserved; on the right (L. 25.5 cm.) concreted nail heads are still visible.

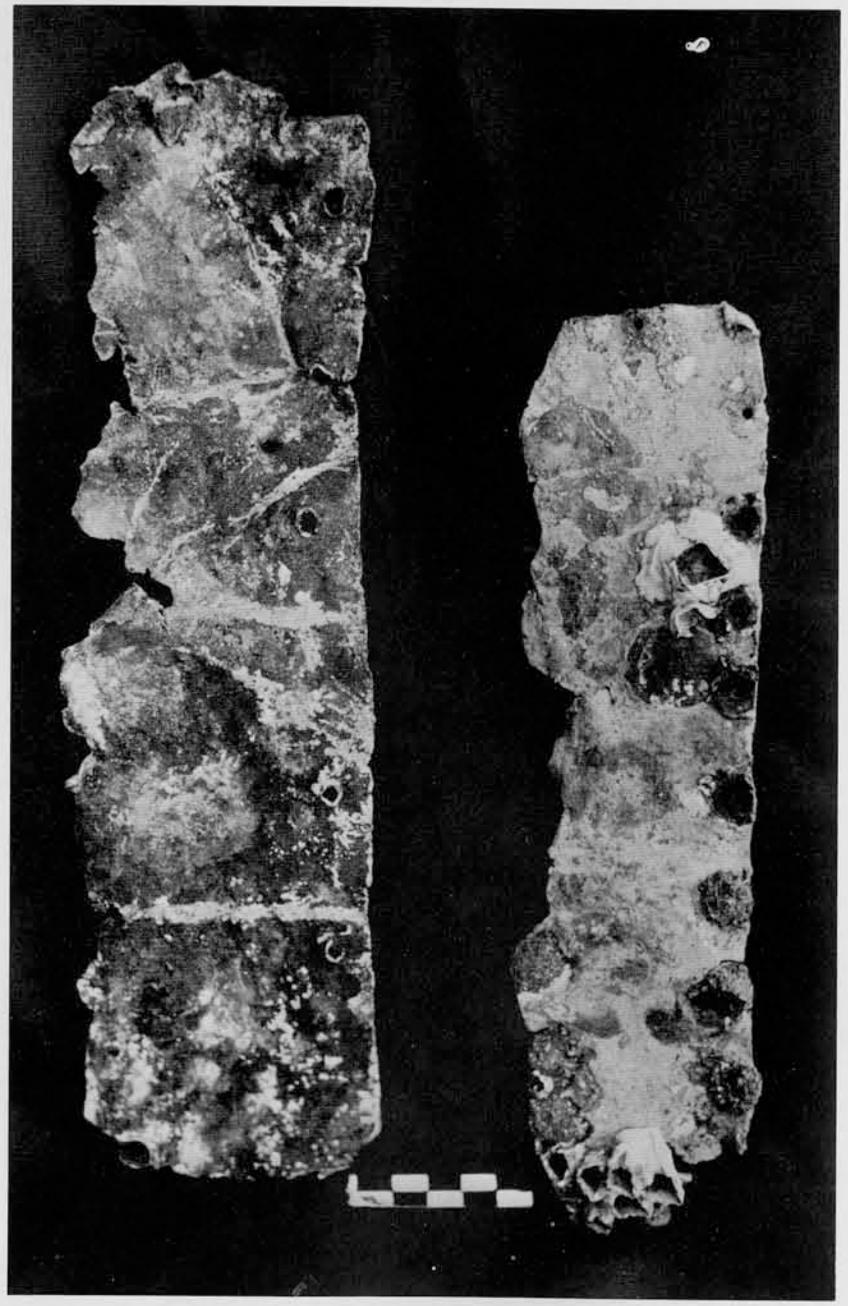
6
Isotope ratios for leads from the Porticello shipwreck.

name of a person, mine, or other establishment associated with the production of the final products at Laurion, the weight or price of the ingot, the sign of the *metronomos* authenticating the ingot's weight, or the stamp of a merchant involved in the lead trade.

If the letters in the stamp represent acrophonic numerals, they might stand for 101 staters (although, actually, if this is what the sign is supposed to mean it would probably have taken a different form). Now a stater was both a weight standard and a coin used in the 5th century: if the stamp signifies the ingot's weight, the ingot should weigh 92,475 grams, and actually it weighs only 25,700 g.

Leaving aside the question of the stamp momentarily, if we apply the other weight standard employed in that period, in which 6,000 weight drachmas equal one weight talent, we have a talent weighing 26,160 g. This figure is so close to our ingot's weight that there is a strong possibility that our ingot was deliberately cast to weigh a talent. If we accept this premise, then the stamp cannot represent the ingot's price of 101 coin staters, because lead was much cheaper at this time. Building records for the Erechtheum on the Acropolis (*IG* I² 374) show that lead sold for about 5 drachmas per talent.

If not weight nor price, the stamp can only then signify a name or names of mines or people involved in the industry. We know many such names for Laurion from Laurion mine leases. But the leases all date to the middle or second half of the 4th century, and it would be foolish to seek a correlation between the names in the inscriptions and the letters on the ingot. The fact that the letters are in a ligature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Object Description	Pb^{207}/Pb^{206}	Pb^{208}/Pb^{206}	Pb^{204}/Pb^{206}
Hull sheathing	0.8325	2.064	0.05300
Whole ingot	0.8330	2.064	0.05309
Half ingot	0.8314	2.0603	0.05298
Anchor stock	0.83736	2.0723	0.053441
Nugget	0.83196	2.0607	0.052984
Cake ingot	0.83349	2.06178	0.05306

6


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7
Detail of the foundry stamp on the whole ingot. The Greek letters are a *sigma*, *iota*, and *eta* in a ligature, suggesting that whoever used the stamp was very active in the manufacture or marketing of lead.

8
Three of the four sections of lead anchor stocks removed from the wreck site. These came from a type of anchor which is not well documented but seems to have been in use in the 5th and 4th centuries B.C. The anchor was composed of a wooden shank, wooden and lead stock, and wooden arms with bronze casings covering the tips.


8

suggests that the stamp's owner was heavily involved in lead mining or trading.

A final word about the ingot's weight. Literary and epigraphical references to lead usually indicate that it was sold by the talent. However, in the accounts for the manufacture of bronze cult statues for the Hephaisteion in the Athenian Agora (*IG* I² 370/371), lead is listed as having been bought by the *krateutes*, which is generally believed to be a pig or ingot of a certain size. Unfortunately, we do not know the size, and the price of the *krateutes* in the Hephaisteion inscription is not preserved to give us a clue. Is the Porticello ingot one of these?

We know from ancient texts that several sources of silver and lead were exploited in the 5th century: Herodotus alone mentions Laurion (VII 144), Siphnos (III 57), Lake Prasias (V 17), Mt. Pangaeon (VII 112), and Thrace (V 23). Of these, only the mines at Laurion are well known. But archaeological investigations of mining regions and isotopic and chemical studies of silver coins, lead objects, and ores and slags are greatly clarifying the picture of mine exploitation in the Aegean. We are less fortunate, however, for sources in the West. In Roman times, lead and silver were obtained in large amounts from mines in Spain, Sardinia, and Italy, according to archaeological and textual indications. Phoenicians were working Spanish mines near Riotinto and Cartagena from the 8th century B.C. if not earlier, and Brill's isotope studies now show that mines at Campiglia Marittima in central Italy might have been the source of lead which has been recovered at sites in Sicily and Italy in 7th and 6th century contexts. But many questions remain to be answered. Did mines in the West supply the needs of western peoples for lead and silver? Did mines in Greece and Asia Minor supply lead and silver only locally? If so, why was lead from Laurion being carried on the Porticello ship into the western Mediterranean? What justification can there be for transporting lead over a great distance to an area which itself abounded in sources of the metal?

This is particularly puzzling in the case of Porticello wreck leads, because the anchor stocks belong to one of the isotope families identified by Brill and called "Group X." It is characterized by an isotopic composition which is common to ores from both Italy and the Levant. It is a geological coincidence that two different mining regions at opposite ends of the ancient world should have produced leads of similar isotopic composition. In addition, it seems that some Group X leads may have been composed of scrap lead from several different sources which had been melted down and mixed together. Whether our anchor stocks are re-used lead or primary lead from Italy or the Levant has not yet been established. Some of the most recent work by Brill and by scientists in England and West Germany indicates that high-accuracy isotope determinations combined with chemical studies on lead samples can resolve such uncertainties.

Conclusive evidence for the dates when mines in Spain, Sardinia, Britain, Italy, and central Europe were worked is not yet available. Once a source was discovered and had been worked for a time, it need not necessarily have been worked continuously: Laurion, which we know best, was not. The extent to which Phoenicians and Carthaginians traded with Greeks in the western Mediterranean is unclear. If Phoenicians restricted trade in metals, it may have been easier, cheaper, or even imperative for western Greeks to import lead from Greece. Many of these questions can be answered in the future by isotope information from leads recovered in closely dated excavation deposits.

Another problem about the Laurion mines which has plagued generations of scholars deserves mention here. This is the question of whether mining operations at Laurion diminished or ceased with the occupation of Decelea by the Spartans in 413 B.C. during the Peloponnesian War. Thucydides (VII 27) tells us that 20,000 slaves fled the mines at that time and went over to the Spartans. Tradition says that mining ceased in 413, and by 407 Athens' silver reserves were so depleted that the state was forced to melt down gold victory statues on the Acropolis for coin and issue silver-plated bronze coins. (Nothing is said about lead reserves!) We do not hear of the mines again until 367 B.C. when the mine leases begin.

Belgian archaeologists working in recent years at Thorikos in the Laurion district have turned up evidence that the mines continued to be worked after 413, to a degree at least, and that it was probably not until 406 or 405 that operations ceased altogether. Work at Thorikos has not produced evidence to suggest a definite date for resumption of mining earlier than the second quarter of the 4th century, and textual evidence on the question is ambiguous. We must remember too that Thorikos was only one part of the much larger mining region, most of which has not been excavated. The Porticello ingots shed no light on the problem; although pottery from the wreck can be dated as late as 385 B.C., it can also be dated as early as 415. Are we justified in preferring the earlier date on the grounds that lead from Laurion would have been exported to the West only at a time when mining activity was in full swing?

An accurate picture of lead trade and industry in Greek times in the Mediterranean will result only from more evidence, in the form of ingots from securely dated contexts, in isotope analyses for leads we already have, and in isotope analyses performed routinely on new finds. Lead had many uses in antiquity; so samples are not difficult to find. Lead rivets were commonly used to mend pottery in antiquity. Architectural uses include roof tiles, floors, cistern and vat linings, and, of course, to fix iron clamps in place. In Roman times, lead replaced terracotta for pipes. On ships, we have seen that it was put to use to sheath hulls, and to form anchor stocks and collars;

sounding leads and scuppers are also documented. Ordinarily too soft for weapons, it was, however, used for sling bullets, perhaps because it was readily available, cheap, and easy to fashion. By itself, lead was used occasionally for lamps, pots, cinerary urns and sarcophagi, and statuettes, but it was also useful when alloyed with other metals, particularly bronze, to improve fusibility and malleability and to lower its melting point; it was also employed as a solder.

Traces of lead occur in silver and electrum coins, and occasionally lead was added intentionally to debase coinage. More legitimately, lead was widely used for seals, stamps, tablets, tokens and tickets for admission to theater or festival performances. White lead and red lead were important coloring agents, and lead also had medical uses, not only as medications, but also in some surgical instruments. Finally, it was useful as a weight *par excellence*, either by itself or as a core for fine bronze counter-balances.

What can be learned from tests on such objects includes not only information about commerce in lead, but also about exploitation of lead and silver mines in antiquity and the ever-changing availability of silver for coin. Though lacking in glamor itself, lead holds secrets which reflect the fortunes of silver.

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