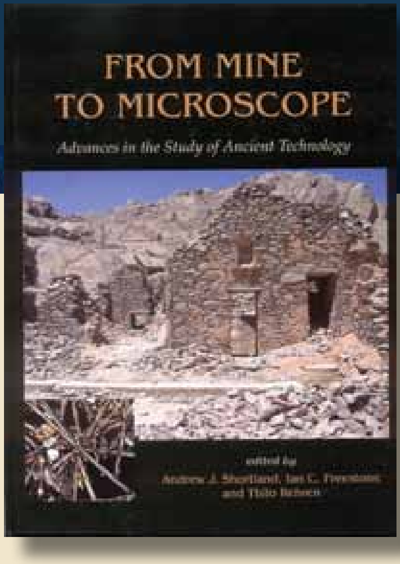
Archaeometry and Shipwrecks

A Review Article

BY JAMES D. MUHLY



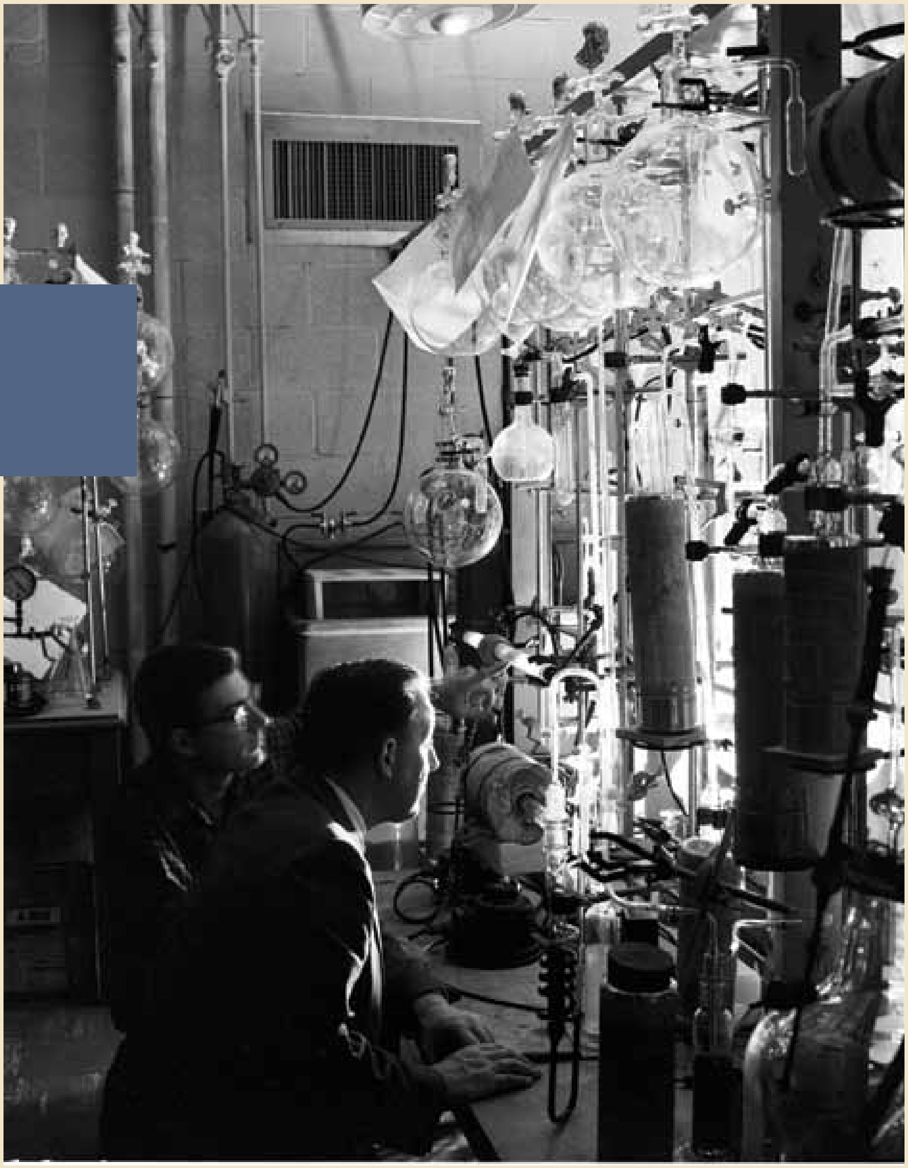
From Mine to Microscope: Advances in the Study of Ancient Technology edited by Andrew J. Shortland, Ian C. Freestone, and Thilo Rehren (Oxford: Oxbow Books, 2009). 230 pp., numerous black and white photographs and drawings, $120.00, ISBN 978-1-84217-259-9.

The volume *From Mine to Microscope* represents an important collection of articles by colleagues and former students of Michael ("Mike") Tite and is a fitting tribute to the work of a superb scholar who also happens to be a most humane individual and a wonderful colleague. The distinguished career of Tite reads very much like the history of the field of archaeometry in the second half of the 20th century. A BSc in physics (Oxford 1960) led to a DPhil (Oxford Research Laboratory 1965), under the supervision of Martin Aitken. After teaching at the University of Essex, Mike became Keeper of the British Museum Research Laboratory (1975–1989) and then, in 1989, was appointed the Edward Hall Professor of Archaeological Science at the Oxford Research Laboratory (1989–2004), replacing his mentor, Martin Aitken. He also took over as editor of *Archaeometry*, the leading journal in the field of archaeological science. It is not possible to imagine the progress made in this field of research in the United Kingdom apart from the career of Mike Tite. Many of the essays in this volume go back to research conducted by the authors for the DPhil degree, done under the supervision of Professor Tite.

Mike Tite doing fieldwork in the Western Desert of Egypt.

Andrew Shortland

Tite's early interest in thermoluminescence dating (TL) soon led to a long-standing interest in the use of the scanning electron microscope (SEM), involving work with Yannis Maniatis, one of his former students. Maniatis went on to play a major role in the development of the Laboratory of Archaeometry at the Institute of Materials Science, part of Greece's National Centre of Scientific Research known as Demokritos. Tite greatly expanded the importance of archaeometry in the UK, and Maniatis did the same for Greece. To the best of my knowledge these two scholars are still working together on several important research projects.

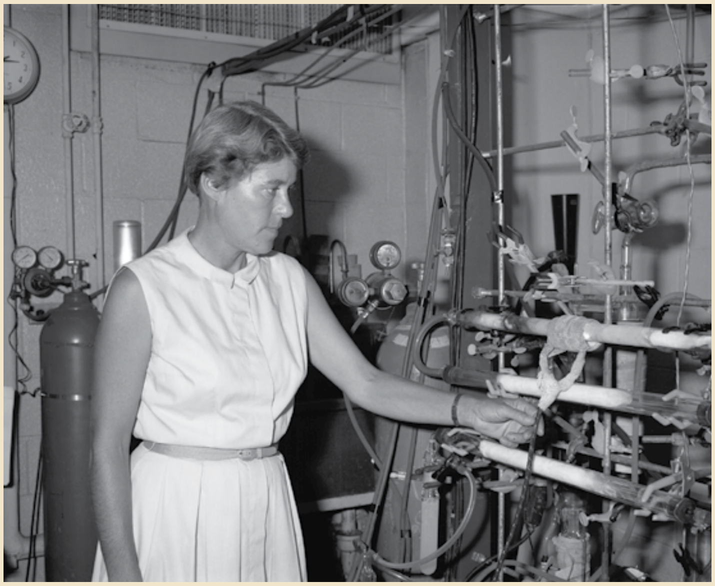


The C-14 laboratory at MASCA, 1959. Research assistant Robert Stuckenrath points out a combustion tube to Dr. Alfred Kidder II, then Associate Director of the Penn Museum. UPM Image # 63181

Penn Museum

It is appropriate here to call attention to the crucial role played by the Penn Museum (then the University Museum) in the development of American research in archaeological science. In 1953, Elizabeth Ralph was hired by the Museum as a Research Associate. She worked in the development of carbon-14 dating, a radiometric method used to date organic materials from archaeological sites. When Museum Director Froelich Rainey created the Museum Applied Science Center of Archaeology (MASCA) in 1961, the discipline of archaeometry had not yet come into being. The important research carried out by Beth Ralph as Associate Director of MASCA (1961–1982)—including the use of the proton magnetometer in the search for ancient Sybaris (1961–1968) and the C-14 dating of organic samples from Museum excavations in Egypt and Mesopotamia—quickly established the importance of MASCA in an exciting new approach to archaeological research.

Ralph had spent six weeks studying radiocarbon dating with Willard Libby at the University of Chicago, and the laboratory she subsequently established at the University Museum



Above, Beth Ralph with combustion tube and equipment used in the process of converting organic material to carbon for dating, 1959. UPM Image # 90945. Below, Beth Ralph with an Olmec Head, 1971. The head was discovered by Ralph and her team during a Cesium Magnetometer Survey at San Lorenzo, Mexico, in 1969. UPM Image # 180670

Penn Museum

was the first one in the world devoted to the radiometric dating of archaeological materials. Two factors were important in making all this possible: a crucial grant from the National Science Foundation and the support of the then president of the University, Gaylord Harnwell, who was himself a physicist.

When it became clear that radiocarbon dates had to be "calibrated" because of variations in the production of atmospheric carbon 14, Ralph went to work with Henry Michael, a pioneer in the field of dendrochronology. Michael was able to provide the exact dates used to create a calibration curve for radiocarbon dates over a period of some 7,000 years. The result was the publication, in the *MASCA Newsletter* for 1973, of the famous "MASCA calibration curve," quickly adopted by scholars all over the world. The career of Mike Tite, especially his work in radiocarbon dating, would not have been possible without the pioneering research conducted by MASCA.

In order to give some indication of the riches to be found in the volume under review, we can look at work being done on objects made of clay, glass, and metal. Work on ancient ceramics has become an essential part of current research in archaeometry. Yannis Maniatis has provided an excellent, detailed summary of what has been learned about the use of fired clay over the past 9,000 years. He argues that "the manufacture of this new material constitutes undoubtedly the first technological revolution in human history" (pp. 11-12). For anyone seeking an understanding of what such research is all about, this essay by Maniatis is the place to begin.

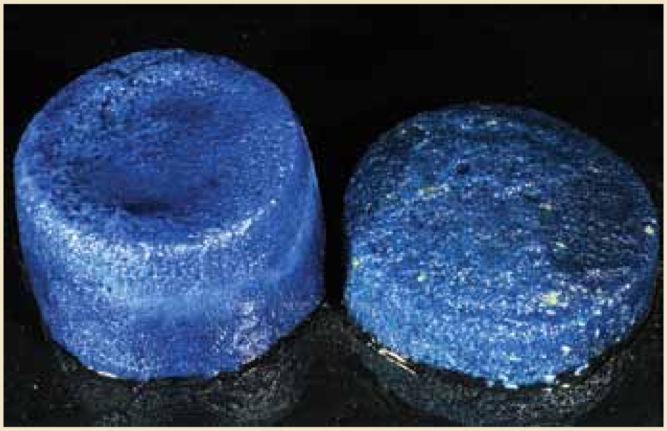
The production of glass came much later, long after work in materials such as frit and faience. It was not until the mid-second millennium BC that glass technology developed in Syria, Mesopotamia, and Egypt; the development of that technology seems to have stimulated the contemporary practice of glazing ceramics, but only in Syria and Mesopotamia, according to the essay by S. Paynter (pp. 93-108). In Egypt the practice of glazing ceramics did not develop until the 1st century BC. There seems to be a basic technological explanation for these differences. In Mesopotamia and Syria both glass and glazed ceramics were made of alkali-fluxed materials, whereas when Egypt finally started to glaze ceramics, it made use of a lead-based technology (pp. 93-94). The reason for this lies in the types of clay that were locally available.

In the 14th century BC, however, the Egyptians were already producing master works in glass, especially the famous glass model of a tilapia fish from Amarna, certainly one of the best-known (and most photographed) objects of glass before the Roman period. Found during the British excavations at Amarna in 1921, it is now one of the prized possessions of the British Museum (see essay by A. Shortland, pp. 109-14). The actual technology of glass production is studied in a fine essay by J. Henderson (pp. 129-38).

Bronze Age glass studies represent a "hot" research topic right now. There are two main reasons for this. The first is the recent discovery, at the Egyptian Delta site of Qantir-Piramesses, of the only known Bronze Age primary glass production site. The evidence for this has now been presented in a magnificent publication by E. B. Pusch and Th. Rehren (2007, see full citation at end of article). This two-volume work introduces a new era in the study of Bronze Age glass but is too recent to be included in *From Mine to Microscope*, a volume long delayed in production.

The second reason concerns recent analytical work on the large number of cobalt blue glass ingots within the cargo of the Uluburun shipwreck. It has now been established that this raw glass, known as cullet, was produced in Egypt (see C. M. Jackson and P. T. Nicholson, 2010). There are also a number of cobalt blue glass beads from Mycenaean Greece. As these beads were certainly of local Mycenaean manufacture, they must have been made of raw glass imported from Egypt, as indicated by the analysis of several of these beads (see M. S. Walton, et al., 2009). This certainly implies that at least some of the blue glass from the Uluburun shipwreck was destined for markets in Mycenaean Greece. What does this tell us about the nature of the Uluburun ship itself?

Glass bottle in the form of a fish from el-Amarna, Egypt, 18th Dynasty (*ca.* 1390–1336 BC). Length 14.5 cm.



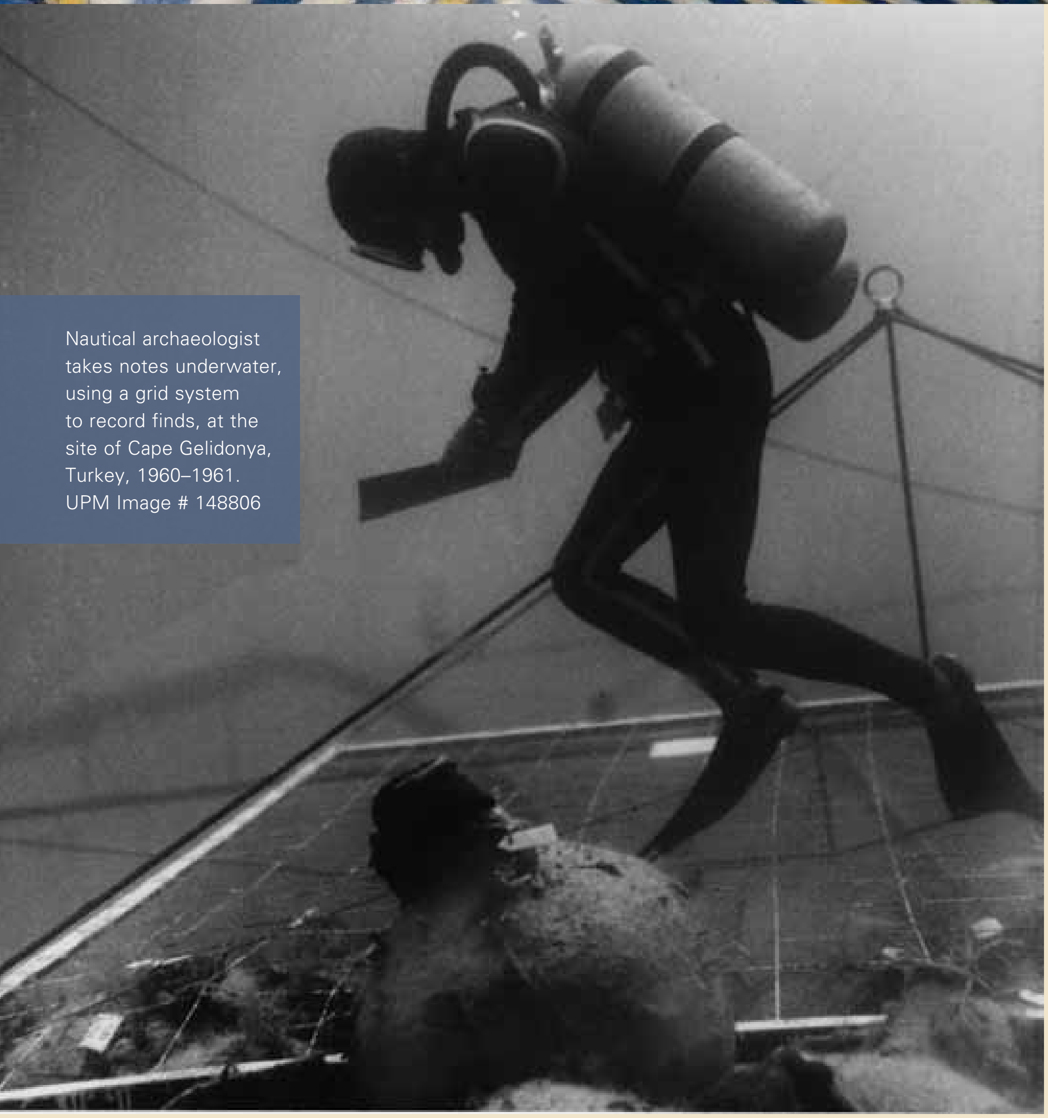
The earliest intact glass ingots of a disc shape found at the Uluburun shipwreck, Turkey. Chemical analyses have revealed the use of cobalt (on left) and copper (on right) as coloring agents.

© Trustees of the British Museum (top), Uluburun project, INA (bottom)

THE CONUNDRUM OF THE SHIPWRECKS' CARGOS

When the Turkish government asked Froelich Rainey, back in 1958, if the University Museum had someone who could excavate what seemed to be an important shipwreck recently discovered off the southern coast of Turkey, Rainey did not hesitate to accept the offer. He then *told* George Bass, a young graduate student in Classical Archaeology at the University, that he was to be in charge of the project. Lack of diving experience was no excuse; the YMCA was offering lessons in scuba diving, using their swimming pool. This was the beginning of Bass' remarkable career in nautical archaeology, first at Penn and then at Texas A & M University (see article by George Bass in *Expedition* 49(2):36-44).

Bass' skill in fundraising was instrumental in the creation of a magnificent facility in Bodrum, Turkey, from which it was possible to organize a series of important excavations of shipwrecks from all periods, but all in Turkish waters. The 1960 excavation of the Late Bronze Age Cape Gelidonya



Nautical archaeologist takes notes underwater, using a grid system to record finds, at the site of Cape Gelidonya, Turkey, 1960–1961. UPM Image # 148806

shipwreck was a pioneering effort, carried out by a group of enthusiastic amateurs. By the early 1980s, with the discovery of a new Bronze Age shipwreck in much deeper water, the field of nautical archaeology had developed in remarkable ways, due mainly to the work centered in Bodrum and carried out by what is now known as INA, the Institute of Nautical Archaeology.

This new shipwreck, designated first as the Kaş wreck and then as the Uluburun shipwreck, electrified the archaeological world because of its amazingly rich cargo. The important thing is that both ships were carrying cargo that included ingots of copper and of tin. There is now general agreement that the Uluburun ship, dating to *ca.* 1300 BC, was carrying a cargo meant as a gift for a king, whereas the cargo of the Gelidonya ship, dating to *ca.* 1200 BC, was to be seen as the stock-in-trade of a sailing smithy.

These are the conclusions of Zofia A. Stos. There is no doubt that her contribution has to be seen as the most important article in this volume in honor of Mike Tite (pp. 163-80). Furthermore, it has to be evaluated within the context of two other contributions to this volume, by A. M. Pollard (pp. 181-89) and by Noël H. Gale (pp. 191-96). All three contributions deal with the highly controversial subject of establishing metal provenance based upon the results of lead isotope analysis (LIA). They, in turn, hark back to a seminal essay by our honoree ("In defence of lead isotope analysis," *Antiquity* 70 [1996]: 959-62). It is the LIA of the copper ingots from both shipwrecks that has propelled the study of the Gelidonya and Uluburun shipwrecks into the forefront of current research in Bronze Age Mediterranean archaeology.

When George Bass put out his final publication of the Cape Gelidonya shipwreck, in 1967, he was already very much aware of the special importance of the curious "oxhide"-shaped ingots included in the cargo of the wreck. Within the following forty-some years that importance has escalated dramatically. The Gelidonya ship was carrying a cargo of 34 complete copper oxhide ingots, plus numerous fragments, and a small number of very corroded tin ingots. This was, at the time, the largest assemblage of such ingots ever discovered. The Uluburun ship, on the other hand, had a cargo that included 360 copper ingots and 160 tin ingots, weighing in total some 12 tons. This was a cargo of raw metal unlike anything ever seen before in Bronze Age archaeology. Hardly surprising that the discovery of the Uluburun shipwreck has totally revised all thinking regarding the scope of the Late Bronze Age metals trade in the eastern Mediterranean.

The copper used to make the oxhide ingots, and also the associated bun ingots, seems to have come from several copper mines on the island of Cyprus, a country long famous as a source of copper for the ancient world. No one really knows

Penn Museum

Above, at the end of the excavation at the Cape Gelidonya shipwreck, workers loaded copper ingots onto a dinghy to be delivered eventually to Bodrum. Below left, archaeologist C. Peachy is shown restoring and consolidating damaged ingots at the Uluburun shipwreck using an underwater curing epoxy and plaster. Below right, two women hold a typical copper ingot of "oxhide" shape from the Uluburun shipwreck.

Cape Gelidonya project, INA (top), Uluburun project, INA (bottom)

Lavrion Copper

Thanks to a recent paper by N. H. Gale, M. Kayafa, and Z. A. Stos-Gale, it has now become necessary to reevaluate the question of copper from Lavrion. Published in 2009, their paper from the Proceedings of the 2nd International Conference on Archaeometallurgy in Europe, held in Aquileia, Italy, in June of 2007, entitled "Further evidence for Bronze Age production of copper from ores in the Lavrion ore district, Attica, Greece," presents, for the first time, very convincing geological evidence for the existence of massive copper deposits in the Lavrion area, especially in the region known as Kamariza. In the oral presentation of this paper, in Aquileia, the authors showed many wonderful color photographs of some of these deposits. Most of this new evidence comes from a special issue of a German periodical called *Lapis* (vol. 24, nos. 7-8 for July-August 1999), devoted to "Lavrion, Griechenland."

Problems remain, including the lack of extensive deposits of copper-smelting slag and the absence of any archaeological evidence for Late Bronze Age mining activity, but Lavrion is an area where mining activity, especially for silver-bearing lead ores, has been carried out from the fourth millennium BC down into the early 20th century AD. All traces of Bronze Age mining and smelting activity could well have been destroyed or buried by later workings in the area. The authors of this paper also claim that there are now 11 ingots made of Lavrion copper, including 3 from LM IB Mochlos, 3 from the Uluburun shipwreck, and 3 from the Cape Gelidonya shipwreck. The problem is that none of these ingots are in the characteristic oxhide shape; they tend to be either so-called bun or slab ingots. The two slab ingots from Tiryns are actually made of high-tin bronze and must represent material destined to be cast in object form. It is still true, therefore, that there are no oxhide ingots made of Lavrion copper. Nevertheless, serious attention must now be given to the existence of massive deposits of copper ore, still to be found at present-day Lavrion.

Above, Noël H. Gale, Zofia A. Stos-Gale, and Stavros Papastavros (IGME) were shown copper deposits underground in 1987 in the Christiana region (Kamareza, Lavrion) by an old mining engineer of the Compagnie Française des Mines du Laurium, who used his old acetylene lamp to illuminate the copper ores (azurite and malachite) in the walls of the gallery.

Noël H. Gale and Zofia A. Stos-Gale

where the tin came from; its origin remains one of the great enigmas of the Bronze Age world. Sources as far away as Central Asia are now being seriously considered, but more for the Early Bronze Age than for later periods.

Stos deals not only with the LIA of the ingots but also that of the bronze artifacts from both shipwrecks, and this is where everything starts to get complicated and controversial. First of all, copper oxhide ingots are known from contexts far beyond the cargo of the two shipwrecks. They have been found all over the Mediterranean world, including Cyprus, Crete, Greece (mainland and islands), South Italy, Sicily (including the island of Lipari), Sardinia, Corsica, and the south coast of France. Such ingots, whole or in fragments, have also been found in Germany, the western shore of the Black Sea, on the coast of southeastern Turkey, in Egypt, and even at the site of the Kassite capital Dur-Kurigalzu, near Babylon. A fragment was found at the site of Emporio on the island of Chios, just opposite the Turkish mainland. They have not been found in the northeastern Aegean (Samothrace, Limnos, Lesbos, the Troad) or along the Aegean coast of Anatolia (Panaz Tepe, Liman Tepe, Çesme), and there must be a reason for this.

In almost all cases copper oxhide ingots have been found at coastal sites, clearly implying a distribution via maritime trade. The Uluburun and Cape Gelidonya shipwrecks clearly document such a trade, but a crucial question remains unanswered: how frequently did such voyages take place? It would be nice to be able to answer that question. Clearly we are dealing here with international trade on a grand, probably unprecedented scale. Zofia Stos regards the Late Bronze Age as representing "the earliest European industrial network" (p. 163). The vast majority of these oxhide ingots do seem to be made of Cypriot copper, even those from Sardinia, an island with its own copper deposits. This use of Cypriot copper started early, at least by the late 16th century BC, as demonstrated by the recent finds from the Cretan site of Mochlos.

Almost all the artifacts from Late Bronze Age sites in the Aegean, on the other hand, seem to be made not of Cypriot copper but of what the Gales have long identified as copper from Lavrion (southern Attica) or even copper from the Taurus Mountains in southeastern Turkey. So what happened to all the Cypriot copper? Where did it go? What was it used for? Many attempts have been made to answer these questions, most recently by Stos (pp. 176-77), but as yet, no convincing explanation has been proposed.

The very existence of so-called Lavrion copper has been called into question. Lavrion was, in ancient times, famous as a source of lead and silver. The existence of the Athenian Empire, in the 5th century BC, was based upon the wealth derived from the silver mines of Lavrion. No ancient author ever refers to Lavrion as a source of copper. Moreover, if large amounts of copper were being smelted from Lavrion ores in the Late Bronze Age, then where are the inevitable heaps of copper-smelting slag? Nothing of the sort has ever been found at Lavrion. In other words, there seems to be a major disconnect between analytical interpretation and archaeological evidence. We now have hundreds of analyzed ingots and hundreds of analyzed artifacts, but the two bodies of evidence seem to exist in separate worlds of reality. No one ever imagined, following some 30 years of very intensive analytical, geological, and archaeological research, that we would find ourselves at such an impasse.

The cargo of the Uluburun ship provides an excellent example of the problems outlined above. The copper ingots seem to be made of Cypriot copper but most of the bronze tools and weapons are said to be made of copper from the Taurus Mountains (Stos, pp. 172-73). Here is a ship carrying a cargo of copper and tin ingots, the raw materials for making bronze, but the bronze artifacts from the wreck were made from an unrelated type of copper. Why? What did the captain of the Uluburun ship plan to do with his metal cargo? Such Cypriot copper, on the basis of present interpretations of the LIA evidence, does not seem to have been used by the metalworkers of Minoan Crete or Mycenaean Greece.

Were the ingots destined to serve as a royal gift, a form of royal gift exchange, but, for some reason, never meant for actual use? Such a proposal seems too bizarre to be taken seriously. The cobalt blue glass ingots seem to have served, at least in part, as raw material for the Mycenaean glass industry. Why not a useful purpose for the copper and tin ingots? The earlier metal hoard from Late Minoan IB Mochlos (*ca.* 1525–1450 BC) shows the same pattern: ingots of Cypriot copper but artifacts of Lavrion and Taurus copper (Stos, pp. 173, 176). The cargo of the Cape Gelidonya, on the other hand, presents a very different pattern, with both the ingots and the artifacts made of Cypriot copper? Why?

What then are we to make of these two remarkable shipwrecks? They are obviously very different in character, and one of the explanations must be found in the difference in date. The Uluburun cargo, *ca.* 1300 BC, has to be seen within the context of the wealth of Mycenaean Greece in the 14th century BC. This is a merchant ship, most likely of Cypriot origin, on a voyage destined for ports on the Greek mainland, especially the Argolid. I see the Uluburun ship as representing the activities of a rich merchant, probably residing at Enkomi. His business was based upon his ability to supply the wealthy princes of Mycenaean Greece with necessary raw materials, thus making possible their opulent life style. The ill-fated voyage—that has provided archaeologists with a lifetime of material for research—must have been but one of many. The copper and tin ingots must have served as raw material for the Mycenaean bronze industry, however one is to explain the seemingly contradictory results of LIA.

The Cape Gelidonya ship, dating to *ca.* 1200 BC, contained a crew of itinerant metalworkers. Unlike the Uluburun ship, the Gelidonya ship was carrying a cargo of raw materials, together with a magnificent collection of metalworking tools, all to be put to practical use. With the collapse of the Mycenaean palaces, in the late 13th century BC, the palatial workshops went out of existence. Knowledge of metalworking skills was in serious decline on the Greek mainland, but not in Cyprus. There, metalworking skills continued to flourish during the course of the 12th century BC, as confirmed by such masterpieces of bronze casting as the Horned God and the Ingot God, both from Late Cypriot IIIB Enkomi.

As new markets for metalwork opened up across the eastern Mediterranean, the Cypriot craftsmen seized the initiative. The Gelidonya ship has to be seen within such a context: itinerant Cypriot metalworkers sailing from port to port, carrying their own raw materials and metalworking tools with them in order to supply the local inhabitants who no longer possessed the skills necessary to fulfill their own needs.

The interpretation of the Cape Gelidonya and Uluburun shipwrecks given here is by no means an orthodox one. It is very different from that proposed by George Bass himself, over the past 40 years. It does, I would argue, satisfy both the archaeological and analytical evidence and reflects the growing recognition of the importance of Cyprus in the international world of the eastern Mediterranean during the Late Bronze Age. Everyone who has dealt with the complexities and ambiguities inherent in lead isotope analysis, including Mike Tite and the contributors to *From Mine to Microscope*, will appreciate that we are still a long way from final statements on almost all the issues that make the scholarship of this period such a challenge. These are exactly the types of problems to which Mike Tite has devoted a long and illustrious career.

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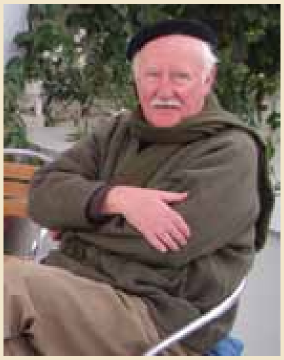

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Lina Kassianidou

For Further Reading

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