

THE ULUBURUN TIN INGOTS AND THE SHIPMENT OF TIN BY SEA IN THE LATE BRONZE AGE MEDITERRANEAN

ULUBURUN KALAY KÜLÇELERİ VE AKDENİZ'DE SON TUNÇ ÇAĞ'INDA DENİZ YOLUYLA KALAY TİCARETİ

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Anahtar Sözcükler: Uluburun batığı, Son Tunç Çağ, deniz ticareti, kalay külçe, bakır külçe, külçe işareti, kurşun izotop analizi

ÖZET

Kaş yakınlarındaki Uluburun Mevkii'nde 14. yüzyıl sonlarında batmış olan ticari bir geminin yükleri arasında külçe halinde 10 ton kadar bakır ve bir ton kadar da kalay yer almaktadır. Uluburun gemisi olarak bilinen bu batıktaki kalay külçeler, kesin olarak tarihlenebilen ve külçe şekilleri belirgin olan en eski kalay grubunu oluşturmaktadır. Kalay külçelerine ek olarak, gemide kalaydan yapılmış bazı kaplar da bulunmuştur. Külçelerin bir kısmı korozyon nedeniyle zarar görmüş veya tamamiyle eriyerek yok olmuşlarsa da, bir çoğu orijinal şekilleriyle günümüze kadar kısmen veya tamamen korunmuş olarak ulaşmıştır. Uluburun gemisinde taşınmakta olan kalay külçelerinin birçoğu, gemiye yüklenmesinden çok önce kesilerek parçalara bölünmüşlerdir. Gemide en az yedi farklı tipteki kalay külçesinin taşındığı saptanmıştır. Bunlardan dördü için elimizde tam olan örneklerin bulunmasına karşın, diğer külçe tipleri ancak kesilmiş parçaların incelenmesi sonucunda anlaşılabilir. Nispeten sağlam durumda ele geçen 110 adet kalay külçesinden en az 70 adedi öküzgözü biçimindedir. Öküzgözü külçelerin hemen tamamı kesilerek kabaca çeyrek veya 1/4'lük bölümlere ayrılmış olmakla birlikte, iki adet sağlam ve bir miktar da yarım külçe buluntular arasında yer almaktadır. Kalay külçelerinden yaklaşık 25 adedinde sonradan yapılmış olan işaretler bulunmaktadır. Bunlardan belirgin olan 16 adet işaretin bir bölümü sadece kalay külçelerinde yer almakta, diğerleri ise gemideki bakır külçelerinde de görülen işaretlerdendir. Yapılan kurşun izotop analizleri sonucunda, kalay külçelerinden bir kısmının Orta Toros'lardaki polimetallik cevher izotopları ile benzerlik gösterdiği, bir bölümünün de Akdeniz'de görülmeyen, ancak Orta Asya'da bulunan cevherler ile ortak özellikler gösterdiği anlaşılmaktadır. Ancak, külçelerin kesin kaynağı henüz tespit edilmemiş olmakla birlikte, tamamının Akdeniz dışındaki kaynaklardan temin edilmiş olması da söz konusudur. Uluburun gemisi, bakır ve kalay külçelerinin yanı sıra diğer birçok ham ve mamül malzemenin Doğu Akdeniz kıyılarından denizaşırı diğer bölgelere ulaştırılması konusundaki en önemli ve belirgin örneklerimizden birini oluşturmaktadır.

INTRODUCTION

The Late Bronze Age shipwreck excavated off Uluburun, approximately nine kilometers southeast of Kaş, in southern Turkey, has provided our clearest glimpse thus far of Late Bronze Age trade in the Mediterranean. Dated to the last quarter of the 14th century BC, the ship carried the largest and wealthiest Bronze Age cargo yet discovered in the Mediterranean. The vessel's cargo consisted primarily of raw materials, but also included a wide variety of manufactured goods (Bass 1986; Bass et al. 1989; Pulak 1988; 1997; 1998; 2001; 2005a; 2005b; 2008a). The raw materials on the ship consisted of about ten tons of copper ingots, most in the typical oxhide shape common to the Late Bronze Age Mediterranean, about one ton of tin ingots, including many in the oxhide shape (Pulak 2000a; 2008b), more than half a ton of terebinth resin (*Pistacia cf. atlantica*) carried in ceramic jars, nearly three hundred disk-shaped glass ingots, hippopotamus teeth and an elephant tusk, ostrich eggshells, and ebony logs. Manufactured goods on the ship included Cypriot pottery packed in large storage jars or pithoi, copper and tin vessels, faience drinking cups, ivory cosmetic containers, glass and faience beads, and inlaid seashell rings (Pulak 2001; 2008a: 296-297; other objects from the shipwreck may be found on the following pages of the same catalog: 313-333, 336-348, 350-358, 360-378). Artifacts for shipboard use included galley wares, tools, fishing implements, food-stuffs, seals, gold and silver jewelry, a jeweler's hoard of gold and silver scrap, weapons, ceramics, and balance weights (Pulak 2000b). These objects represent some of the personal possessions of the ship's crew and passengers. The distribution of artifacts on the seabed at Uluburun and the surviving portions of the hull suggest that the vessel was about 15 meters long (Pulak 1999; 2002) and, based on the cargo, stone anchors, and ballast recovered, had a capacity of at least 20 tons burden. However, since the amount of perishable cargo on board is not known and very little of the vessel's hull survived, estimates of the ship's size and capacity remain somewhat speculative.

An analysis of the ship's cargo illuminates many aspects of long-distance trade in the Late Bronze Age Mediterranean. Most of the raw materials and trade goods on the ship are of Canaanite and Cypri-

ot origin, while others would have been obtained from nearby hinterlands or sources farther inland, all of which would have been brought by caravan to ports before they were loaded on the ship. The Uluburun ship, therefore, is yet another indicator of a sea route for the east-west transport of raw materials and other goods.

Assigning a specific home port for the Uluburun ship and its crew is not an easy task. Based on an analysis of the personal effects of those on board the ship and specific objects intended for shipboard use, it would appear that the ship began its journey somewhere along the Levantine coast, even though a major portion of the ship's diverse cargo originates from Cyprus. Preliminary petrographic analysis of the ship's stone anchors and its galley wares, such as plain bowls, jugs, and all the oil lamps used by the crew aboard the ship, has helped narrow down the origin of the vessel to an area most likely located on the northern Carmel coast of Israel, and southernmost Lebanon. A port city in this general region, such as Tell Abu Hawam, may have been the homeport of the Uluburun ship or at least the origin of its final voyage (Pulak 2008a: 299). It is likely that the ship took on most or all of its cargo, regardless of origin, from a single port on the mainland, which served as an entrepot or a way station, rather than directly from Cyprus. This is suggested by the Canaanite origin of the ship and its crew, the diverse nature of the non-Cypriot component of the cargo assembled from many sources near and far, and the way in which some Cypriot fine wares were stored with and stacked inside mainland wares from the northern Carmel Coast. While the Cypriot pottery cargo comprises nearly all major export types made on the island, there is considerable variation in style, size, and craftsmanship among the individual pieces within a given type. This suggests that the assemblage consisted of limited or leftover pieces obtained over a long period of time through different shipments and, perhaps, from diverse workshops. Had all the pottery been procured directly from Cyprus together as a single group, they would have been significantly more homogeneous within the type groups (Pulak 2008a: 299). Although not certain, the variations observed among the basic copper ingot shapes and the array of incised markings on them suggest

that the ingots were also previously transshipped from Cyprus to a mainland entrepot where they were probably stored for an indeterminate length of time before being loaded on the ship. This entrepot was most likely located near the ship's homeport, possibly at Tell Abu Hawam itself or a similar site in the same general region. Although Tell Abu Hawam is a comparatively small site, excavations there have uncovered an international assemblage of artifacts, including many Cypriot wares, leading to its identification as the port city associated with the major inland site of Megiddo.

The general direction of the voyage is also clear. Winds and currents on the southern coast of Anatolia run from east to west, and these were exploited by Bronze Age seafarers. From its likely origin on or just north of the Carmel Coast, the Uluburun ship sailed north along the Levantine coast and then headed west, hugging the southern coast of Anatolia, most likely keeping the northern coast of Cyprus to its port side until it sailed past the island, and Cape Gelidonya to its starboard, a site of another Bronze Age shipwreck (ca. 1200 B.C.), only to founder at Uluburun. Mycenaean objects on the ship strongly suggest the presence of at least two high-ranking Mycenaeans on board, perhaps messengers or officials escorting the vessel's rich cargo to a destination in the Aegean (Pulak 2005c; for Uluburun Mycenaean pottery, see Rutter 2008). With its ten tons of copper ingots and one ton of tin ingots, therefore, the Uluburun ship provides our strongest, indisputable evidence for a Late Bronze Age east-west sea route for shipping basic raw metals along the southern coast of Anatolia. Tin is an essential component of bronze, the eponymous metal alloy of the period. However, because it was unavailable locally in the Mediterranean during the Bronze Age, it was supplied to Mediterranean civilizations using ships such as that found at Uluburun. It is also in the Uluburun tin ingots that we have our first archeological evidence for the bulk trade of tin in the form of distinct metal ingots, and for the range of ingot shapes, including the oxhide shape, in which tin was cast and traded during this period.

Other evidence for Bronze Age trade in metals along this sea route includes approximately two tons of copper oxhide ingots recovered by sponge divers in 1907 or 1908 from a 16th–14th-century B.C. shipwreck site reported near Side in the Bay of Antalya,

southern Turkey (Buchholz 1959: 27, Pl. 3:5-6, 30; 1966: 63, Fig. 2b, 65). An unpublished report about the site suggests that the approximately two tons of copper oxhide ingots salvaged by the sponge divers from the wreck represent only a fraction of the ship's cargo of copper ingots. Although none of the objects described by the sponge divers from this wreck are tin ingots like those excavated at Uluburun, it does not negate the possibility that tin ingots were also carried on the ship alongside the copper ingots. Further west on the southern Turkish coast, the remains of a smaller, late 13th-century BC shipwreck were found at Cape Gelidonya. The cargo of the ship consisted of primarily scrap metal in the form of bronze tools, weapons, and other items, as well as at least 34 copper oxhide ingots and also some tin. Although the tin had disintegrated, it was most likely originally in ingot form and not tin oxide ore or cassiterite (Bass 1967: 52-83). Bass noted that three piles of white, powdery tin oxide were found on the wreck under the copper ingots. A single tin pile collected from the seabed weighed 8 kg when dry, and represented approximately half of what had been preserved on the wreck. The tin was only preserved where it was covered by the cargo of copper ingots, so it is possible that more tin was on board and was later washed away. Spilled tin oxide was recovered from a roughly rectangular concretion (approx. 6 x 6 cm) in one area; Bass suggests that the concretion formed over the tin ingot before it was destroyed by electrolytic action due to its physical contact with the copper (Bass 1967: 82-83). On a return trip to Cape Gelidonya in 1987, the author collected two amorphous metal lumps, presumably fragments of ingots, from the original excavations spoil heap. The metal lumps were identified as tin-lead alloys, of approximately 65% tin and 35% lead.¹ It was concluded that such a percentage of lead must have resulted from deliberate alloying rather than the lead content of the ore, since lead does not occur in tin deposits in such high concentrations.²

The maritime trade route continued west, passing the Uluburun promontory, before reaching the southwestern tip of Turkey, where a sponge trawler is said to have netted a copper oxhide ingot off Knidos in water more than 100 meters deep (the ingot was later dumped back into the sea) (Bass 1986: 272). From this region, ships would have likely continued west, towards Greece, or north into the northern Aegean. Other Bronze Age metal ingots found on or

near probable coastal trade routes include an oxhide ingot found on land near Sozopol on the Bulgarian coast of the Black Sea (Karaitov 1978; Dimitrov 1979: 70, 73, Fig. 3; Bouzek 1985: 20-21, pl. 4:2; Gale 1989: 248, Fig. 29:1), an oxhide ingot corner found 3 km from the coast at Şarköy near the Sea of Marmara (Harmankaya 1995: 232-233, 254, pl. 17), and a hoard of 19 copper ingots from a shipwreck near Kyme in Euboea, Greece (Buchholz 1959: 35-37, Pl. 5:3-4; 1966: 62). The Kyme ingots, however, are smaller, have much smoother surfaces than the typical oxhide ingots, and shaped somewhat differently from their Late Bronze Age counterparts, and may therefore be of a later period.

Copper, tin, and lead ingots dating to the Late Bronze Age have also been found at two probable shipwreck sites near Haifa on the Israeli coast. One of these, found just south of Haifa, on the Hishuley Carmel coast, yielded four typical Bronze Age stone anchors with a single apical cable hole, a copper oxhide ingot, and five tin ingots (Galili et al. 1986: 25-34). The tin ingots are of an irregularly-shaped, sand-pit cast, plano-convex form, with their weights varying between 2.2 and 4.2 kg. Three of these ingots bear incised marks of unknown origin, but provisionally thought to be from the Cypro-Minoan syllabary by the excavators (Galili et al. 1986: 32). The second site, slightly farther north on the same coast, at Kfar Samir, thought to date to the 14th or 13th century BC, yielded five typical Late Bronze Age stone anchors more or less of the same size, a bronze sickle-sword, various smaller bronze objects, five small lead ingots, eight bar-shaped tin ingots, and two large plano-convex, roughly discoid tin ingots. One of the latter tin ingots was sawn in half in antiquity and weighed a massive 36 kg (Raban and Galili 1985: 326-329). One of the bar-shaped tin ingots bore an incised mark, as did all five of the lead ingots. Two rectangular tin ingots, thought to have come from a site off shore near Haifa, Israel, are without a secure archaeological context. The ingots are 31.4 cm and 32.4 cm long, 19.0 cm and 21.6 cm wide, and 3.7 cm and 3.6 cm thick, and weigh 11.4 and 11.9 kg, respectively (Maddin et al. 1977: 35-47). Each ingot has two incised marks on their wider top surfaces, with one of the marks found on both ingots. Two of the three incised marks are identified as being of Cypro-Minoan syllabary, and the third, although not represented in its exact form among Cypro-Minoan syllabary, is thought to be a member

of the same family of signs. Since Cypro-Minoan is known to have been used from the end of the 16th century to the end of the 11th century BC, the ingots were thought to date to that period (Maddin et al. 1977: 46). Although the source of the tin would have lain outside of Cyprus, it is assumed that the ingots passed through Cyprus where they received the Cypro-Minoan markings, which are also found on some Late Bronze Age copper oxhide and plano-convex discoid ingots found at various sites around the Mediterranean. Two additional ingots found later, of the same shape and size as the earlier ingots, also carried a pair of incised marks on each ingot. The two marks on one of the ingots was identical to one of the two marks found on each of the two earlier ingots, suggesting that all four ingots came from the same unknown shipwreck (Artzy 1983: 52-53). This same ingot, however, also had the impression of a human bust, identified as the fountain goddess Arethusa, and thus the ingot was dated to the 5th century BC on stylistic considerations. If this attribution is correct, then the tin ingots could not have come from a Bronze Age shipwreck. Consequently, the origin of these ingot markings were sought outside of Cyprus, with Iberia proposed as a possible source (Artzy 1983: 54). It is hoped that future lead-isotope analysis will be able to resolve the question of origin for these four ingots.

Although copper oxhide ingots and ingot fragments occur at a number of Bronze Age coastal sites in the eastern and central Mediterranean (Gale 1999: 111), tin is noticeably absent at these locations. One probable reason for this is that, unlike copper, tin corrodes and becomes difficult to recognize in the archaeological record by the non-specialist archeologists and therefore is easily overlooked. At the port town of Mochlos on Crete, however, recent finds include fragments of copper oxhide ingots and a tin ingot in a LM IB context (c. 1400 BC), which had disintegrated into tin oxide but whose rectangular slab shape was preserved by a plaster cast (Soles 2005, 2008; Whitley 2005:102-104). These ingots would have reached Crete on ships such as those that sank at Uluburun and Cape Gelidonya with their cargo of copper and tin ingots. Recent reevaluation of three early archaeological excavations on Nuragic Sardinia, as well as a few fragments of recently discovered tin metal from another site, have now also confirmed the use of metallic tin in Sardinian bronze making (Lo Schiavo 2003: 121-124).

THE TIN INGOTS FROM THE ULUBURUN SHIP

The Uluburun ship's primary cargo of copper and tin ingots is the largest discovery of metal ingots from the Bronze Age Mediterranean (Pulak 2000a; 2008b). Much of the copper was in the form of 354 copper oxhide ingots, with a preserved weight of approximately 18 to 30 kg each. The ingots were of raw, blister copper rather than recycled copper or bronze (Hauptmann 2002: 13). Most are of the "four-handled" shape known from many Late Bronze Age sites, but 31 are of a unique shape with only two "handles" or corner protrusions. Six smaller oxhide ingots, two pairs of which were cast in the same mold, a smaller ingot with the same general shape as the previous four but without corner protrusions, and a thick, unique ingot with short, bulky corner protrusions were also found.³ The ship additionally carried 121 smaller copper bun or plano-convex discoid ingots, varying in weight, but averaging about 6.2 kg apiece. Fragments of 10-15 copper bun ingots were also recovered. It is logical that copper and tin would have been shipped together, and presumably in the appropriate proportions, since they were used together to make bronze. The ten tons of copper and one ton of tin on the Uluburun ship approximates the required proportions of the two metals to produce 11 tons of bronze at the optimal copper-to-tin ratio of 10:1.

The Uluburun ship's tin ingots are the earliest known from a well-established archaeological context and are the first with distinct, easily-recognizable ingot shapes of at least seven different types. Some of the tin ingots excavated on the ship had disintegrated through the action of corrosive salt water and perhaps also by electrolytic reaction, which resulted in the production of tin oxide with a consistency of toothpaste, which readily washed away under water during excavation. Corrosion damage to the ingots varied, from small and large holes in otherwise intact ingots to the complete loss of the ingot's original shape and mass (Fig. 1). Tin corrosion products were collected from the site whenever possible, but the total weight of tin recovered must be much less than that of the original cargo. Nevertheless, the recovered quantity of tin weighs approximately one ton.

Although several different types of intact ingots were recovered, the majority of the tin cargo consists of pieces of larger ingots that had been cut some time before they were stowed on the ship. At least 70 of

the approximately 110 relatively well-preserved tin ingots and ingot fragments recovered from the wreck are in the oxhide shape used for most of the copper ingots. Most of the tin oxhide ingots consisted of pre-cut corners of complete oxhide ingots (Fig. 2); only two of them were uncut and complete (Fig. 3), and eight were sectioned into half or near-half ingots. Although poorly preserved, the complete examples of the better-preserved tin oxhide ingots suggest their weights to be roughly comparable to those of the copper oxhide ingots. Other ingot shapes are also represented, including complete (Fig. 4) and partial rectangular slab ingots (Fig. 5), quadrants of rectangular ingots with rounded corners and beveled sides, wedge-shaped sections cut from very thick ingots of indeterminate shape (Fig. 6), halves of elongated ovoid ingots, bun or plano-convex discoid ingots (Fig. 7), and a unique thick rectangular ingot pierced at one end, having the appearance of a stone anchor of the type carried on the Uluburun ship (Fig. 8). Although some of the complete ingots and ingot fragments have one or more perforations punched through them, probably to facilitate their handling or aid in securing them to pack animals for transport, none of the oxhide ingots, whether intact or cut, were perforated.

The uncut, complete copper and tin oxhide ingots probably represent the primary shape in which the smelted metal was transported from mining areas to trading or distribution centers. Having reached these destinations, most of the tin ingots were cut up before redistribution; perhaps ingot pieces of smaller weights were considered more convenient for weighing, transporting, or trading. Smaller ingot pieces would also have been required when only a limited quantity of tin was required for exchange. The Uluburun tin ingot assemblage was, therefore, most likely gathered through a variety of mechanisms such as direct trade from a primary source, local barter, levies, taxes, or gifts in order to achieve the 1:10 tin-to-copper ratio found in the metal cargo of the Uluburun ship. The fragmentary state of most of the tin ingots suggests that they were collected from one or more distant sources, perhaps changing hands several times and then being stored over an extended period before being loaded on the ship. On the other hand, much of the copper cargo consists of intact ingots (with a small number of cut and broken ingots also found) and was almost certainly procured directly from Cyprus, without having changed hands and being

cut into smaller pieces during this process, before being stockpiled in a mainland entrepot. This situation also indicates a closer link to the source or sources of the copper ingots.

THE INCISED MARKS ON THE ULUBURUN INGOTS

The marks incised on the Uluburun copper and tin ingots offer some evidence for the organization of this trade, although the significance of these marks is still poorly understood (Table 1). All marks, whether on copper or tin ingots, were made by cutting or incising with a chisel, using multiple strokes; thus, all of the marks are secondary marks, which could have been placed on the ingots any time after the ingots had been cast and allowed to cool. Preliminary examination of the copper ingots show that at least 162 of the copper oxhide ingots are incised with at least one, and rarely up to three, marks on their upper surfaces. At least 32 different types of marks occur on the upper, rough surfaces of the copper oxhide ingots; 13 appear more than once, and one is repeated as many as 17 times. At least 26 copper oxhide ingots have linear markings chiseled into the sides of the ingot. Five of the ingots with such marks (KW 2512, 2744, 2816, 3027, and 4003) also have incised marks or score marks on their rough, or upper, surfaces (Pulak 1998: 194-196; 2000b: 152-153). These marks, usually consisting of single, opposing, diagonal strokes that form alternating 'V's, are much simpler than those placed on the upper surfaces of the ingots and may be tally marks rather than marks with the same function as those on the rough surfaces of the oxhide ingots. Among the plano-convex discoid or bun ingots, 62 have marks incised into their lower or smooth mold surfaces. This is in contrast to the oxhide ingots, where the marks are placed only on the rough upper surfaces of the ingots. These marks are similar or identical to marks found on the copper oxhide ingots. Seven different varieties of marks occur on the copper bun ingots, five of which also occur on the copper oxhide ingots. Some of the Uluburun ingot marks appear to have maritime themes: fishhooks, fish, possible quarter rudders, ships, and perhaps also tridents, which suggest that they were made in an area near the sea (Pulak 1998: 194-196). Some of the marks have counterparts in ancient scripts, especially in the Cypriot-Minoan syllabary, such as the trident-shaped mark (Table 1: b2) mentioned above, but others do not

appear to correspond to any known mark and may simply be figural or abstract representations.

At least 25 Uluburun tin ingots were found with incised marks, although only 16 are fully preserved, four are partially preserved, and the shape of one is indeterminate. Other marks may have been completely obliterated by corrosion and blistering of the ingots' surfaces. With one exception, that of a quarter rectangular slab ingot, with mark f5 (Table 1), which may be a partly preserved variant of mark d6, all of the marked ingots are quarter oxhide ingots; none of the intact tin ingots bear any marks. These marks comprise ten different types, six of which are found only on tin ingots (Table 1: f3-6, g1-2). Some of these marks seem to be minor variations of the other marks. For example, the mark found on tin ingot KW 203 (Table 1: g2) is found on both the copper oxhide and bun ingots, as well as on two of the tin ingots, but without the chiseled line parallel to one of the arms of the 'U' (Table 1: b3). The mark on tin ingot KW 2777 (Table 1: f4) is similar to one seen on four other tin ingots (Table 1: f3), but lacks several extra strokes at the terminus of the arms and body of the mark. Finally, the marks on ingots KW 315 and KW 946 (two parallel chisel marks—Table 1: g1) are similar to that on KW 722 (three parallel chisel marks—Table 1: f6).

Four of the tin ingot marks (Table 1: a5, b3-4, d6) also occur on either the copper oxhide or copper bun ingots. Two tin ingots (KW 403 and KW 3061) have two identical or nearly identical marks incised on both the upper and mold surfaces of the ingots. Other tin ingot fragments have incised marks that may be only random chisel marks, guidelines for cutting the ingot, or accidental excavation damage; two such ingots (KW 946 and KW 1772) also have incised marks. Score marks occur on up to 16 of the copper oxhide ingots from Uluburun, where they usually bisect the ingot or delineate a corner to be broken or cut off. This was a common method for breaking up metal ingots, as seen from the oxhide ingot assemblages at Cape Gelidonya, Şarköy, and other sites. In the case of copper ingots, however, after scoring the ingots, breaking proceeded by forcefully striking the ingot with a sledge hammer, causing it to fracture along the score mark. With tin ingots, the ductility of the metal prevented this. All the cut tin ingots from Uluburun, whose edges were sufficiently preserved, reveal that the ingots were cut

deeply with a chisel from either one or both sides and the remaining bridge of metal broken through by fatiguing the metal through bending it forward and backward repeatedly (Fig. 9).

The marks on all of the Uluburun copper and tin ingots are incised, which suggests that they were made at a point of export or receipt rather than at the point of manufacture. This is all the more applicable for the Uluburun tin ingots since only the cut ingots are thus marked. The marks could be owners' marks or marks indicating the receipt of ingots from a particular source or through a certain agent or consignor. This evidence contrasts with other copper ingots, such as those from the Cape Gelidonya shipwreck, where some of the ingots are marked with 'primary marks' that were cast into the ingot or impressed on the ingot when the metal was still soft (Bass 1967: 72). Along with the fragmentary state of the tin ingots, the secondary marks suggest that the ingots were assembled from a variety of secondary sources, where they were divided and marked, collected at a central trading settlement, and then sent on to the port where the Uluburun ship was loaded. That some of the tin ingot marks have Cypro-Minoan counterparts is seen as an indication that the tin ingots passed through Cypriot hands on Cyprus (Maddin et al. 1977: 46; Muhly 1978: 45; Wheeler-Stech et al. 1979: 148), which may well have been the case. The presence of these marks on the Uluburun tin ingots and those found off the coast of Israel have also been interpreted as a control and manipulation of the tin supply by Cypriots, who marketed the imported tin along with their Cypriot copper (Kassianidou 2003: 115-116). This may be so, but one must keep in mind that not all the tin ingots are marked, those that bear marks similar to Cypro-Minoan script have similar counterparts in other ancient scripts of the region, and many other marks on the tin ingots do not appear to correspond to any kind of ancient script. Moreover, since the tin came from the mainland and had to pass through the hands of various city-states along the Levantine coast, unlike the copper which was produced on Cyprus, it would have been impractical and difficult for the Cypriots to procure all the tin from their maritime merchant neighbors only to sell some of it back to them, as well as marketing it exclusively to other tin-starved Mediterranean cities. One could only assume at this point, therefore, that

some of the tin circulating in the eastern Mediterranean, where tin was an important commodity sometimes used as a form of currency, was exchanged through Cypriot hands. Since the Uluburun tin ingots represent a stockpile of previously-circulated tin that was accumulated over time, it is only logical that some of the ingots also carry Cypro-Minoan syllabary.

THE OXHIDE INGOT SHAPE AND TIN SOURCES IN THE MEDITERRANEAN

The origin of the oxhide ingot shape is unknown, but it appears to have developed some time in the first half of the second millennium BC. The earliest evidence thereof appears at 16th-century sites on Crete and is shown in contemporary Egyptian tomb paintings, where they are often associated with Syrian merchants and tribute-bearers (Pulak 1998: 193; 2000b: 138; Bass 1967: 62-67). Later copper oxhide ingots, in contexts dating between the 14th and 12th centuries BC, have been found in Iraq, Syria, the Nile Delta, Turkey, Greece, Cyprus, Israel, Crete, Bulgaria, Sicily, Sardinia, Corsica, southern Germany, and southern France (Domergue and Rico 2002: 141-144; Lo Schiavo 2005: 402-408, 406-408; Gale 1991: 200-201; 1999: 117; Primas 2005: 389; Primas and Pernicka 1998: 27-50). Lead-isotope data indicates that nearly all of the copper oxhide ingots derive from several copper deposits in Cyprus, although a selection of the earliest oxhide ingots from Crete come from an unknown source or sources, which, based on the early geological (Precambrian and Devonian) dates of these ores, appear to be outside the Mediterranean region; ores of such early geological dates, however, are found in Central Asia (Gale and Stos-Gale 2005: 117-131; Stos-Gale 2004: 53-59; Gale et al. 2000: 339; Stos-Gale et al. 1997: 109-112; 1998: 115-126).

The sources of Bronze Age tin for the eastern Mediterranean region have been more difficult to determine. Tin bronzes begin to appear in significant numbers in the Near East and the Aegean during the third millennium BC. The Persian Gulf site of Tel Abraq may have been supplied with tin from the same source as a number of Aegean sites, perhaps indicating large-scale mining and export from a single region (Weeks 1999: 49-50, 52, 59). Ancient texts from Mari in Syria dating to the early second millennium BC indicate that tin was exported to the

west of the city and probably came from a source or sources to the east or northeast (Pulak 1998: 199; Dossin 1970: 101-106; Muhly 1985: 283-285; Weeks 1999: 51). The tin from Mari was transported in the form of slabs of approximately 7 minas (2.5 kg) each (Veenhof 1972: 34-35). Recent research has uncovered tin deposits in the Zeravshan Valley of Uzbekistan and Tajikistan. In this region, at the sites of Karnab and Mushiston, ancient tin mining galleries dating to the Andronovo culture (c. 2000-1500 BC) were identified based on ceramic and radiocarbon dates (Cierny and Weisgerber 2003: 24-29; Cierny et al. 2005). Tin deposits have also been identified in eastern Kazakhstan (Cierny et al. 2005: 440). Excavations in central Anatolia at an ancient mine at Kestel and a nearby Bronze Age settlement at Göltepe show that a tin deposit in the Taurus Mountains north of Bolkardağ was exploited during the Early Bronze Age and, perhaps, intermittently over the next thousand years (Yener 2000: 71-109; Yener et al. 2003: 181-187). However, at this site there is no evidence of Late Bronze Age exploitation. A tin deposit has been found in Turkey at Madenbelentepe, in the Handere Valley near Soğukpınar, south of Bursa, but there is no evidence of any ancient exploitation at this deposit (Belli 1991: 7). The Tell al Rimah tablets, dated to the early 13th century BC, contain references to 25 kg of tin imported by Assyrians from the land of Nairi in southeastern Anatolia (Belli 1991:2) as well as varying amounts of tin (up to ten talents) in a number of loan contracts (Wiseman 1968: 175-176). Belli (1991:2-3) notes that Assyrian tributaries in the lands southeast of Lake Van, Diyarbakir, and northern Syria paid tribute in tin, probably obtained from a major trade route running from Afghanistan to the Mediterranean.

During the 19th century BC tin was exported overland from Assur to an Assyrian trading settlement at Kaneş/Kültepe in south-central Anatolia. Clay tablets excavated from the site detail the importation of large amounts of tin from Assyria for sale in Anatolia (Veenhof 1972). Estimates vary on the amounts imported: based on surviving tablets, McKerrell (1978: 21) estimated that approximately one ton of tin a year was imported, while Larsen (1976: 91) estimates that about 13,500 kg of tin were imported to Kaneş/Kültepe over fifty years. Tin exports from the source used by Old Assyrian merchants may well have been much larger than indi-

cated by the Kaneş/Kültepe tablets. A clay mold from the site for making bar-shaped ingots has been identified as being used for tin ingots, but this identification has yet to be verified.⁴

Surviving documents of Assyrian merchants from Kaneş/Kültepe indicate that tin was transported in donkey caravans and was carried in several forms. In some instances, tin quantities are called riksum, from a root word meaning “tied up, bound together”; rikšū of gold and silver are mentioned in texts as weighing between a few shekels and two minas, while rikšū of tin are recorded as weighing between 5-15 minas (Veenhof 1972: 33). Several references involve dividing or mixing metal loads into rikšū; this appears to indicate that the tin was handled in small, possibly irregular pieces wrapped into bundles of a standard weight (Veenhof 1972: 34-35). Bags, probably of leather, called šuqlum were used to carry gold and silver objects and amounts of copper up to 100 minas; these may have also been used to transport and store tin (Veenhof 1972: 40-41). For long-distance transport, however, wrapped bundles called šuqlum, or “standard weight”, of approximately 65 minas (c. 32.5 kg), were commonly used (Veenhof 1972: 28-30; Veenhof and Eidem 2008: 82). Textiles were “systematically” used for wrapping the tin load into bundles of specific weight; two “textiles for wrapping” were used for each šuqlum, which was then loaded on one side of a donkey (Veenhof 1972: 28-30). Each donkey carrying tin was typically loaded with two šuqlum packed in two half-packs, one each hanging from either flank of the donkey; these packs would contain a total of around 130 minas of tin. A smaller top-pack of 10-12 minas of “loose tin”, in addition to several textiles and perhaps some food and personal possessions, would be loaded on top of the donkey. The large packs were sealed with clay bullae before departure to prevent tampering en route, while the ‘loose tin’ in the top pack could be used to pay expenses on the road (Veenhof 1972: 31-32, 45).

Several of the Kaneş/Kültepe documents indicate that tin was also transported in the form of oblong ingots or slabs; one document mentions a slab of approximately 4.1 kg, while another mentions a load of 3 slabs weighing 32 ¼ minas, or approximately 4.9 kg apiece (Veenhof and Eidem 2008: 82). These slab ingots are listed in groups which together make up a standard weight of approximately 29.6 kg, the

weight transported in one half-pack of a donkey (Veenhof and Eidem 2008: 82). This weight corresponds to a talent weight and appears to roughly correspond to the weight of the better preserved, heavier Uluburun copper ingots and also, to some extent, the weight of the Uluburun rectangular slab and oxhide ingots. The Kanış/Kültepe texts show that tin was imported in large amounts overland to Anatolia from an eastern source, perhaps the same source or sources which supplied the tin ingots of the Uluburun shipwreck 500 years later. There is no evidence that indicates the use of oxhide ingots in this period, however.

The importation of tin from a western source is also theoretically possible, but so far there is no direct evidence for such a link during the Bronze Age (Muhly 1973: 183, 268-269; 1985: 286-287; Penhallurick 1986: 123-138).⁵ Scraps of imported tin have been found on Nuragic sites in Sardinia, and small tin deposits are known on the island, but evidence of Bronze Age mining and exploitation of local deposits is lacking (Valera and Valera 2003: 3-4). Recently discovered alluvial cassiterite deposits and copper ores in the mountains of western Serbia, in the Central Balkans, also lack evidence for their exploitation during the Bronze Age. Although many mining activities and remains of artifacts such as hammers and ceramics in the region exists, these appear to be connected with the exploitation of copper only (Durman 1997: 11). Small tin deposits occur in Greece and Tuscany, but these show no evidence of exploitation in the Bronze Age (Skarpelis 2003; Gale and Stos-Gale 2002: 291). There is a similar lack of evidence for the export of tin to the Mediterranean from the Erzgebirge mines in the Alps of northern Bohemia and southern Saxony (Muhly 1985: 288-290; Stos-Gale et al. 1998: 119-120; Niederschlag and Pernicka 2002: 51)⁶ or from smaller deposits in the Eastern Desert of Egypt, Saudi Arabia and Yemen (Muhly 1985: 283; Rapp et al. 1999; Weeks 1999: 50, 60).

Thirty-two tin ingots were sampled from the Uluburun ship by drilling and the microscopic structure of the metal examined using optical emission spectrometry. The tin ingots found were found to be highly corroded, often with only a small core of metal remaining, surrounded by tin corrosion products, formed by a combination of tin, copper, and precipitation from seawater. Microscopic observation of the tin ingots showed that they were structurally

homogenous and had few inclusions of any kind, other than a few small crystals of magnetite (Hauptmann et al. 2002: 15-16). Chemical analyses of the sampled tin ingots were also performed. These tests showed that the tin ingots were extremely pure, with few trace elements, and that the lead levels in the Uluburun tin ingots were generally low. Among a group of 72 tin ingots, the lead concentrations ranged from less than 10 parts per million (ppm) to 2,759 ppm, with five of the ingots having concentrations greater than 3,000 ppm, and, in one instance, as high as 10,805 ppm. Of these ingots, 32 have lead concentrations below 100 ppm, 17 between 100 and 1,000 ppm, and 23 greater 1,000 ppm.⁷ Roughly similar groupings based on lead concentrations were obtained from earlier chemical analyses of tin ingots from Uluburun, and the Hishuley Carmel and Kfar Samir shipwrecks near Haifa, Israel. The tin ingots with low-lead content from Uluburun generally correspond closely to the lead content of tin ingots from the Hishuley Carmel shipwreck, while the Uluburun tin ingots with the higher lead content correspond to the lead content in an ingot from Kfar Samir shipwreck (Hauptmann et al. 2002: 16-17). The four tin objects from Uluburun (discussed below) match the analyzed group of tin ingots with the higher lead content (Pulak 2000a: 155).

Lead-isotope analyses of 99 of the Uluburun tin ingots also show two fairly distinct groups: a group (B) with an average high-lead content that overlaps well with polymetallic ores and tin from the Bolkardağ region of the Taurus Mountains of south-central Anatolia, and a group (A) with an average low-lead content that has no overlap with the lead-isotope fingerprint of Taurus ores (Fig. 10). It may be suggested, therefore, that Group B ingots originate from the Taurus range and Group A ingots from Central Asia (Stos-Gale et al. 1998: 119; Pulak 2000a: 153-155; 2001: 23). It should be stressed, however, that the proposed sources for the Uluburun tin ingots is only a tentative one. Future research and geological prospecting may reveal additional tin deposits with similar lead-isotope fingerprints to that of Group B located outside the Mediterranean region. Group A tin ingots, however, are from tin ores of geologically early origins that do not occur in the Mediterranean, and their source is likely to be in somewhere in Central Asia, including Afghanistan. Weeks (1999: 60-61) points out that tin deposits in Afghanistan vary in age from Precambrian to Oligocene; thus, if two nearby

tin deposits of different geological ages were exploited for tin, the resulting ingots could easily have different lead isotope signatures. What is clear, however, is that the lead-isotope data from the Uluburun tin ingots do not overlap with any of the major tin sources in Europe, specifically with those of the Erzgebirge region of the Alps or with tin sources in Cornwall and Spain (Pulak 2001: 23) (Fig. 11). Moreover, none of the ingots' lead-isotope signatures match that of an Early Bronze Age tin bangle found at Thermi on Lesbos (Stos-Gale et al. 1998: 119). The lead-isotope signature of the tin ingots found off the Israeli coast at Hishuley Carmel overlaps that of the Uluburun Group A tin ingots with low lead concentration; the lead-isotope signature of this group has not yet been matched to a specific tin source but, based on its early geological origins, is thought to lie in Central Asia. Of the 99 Uluburun tin ingots, for which lead-isotope values are available, 29 are of Group A, and have an average lead concentration of approximately 15 ppm. The remaining 70 ingots conform to Group B and have an average lead concentration of approximately 1,100 ppm (Fig. 10). There seems to be no clear correlation among the analyzed tin ingots between the shape of an ingot and its lead-isotope group. While tin oxhide ingots occur both in Groups A and B, Group A ingots consist of only oxhide ingots with three exceptions, two of which are wedge-shaped ingots cut from very thick ingots of indeterminate shape (the two wedges may have been cut from the same ingot), and a corner of a rectangular slab ingot.

Very few finished tin objects are known from the Late Bronze Age Mediterranean (Pulak 1997: 243; 2001: 43; Muhly 1980: 34-35). An Early Bronze Age bracelet or ring was found on Lesbos (Lamb 1936), and two rings occur in the Late Bronze III sanctuary at Phylakopi on the island of Melos (Renfrew and Cherry 1985). A tin ring was found in a tomb at Tel Abraq in the United Arab Emirates dating to the end of the third millennium BC (Weeks 2003: 123-124), and a tin-lead bangle dating to the early second millennium BC was discovered at Tepe Yahya in southeastern Iran (Thornton 2007: 130). Four tin objects were found on the Uluburun shipwreck. Three are vessels: a plate (KW 422), a mug (KW 313), and a tin pilgrim flask (1085). The pilgrim flask is very similar to an example from an 18th-Dynasty Egyptian tomb (Ayrton et al. 1904: 50, Pl. XVII.20); the other two

vessels are unique. Gillis (1999) has also proposed that some Mycenaean ceramic vessels had occasionally been covered in tin to give them the appearance of vessels made of precious metals (Gillis 1999: 141-142). The fourth tin object from the Uluburun ship is an elbow joint of a drinking straw (KW 419), probably for drinking beer. The drinking end and an elbow joint would have been metal, while the two tubes of the straw would have been made of cane (Weisgerber 2005).⁸ Iconographic evidence from Egypt and Anatolia show how a complete beer straw would have been used (Weisgerber 2005). The rarity of tin vessels in the Bronze Age Mediterranean suggests that the vessels on the Uluburun ship were prestige items intended as gifts for royalty or high-ranking individuals at the ship's destination.

The tin ingots of the Uluburun shipwreck represent the largest body of physical evidence for the large-scale transport of tin in the Bronze Age. Further archaeometric analysis is needed for determining the source or sources of the Uluburun tin, but preliminary lead isotope analyses suggest that the metal originated from at least two separate sources, one in the Taurus Mountains of south-central Anatolia, the other an as-yet unidentified source, most likely in Central Asia. Geological evidence for tin sources in the eastern and central Mediterranean open the possibility of local exploitation of tin for bronze, but no direct evidence exists for the use of any of these deposits as major sources of tin for the eastern Mediterranean in the Late Bronze Age. The bulk of the tin used in this period likely arrived in the eastern Mediterranean region along the same trade routes traveled by the tin ingots of the Uluburun ship, first being carried overland from their source or sources (probably in central Asia) to a Levantine port, then transported by sea to Cyprus and the Aegean, and other destinations. Evidence of these sea routes in the form of copper and tin ingots from underwater sites and port towns occurs on the coast of Israel, the southern coast of Anatolia, the Aegean, and at the port town of Mochlos in Crete. These finds are doubtless only a miniscule proportion of the total tin cargo shipped in this period.

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NOTES:

- ¹ Robert Brill of the Corning Museum of Glass, personal communication, August 31, 1989. The tin-lead alloy metal lumps or ingot fragments from Cape Gelidonya could have been produced experimentally, or the lead deliberately added as an adulterant, or to make a very early example of pewter or a solder; a single metal clasp from a 10th-century AD deposit at Shamsir Ghar in Afghanistan has a similar composition to the alloy recovered from the Cape Gelidonya wreck (Dupree 1958: 292).
- ² A single tin ingot from the Uluburun wreck (KW 199) was found to contain at its core two pieces of partially melted small lead bar ingots (Pulak 2000a: 155, fig. 24). This was an extensively corroded plano-convex discoid or bun ingot, much cruder than the other tin ingots found at Uluburun; unlike the other tin ingots, KW 199 appears less likely to have been cast at a primary source, and was perhaps formed from tin scrap instead.
- ³ The unique small oxhide ingot with short, bulky corner projections has an unusual lead-isotope fingerprint, which appears similar to the isotopic field of Lavrion in Greece. Even so, the ingot must have originated from Cyprus, but was probably made from copper ores that were different than those smelted for most of the other ingots on the Uluburun ship. (Pulak 2001: 21-22).
- ⁴ Müller-Karpe (2005: 492; 1994: Taf. 21,2) identifies a clay mold for bar-shaped ingots from Kanis/Kültepe as being for tin due to the approximate weight of four shekels (32-34 g); he reasons that this weight is perfect for adding to the re-melting of a one mina (approximately 500 g) copper ingot, to produce a 6-7% tin bronze, a similar copper-to-tin ratio found in bronze artifacts from the site. However, the re-melting of ingots or tin scrap imported by Assyrian merchants would be an unnecessary expenditure of time and fuel; the tin would melt more easily in small pieces than as a large ingot, and it could have simply been broken up and weighed before being combined with the copper.
- ⁵ Shipments by sea of tin ingots from western tin sources, however, do occur after the Bronze Age. The Archaic shipwrecks of Cala Sant-Vicenç (520-500 BC) (Nieto and Santos 2008: 238-241) and Bajo de la Campana A (6/5th century BC) (Bernal et al. 1995, 16: 30-32), both in southern Spain, and Roman shipwrecks of Bagaud B (late 2nd century/early 1st century BC) (Long 1985: 93-94; 1987: 151-153) and Port-Vendres II (AD 42-48) (Colls et al. 1977: 7, 11, 18) in southern France, Rodona (1st century AD) (Parker 1992: 365) in southern Spain, and Capo Bellavista (late 1st century BC/1st century AD) (Gianfrotta 1996: 138) off Sardinia, are among the more noted examples of wrecks with tin ingots. Since these ingots have not been subjected to lead-isotope analysis, their precise sources are not known.
- ⁶ Niederschlag and Pernicka (2002: 51) mention the discovery of Late Bronze Age or Early Iron Age pottery in the vicinity of a tin alluvial deposit in the Erzgebirge region. Bronze Age settlements are also located approximately 20 km from the ore deposits of the eastern Erzgebirge. However, no evidence for direct Bronze Age tin exploitation (stone hammers or other mining tools, mineshafts, furnaces, etc.) has been found.
- ⁷ The analyses for lead content and lead-isotopes were made at the Isotrace Laboratory at Oxford and have not yet been published in full.
- ⁸ Weisgerber (2005: 157) identifies the elbow-joint of the drinking straw as lead, but a chemical analysis by Robert Brill (personal communication, August 31, 1989) identified a sample from the object as tin-lead alloy.

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	1	2	3	4	5	6
a						
b						
c						
d						
e						
f						
g						

Table 1: Incised marks found on the Uluburun copper oxhide and plano-convex discoid or bun ingots, and tin ingots. Symbols f3-6, and g1-2 are marks found only on the tin ingots

THE ULUBURUN TIN INGOTS

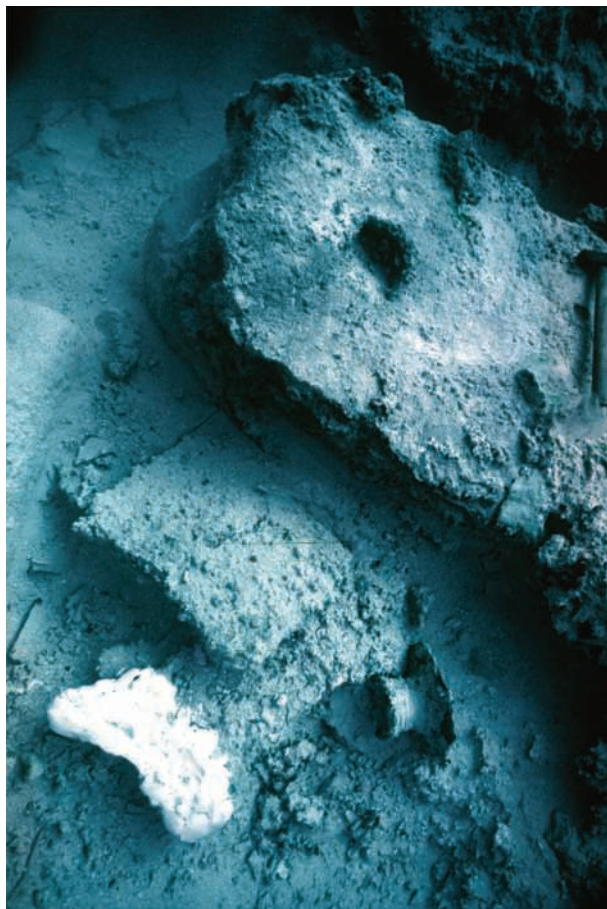


Fig. 1. Two intact tin ingots *in situ* on the Uluburun shipwreck. An oxhide ingot lies under a rectangular slab ingot, both of which are trapped beneath one of the ship's 24 stone anchors. The disintegrating portion of the oxhide ingot was reinforced with metal bars and consolidated with plaster before being raised to the surface.



Fig. 2. Quarter oxhide ingots cut in antiquity from four separate intact tin oxhide ingots. No matching quarters have yet been located. Clockwise from top left: KW 204, KW 633, KW 403, and KW 205. Note that three of the ingots are marked with incised marks: b4 (KW 205) and d6 (KW 204 and KW 403), see table 1.

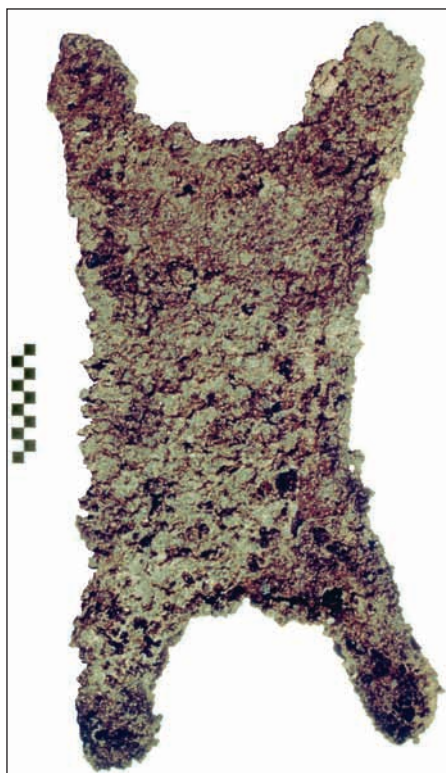


Fig. 3. One of three intact tin ingots (KW 1932) recovered from the wreck.



Fig. 4. Rectangular slab ingot (KW 2915) with corner cleaned of marine encrustation, revealing original surface of ingot blemished with corrosion "warts". Note chisel-punched hole at center of cleaned section.



Fig. 5. Three rectangular slab-ingot sections cut in antiquity (KW 2434, top left; KW 201, top right; KW 244, bottom). Note chisel-punched holes roughly corresponding to the center of each quadrant, presumably for ease of carrying the ingot and its fragments with lines passed through them. Lower ingot is half an ingot, hence the presence of two holes. That the lower left hole was cut through during the sectioning of the ingot indicates that all four holes were pre-drilled before the ingot was cut into sections. This indicates that the ingots were “designed” to be cut and transported in quadrants at a later time.

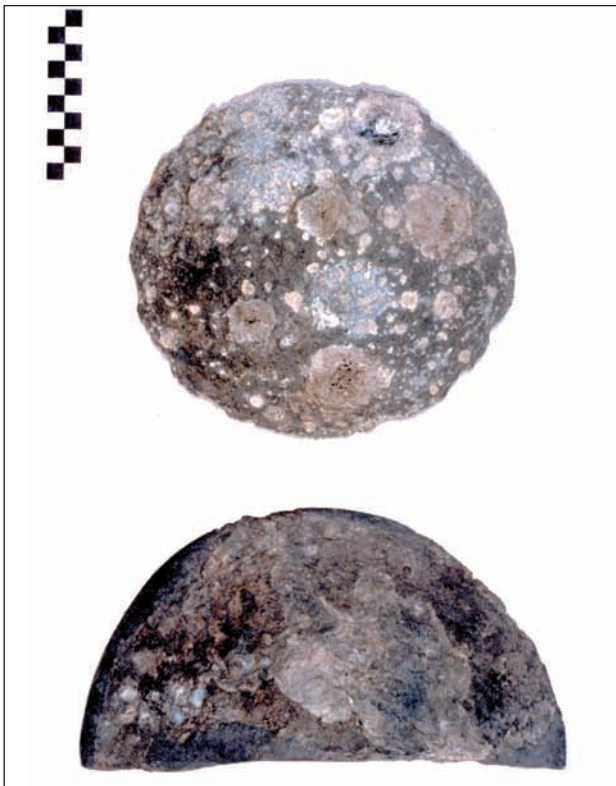


Fig. 7. Intact small (KW 401) and cut large (KW 519) plano-convex discoid or bun tin ingots.

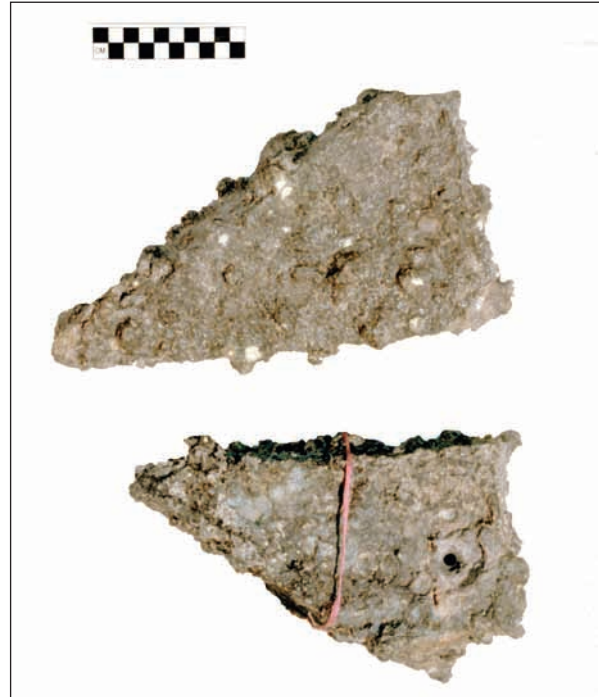


Fig. 6. Two tin ingot wedges cut from a very thick and heavy ingot of possibly discoid shape; KW2365 (top) and KW 2329 (bottom).



Fig. 8. Large rectangular tin ingot (KW 3935) with apical hole, resembling the stone anchors aboard the ship.

THE ULUBURUN TIN INGOTS



Fig. 9. Edge of quarter oxhide ingot KW 204 showing evidence of cutting from both sides with a chisel and then breaking the portion of bridging metal in the middle by repeated bending of the ingot in opposite directions.

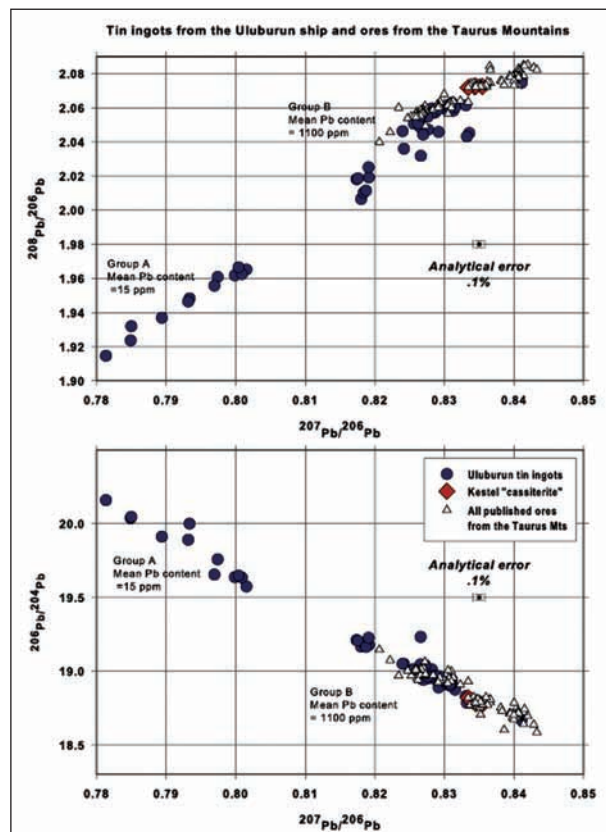


Fig. 10. Lead-isotope diagram of 99 UluBurun tin ingots and ores from south-central Taurus Mountains. The lead-isotope ratios of the UluBurun tin ingots form two separate signature groups: A and B. Group A tin ingots have significantly lower average lead concentration than that of Group B ingots. Only Group B ingots overlap the lead-isotopic field of Taurus ores. Courtesy of Zofie Stos-Gale, Noel H. Gale, and Robin Clayton.

Fig. 11. Lead-isotope diagram of European tin ores (cassiterites) from three mines in Cornwall, the Huber mine in the Erzgebirge region of the Alps, Val del Flores in Iberia, and 99 tin ingots from UluBurun. Ten tin ingots from Kfar Samir and five tin ingots from Hishuley Carmel shipwrecks off the coast of Haifa, Israel, are also shown. The two shipwreck ingots overlap the lead-isotope field of the UluBurun ingots, suggesting that all originate from the same source or sources. Courtesy of Zofie Stos-Gale, Noel H. Gale, and Robin Clayton.

