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A set Archaic anchor arm exposed within *P. oceanica* matte at Klazomenai/Liman Tepe, Turkey: A contribution for understanding marine stratigraphy

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Excavation in *Posidonia oceanica* matte in the ancient harbor of Klazomenai/Liman Tepe, on the Aegean coast of Turkey, demonstrates the stratigraphic archaeological potential of underwater excavation. Among the finds is a fractured wooden anchor arm exposed in situ. The anchor arm dates to approximately 600 B.C. based on stratigraphically associated ceramics, a dating supported by radiocarbon. The arm was found embedded in this marine sediment, which preserved the arm in its set position within the ancient sea floor. This archaeological excavation through matte and silt harbor sediments overturns the misconception that stratigraphic excavation is impossible in a marine environment. The excavation further boosts optimism regarding the preservation of maritime heritage along the littoral of the eastern Aegean and the many other Mediterranean regions where *Posidonia oceanica* grows.

Keywords: marine excavation, *Posidonia oceanica* matte, Archaic Period harbor, anchor, Klazomenai/Liman Tepe

Introduction

The stratigraphic coherency of marine-excavated sediments is often doubted. This paper takes the case study of the stratigraphic situation of a wood and metal anchor arm exposed during joint University of Haifa and Ankara University underwater excavations at Klazomenai/Liman Tepe to demonstrate that such doubt is unfounded in this case. It will further be demonstrated that substantial stratigraphic sequences commonly exist in Mediterranean marine environments, being found along the shores of much of the basin.

The site of Klazomenai/Liman Tepe is located ca. 40 km west of Izmir, Turkey, on the northern side of the Çeşme Peninsula in the municipality of Urla (FIG. 1). According to Classical writers, Klazomenai was the name of the Iron Age through to the Archaic Period site, but researchers of the prehistoric levels prefer to employ the geographic name of the hill, Liman Tepe ("Harbor Hill"). Its location in the Bay of Izmir to the lee of near-shore islands protects the hill from large fetch storm waves and swell, a beneficial situation that partly accounts for the settlement's relatively early occupation. Terrestrial archaeological excavation has revealed that the site was inhabited from at least the Chalcolithic era (ca. the 5th millennium B.C.) through the Roman period, with perhaps only short periods of abandonment (Erkanal 2001).

The favorable geographic situation of the site, including a direct route to Anatolia's interior, promoted maritime and terrestrial trade. In the first half of the 1st millennium B.C., the area was the site of the Ionian settlement of Klazomenai until it was relocated on an island, now named Karantina, as a consequence of the Persian invasion and the sacking of the Lydian Empire (Ersoy 2004: 62–63). Pausanias (1933: 7.3.9) and Pliny (1961: *HN* 5.31.117) attribute the remains of an ancient causeway connecting this island with the peninsula to Alexander the Great's patronage. These remains are still visible today alongside the modern road (FIG. 2). This causeway served to unite the settlement of Klazomenai on the island, with the rival settlement of Chyton on the mainland (Özbay 2004: 149). After the causeway was constructed, the primary settlement appears to have remained on the island, and a harbor serving Klazomenai, likely dating from the Classical and Roman periods, was situated on the western side (Erkanal 2014: 301).

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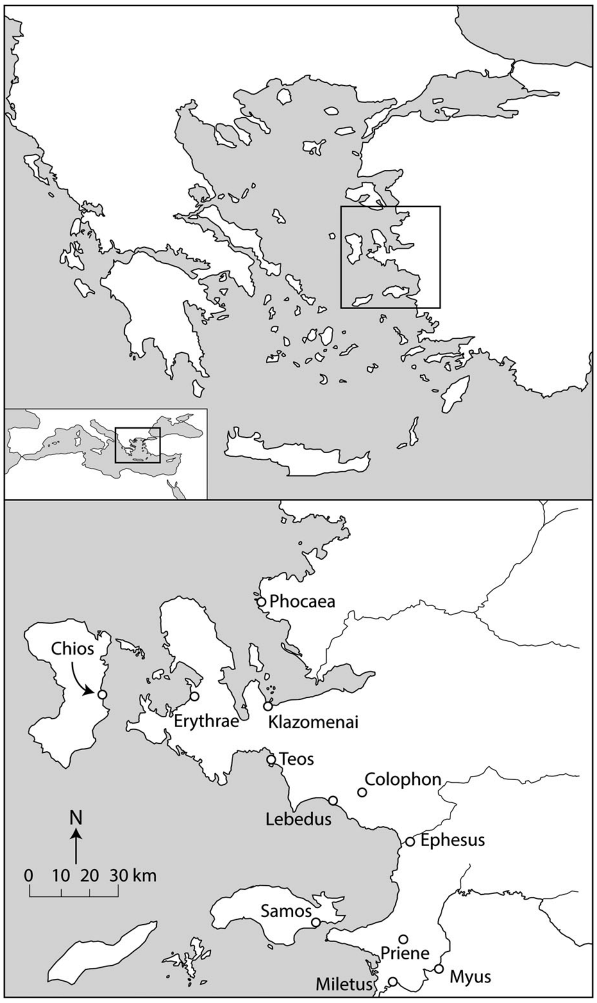

Figure 1 Map illustrating the location of Klazomenai/Liman Tepe on the southern shore of the Bay of Izmir and the other Ionian cities. Map by G. Votruba.

The two most pronounced features of the underwater boulder-strewn site are a tongue-shaped projection ca. 140 m long and 40 m wide, and a secondary mole projecting perpendicular from it with a visible length of ca. 30 m (FIG. 2). As the greatest fetch and prevailing winds are from the north, these two features, when partially emerged, would have created a protected harbor basin on their lee side, with perhaps 100 m of all-weather quay space along the lee edge of the large mole.

Excavation within the larger mole in Area D has determined that it was constructed during the Archaic Period and was also used in the 4th century B.C. (Artzy 2009: 14). The moles are now submerged at least 1 m, which may merely be the result of gradual increases in sea level and erosion, although abrupt tectonic events cannot be excluded (Goodman *et al.* 2008; Goodman *et al.* 2009: 101; after Lambeck 1995, 1996). Although Goodman and colleagues did not identify sea-level indicators diverging from Lambeck's global isostatic models, that neotectonics is a significant factor in the Aegean region is well documented (e.g., Fouache and Dalongeville 2004). Nearby, there are indications of terrestrial structures at or below sea level, including Roman villa foundations and parts of walls of an Archaic cemetery (Müller *et al.* 2009: 127, 133). The recent geologic history of the region is based on superimposed sequences of deltas, formed as a result of Quaternary glaciations, around projecting volcanic, limestone, and marl bedrock (Aksu *et al.* 1987).

A trench, Area A3, was excavated with the use of a diesel pump flexible hose dredger system during short periods between 2002 and 2008, near the distal end of the smaller mole. The objective was to study the architectural remains and the stratigraphy within the hypothesized adjacent harbor basin (FIGS. 2, 3). The lightly sloping sea floor adjacent to the exposed portion of the mole is at an approximate depth of −2.75 m (depths reported are in relation to mean sea level), and the trench was excavated nearly 3 m at its deepest point (reaching a total depth of −5.6 m). The modern sea floor in the area consists primarily of green *Posidonia oceanica* (L.) Delile seagrass leaves (ca. 50 cm long) that hardly sway with the regularly low-energy submarine currents of the area, interspersed with pockets of sand typically no more than 10 cm thick.

Posidonia oceanica matte and consolidated marine stratigraphic sequence

At the commencement of excavation at the underwater site, it became clear that the primary material making up the present sea floor is unlike that generally noted in harbor excavation reports and geoarchaeological studies. The sediment is a mixture ranging from fine silt to large-grained sand, within a primary matrix of organic material seemingly derived from the roots of plants. Upon referring to the marine biological literature, it became clear that the material being excavated is what is called "matte." Matte is the product of a single species of marine phanerogam, *Posidonia oceanica*. It is one of several seagrass species that grow in the Mediterranean but is by far the most dominant, and is the only one with root and rhizome features robust and fibrous enough to remain intact after the organism itself has died (Borum and Greve 2004: 5–6; Gobert *et al.* 2006: 391). This preservation is also partially due to the anoxic conditions of the matte. While the leaves disintegrate, the substructure of the plants, along with trapped sediments, serves as a base for the growth of future generations. The living plants spread, and their roots become entangled among the slowly disintegrating, organic remains (FIG. 4). Matte accumulation ultimately results in an overall slow rising of the sea floor, sometimes described as reef formation (e.g., Pasqualini *et al.* 1998: 362; Borum and Greve 2004: 5; Marbà *et al.*

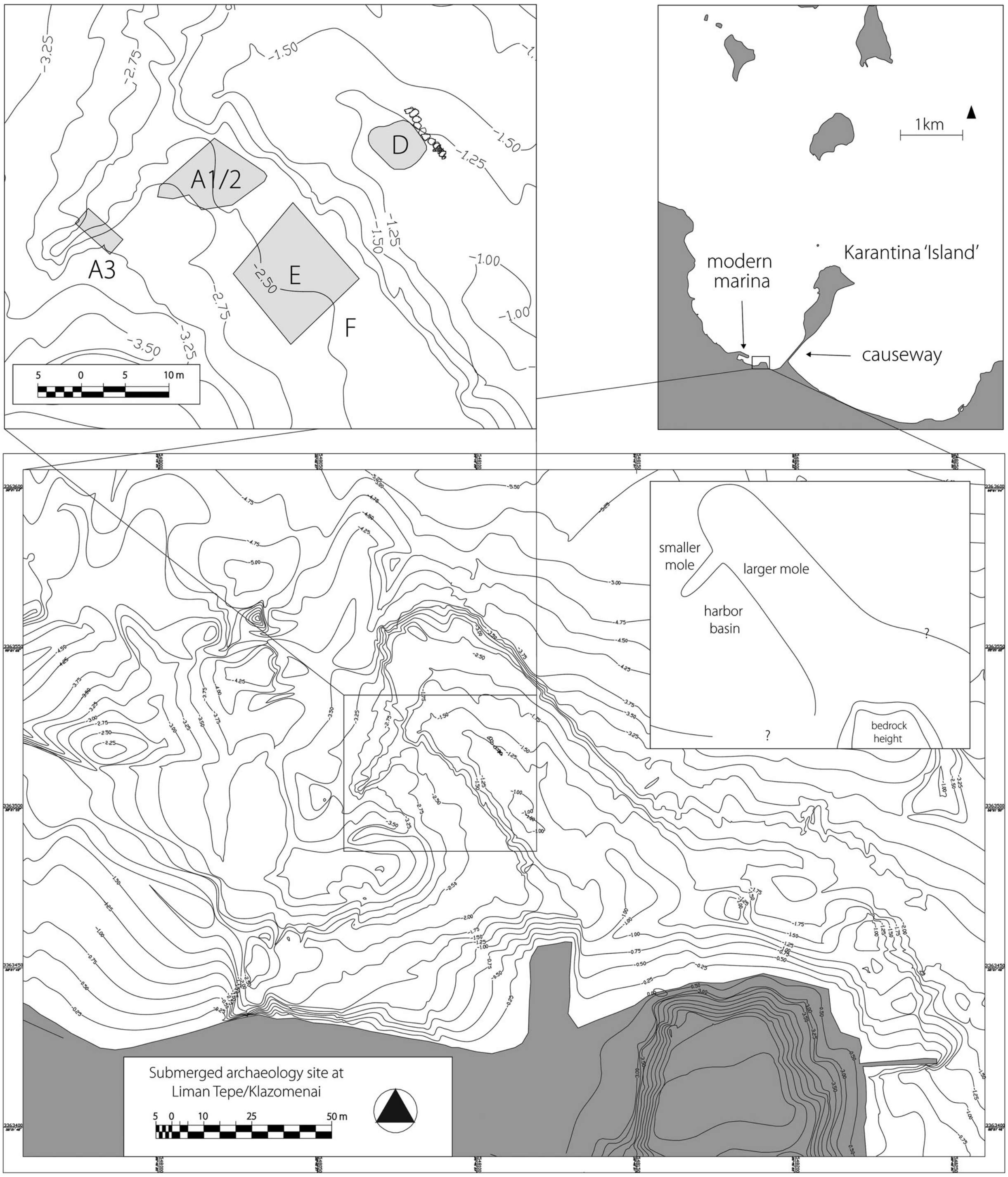

Figure 2 The region and bathymetric map of the submerged features and excavation trenches mentioned in the text. Inset within the map is a sketch of the presumed outline of the moles whose original shoreline remains uncertain. Map by Y. Salmon and G. Votruba.

2004: 15), and is largely independent of sediment deposition rates (Mateo *et al.* 1997).

Far from being unique to the area of Urla (Pergent-Martini and Pergent 1994), *P. oceanica* is a highly significant factor in the formation of much of the Mediterranean submerged coast, growing extensively from southern Spain to Cyprus, including much of North Africa (Borum and Greve 2004: 5–6; Gobert *et al.* 2006: 388–389, 391). *P. oceanica* meadows around the island of Corsica have been mapped and assessed as an example; the species occupies nearly 50% of the coast (Pasqualini *et al.* 1998). The remainder is mainly sand patches that are primarily the result of laying bare and subsequent infilling with sand from the use of explosive devices, trawling, and dragging boat anchors (Pasqualini *et al.* 2000).

The species avoids the relative cold water (and generally varying density) entering through the Strait of Gibraltar. The species is also sensitive to salinity, which possibly explains the almost complete absence

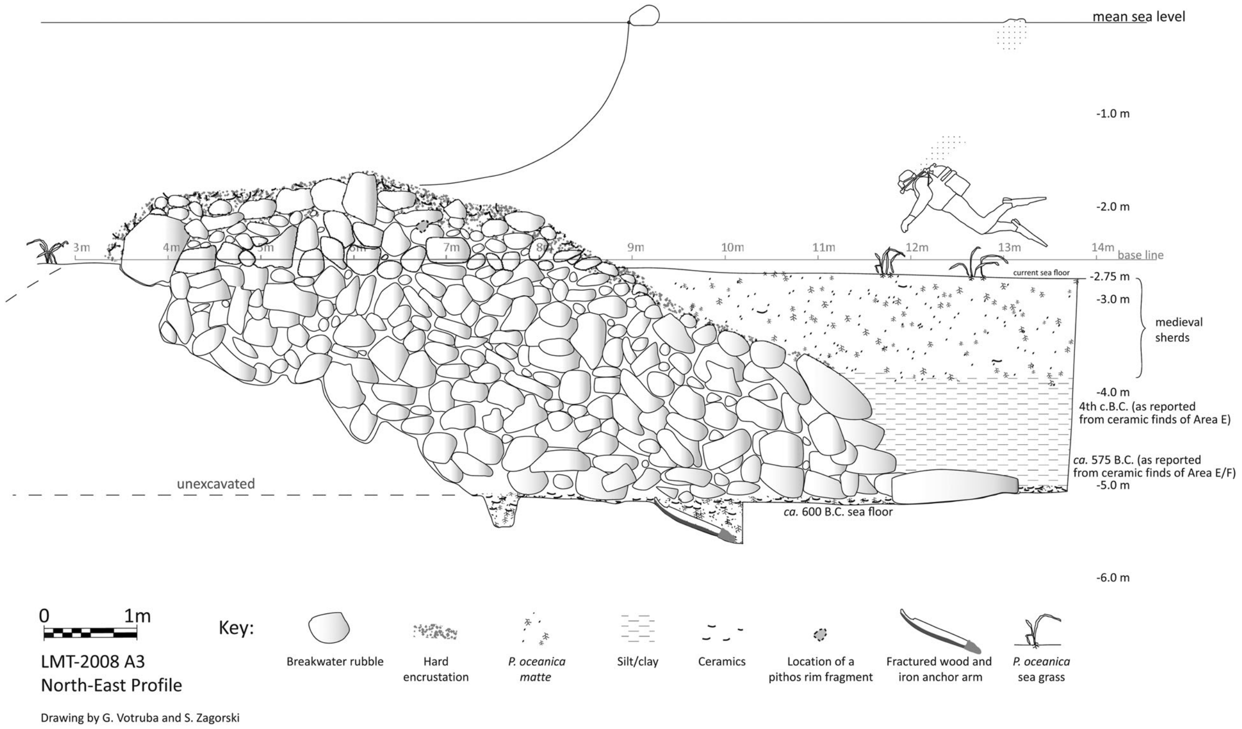

Figure 3 Profile drawing of the Area A3 trench and the in situ location of the anchor arm. The trench cuts through the smaller mole with a perpendicular orientation. Drawing by G. Votruba and S. Zagorski.

of *P. oceanica* from the easternmost Mediterranean coast (Lipkin 1977: 265, 268). Due partially to the lower salinity, the species largely eludes deltaic regions (notably the Nile, the Rhône, and the northern Adriatic), but this is also a factor of the decreased water clarity as the phanerogam is dependent on accessibility to sunlight. In cases where the water is exceptionally clear, the species can grow to ca. 50 m deep,

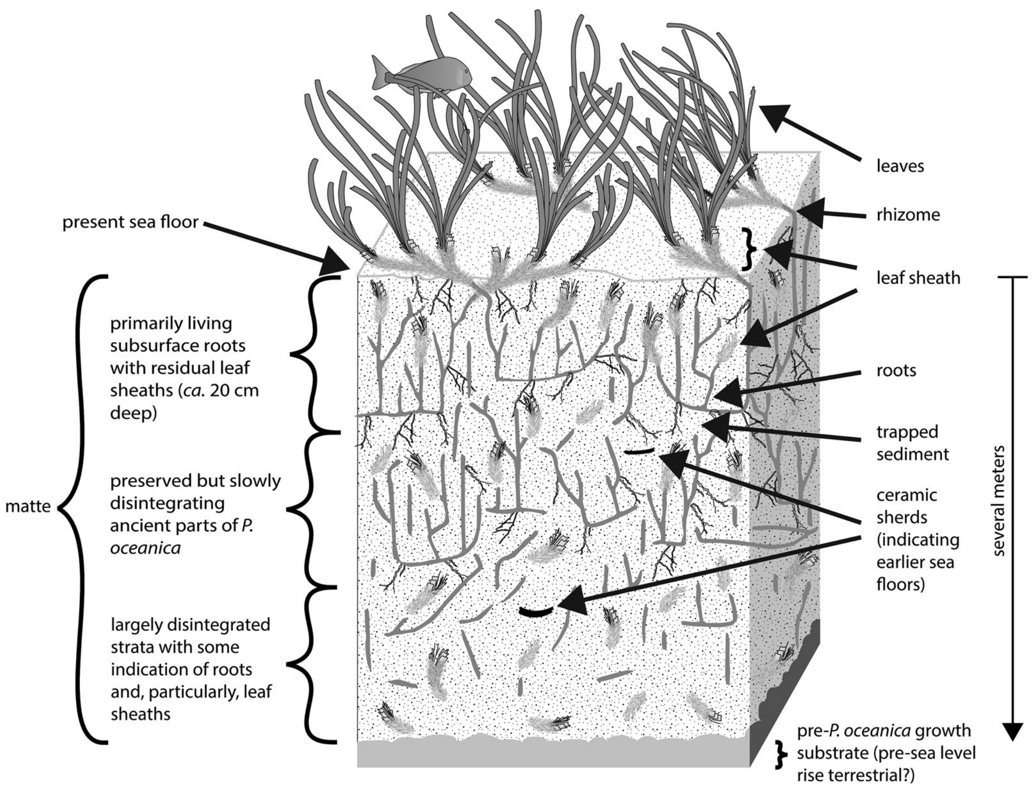

Figure 4 Schematic drawing of *Posidonia oceanica* matte as observed during excavation and reported in biological literature. For the sake of illustration, the organic fraction (rhizomes/roots) of the matte is heavily under-represented. Illustration by G. Votruba; based on Borum and Greve 2004: fig. 1.7, and Gobert *et al.* 2006: fig. 3.

but in more turbid waters, it may be limited to 10 m. It can grow as high as the intertidal zone. Ultimately, *P. oceanica* is able to grow along most of the Mediterranean coastal sea floor, where the species tends to display a colonizing behavior, growing in patches or even great swaths called "meadows." *P. oceanica* meadows behave as significant sediment sinks as the space between the undulating leaves is largely of dissipated energy, promoting the deposition and retention of suspended sediment (Gacia and Duarte 2001). This largely explains the fraction of silt and sand seen within the matte.

P. oceanica also has a wide chronological range, with several studies demonstrating that meadows and their residual matte have been common in the Mediterranean for thousands of years. These studies suggest that the species would have followed the Holocene rise in sea level (commencing ca. 11,000 B.P.), covering where previously there had been terrestrial sediments (Mateo *et al.* 2002: 168). In several locations, coring projects and studies of heavily eroded *P. oceanica* matte have revealed that it can reach several meters in thickness. It has thus been calculated that the sea floor rises at a rate of a centimeter or so per decade (Mateo *et al.* 1997, 2002; Lo Iacono *et al.* 2008). Mateo and colleagues (1997, 2002) have studied matte off the southeastern coast of Spain, the southern coast of France, and the western coast of Italy, recording sequences as deep as 5 m below the sea floor. Molinier and Picard (1952) recorded sections of at least 6 m thickness along the coast of France. Lo Iacono and colleagues (2008) studied matte sequences off the eastern coast of Spain, coring to a depth of 6 m where the matte was in contact with gravelly deposits and rocky substratum, which matched the thickness of the matte as previously interpreted through seismo-acoustic imaging. The imaging further suggested that the maximum thickness values within the study area's small bay could be 6.5 m.

Thick swaths of matte have been reported and excavated to expose a number of shipwrecks, but the strata itself has only been briefly described (e.g., Nesteroff 1972: 176; Beltrame 1998: 152, 154). Shipwreck assemblages where *P. oceanica* is specifically reported to have preserved them include Culip (Mateo *et al.* 1997), Cavoli (D'Agostino 1991: 187, 190), La Rabiou (Joncheray and Joncheray 2009: 68, 83), Dramont G and Nord-Camarat (Joncheray 1987: 54, 75–76, 81–82), and Mazzarón 2 (Negueruela *et al.* 2004; Negueruela 2004, 2005). In the last, a sample was collected to help radiocarbon date the ship. A particularly well-documented wreck, with an overlaying *P. oceanica* matte around 1–2 m thick above the assemblage, lies at the bottom of the bay of Madrague de Giens (Tchernia 1978: 10–11, see particularly pls. I, III, and XII). Girard (1978: 112), in explaining the pollen sampling of the site, describes the matte as consisting of putrefied roots incorporated with shell and mineral sand, creating a layer that sealed the ship and that acts as a sediment trap preserving the pollen within (see also López-Sáez *et al.* 2009). Several researchers have remarked that many other wrecks are undoubtedly hidden beneath *P. oceanica* sea floors (Gianfrotta and Pomey 1980: 57–59; Joncheray 1989: 136).

Based on most wrecks and harbor excavations cited to date, the material is described using its generic and colloquial names of "Poseidonia," "seagrass," "eelgrass," or "Poseidon grass." At Populonia, in western Italy, an attempt to excavate a section through an ancient breakwater was thwarted because "the thick layer of weed (about 1.2 m) known as *poseidonia* above the ancient bottom level made excavation impossible" (McCann *et al.* 1977: 282; for similar comment regarding *P. oceanica* matte related to shipwreck excavations, see Dumas 1964: 26). Our experience at Liman Tepe may help qualify this statement, which demonstrates that although excavation through matte is not impossible, it is nevertheless rife with difficulties. Commencing from the sea floor surface, the intertwined and highly fibrous roots create a formidable barrier that can be broken only with the use of hand tools (and great physical effort), in conjunction with dredger intake hoses. Although each strike of the hand-hoe cuts through the fibrous roots, it also releases fine silt into the water column. This rapidly reduced visibility and required careful placement of the dredge intake hose adjacent to the point of the strike. Particularly problematic was the need to continually adjust the orientation of the ballasted dredge exhaust to stop the current from carrying the suspended silt that was constantly being extruded as a grey cloud back over the trench. Often, the current was nonexistent, which made clouding of the entire area slow but inevitable.

The lower roots of the matte are easier to cut through and excavate due to their longer disintegration period. Although some compaction is evident, it is minor because the high proportion of sediment within the peat largely offsets any compaction even considering the degradation of the organic material (Mateo *et al.* 2002: 170). Ultimately, the matte retains a constant hard sponge-like consistency throughout, with firmness increasing with depth. The rhizomes, particularly, tend to disintegrate earlier and then the roots, and finally, the fibrous leaf sheaths display the greatest preservation (Mateo *et al.* 1997: 108). The primary visible detritus of the deepest excavated strata at Klazomenai are the leaf sheaths that appear as furry elongated bunches one or two centimeters thick and several centimeters long

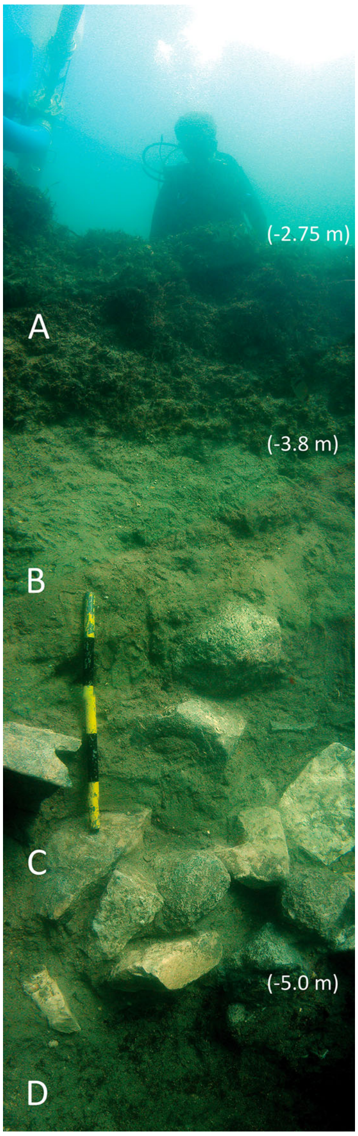

Figure 5 Vertical photomosaic imaging of the southeastern baulk of the A3 trench. The silhouette of a diver sitting upon the modern sea floor is visible above. The harbor basin's conspicuous stratigraphic layers are clearly discernible: A) The dark organic uppermost *Posidonia oceanica* matte layer; B) The light grey fine silt/clay that lay upon the inner harbor talus stones; C) Of the smaller mole; D) Beneath these stones the Archaic *P. oceanica* matte begins. The scale bar is 50 cm. This baulk face is sloping, located between the 13 and 10 m lateral basepoint marks of the profile drawing of Figure 3. Photograph by G. Votruba.

(cf. FIGS. 4, 5, 6, 7), although considerable root fragments were visible as well.

Based on the above, the presence of *P. oceanica* matte is beneficial for archaeological research. The sections of the excavated area remained stable, and changes were observed along the baulk faces. Although the excavation of the upper portion of the matte was a difficult process, the consolidated consistency preserved the stratigraphy. The few, as yet generically dated "medieval," sherds found within the upper ca. 1 m thick matte layer displayed a pattern of increasing age with depth (FIG. 5; layer A). The levels that these sherds were found indicate the general location of the past sea floors upon which the sherds were deposited. The sparseness of these encrusted sherds is indicative of occasional storm-wave wash instead of significant nautical activity in the area, and there is little evidence of anything but minor settlement in the vicinity during the Medieval period.

When it became clear that the stratigraphy was consolidated and chronologically coherent, the excavation proceeded by employing terrestrial methodology and precise lateral measurement. The difficulty of using optical leveling instruments underwater prevents the sub-centimeter elevation measurement accuracy feasible terrestrially. Measuring from land with such devices also results in significant error and is largely dependent on the ability of the divers to keep the heavy and awkward reflector pole true against the waves, currents, and blinding reflection of the sun upon the sea surface. When base points were established, the depth could be measured with plumb-bobs and bubble level lines. For practical reasons, the daily level measurements were made using digital depth gauges that provide resolution of 10 cm increments, which were measured each season against a suspended measuring tape for accurate calibration. Because the sea level changes constantly, the value of the gauge must first be compared with that of fixed base points set up around the trench.

Overcoming a misconception about marine stratigraphy

The marine excavation at Liman Tepe has demonstrated that a misconception must be overturned regarding the nature of marine stratigraphy. Statements such as the following by Hohlfelder (1998: 316) should be reconsidered: "Excavating stratigraphically in the Mediterranean is always a difficult task, and often it is simply impossible. The currents, waves and surge at times seem to deny access to the unique archive of data that are sequestered beneath the ocean floor. Trench balks are impossible to maintain. Unwanted material can appear in a zone of archaeological concern with alarming regularity" (for the same sentiment, see Holum *et al.* 1988: 91; Oleson and Hohlfelder 2011: 822–824). This situation

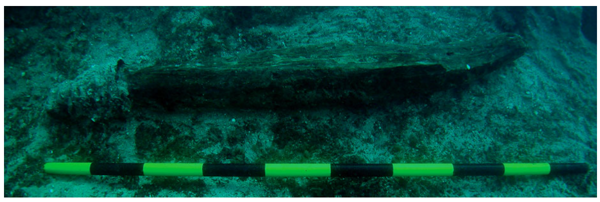

Figure 6 The eastern profile of the anchor arm. The darker portions among the sediment are the preserved leaf sheaths and roots of the Archaic *Posidonia oceanica* matte among lighter-colored fine sediments. Photograph by G. Votruba.

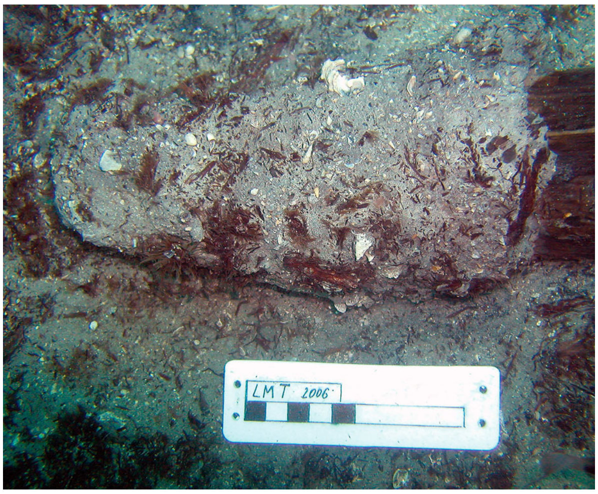

Figure 7 The superficially corroded iron tooth of the anchor arm. The chemical process of the iron's concretion has bound the surrounding sediment to it, which is stuck hard and cannot be cleaned. The string-like bunches among the grey sediment are the preserved fragments of leaf sheaths and roots of the Archaic *Posidonia oceanica* matte, through which the anchor arm had penetrated. Photograph by G. Votruba.

does not apply to the underwater excavation at Liman Tepe, especially Area A3 where sand stratigraphy, or other forms of unconsolidated sediment, are absent. Rather, Mateo and colleagues (2002: 171) have concluded, due to matte's firmness, that bioturbation, erosion and re-disposition phenomena, are unlikely to have a significant effect on the chronology of its strata.

The assumption that consolidated marine stratigraphy is rare or impossible was reached because the majority of marine excavation has been completed within harbor sediments in the Levant (Caesarea Maritima, Atlit, etc.) where *P. oceanica* is not common, and where the exposure of the coastlines results in regularly unconsolidated sand stratigraphy. The region is particularly hampered by the sediment forced northward from the Nile Delta due to the prevailing counter-clockwise trend of the sea currents along the coastlines of the Levant (Inman and Jenkins 1984).

It is also apparent that the matte sediment has not been sufficiently described at marine harbor excavations elsewhere, such as at relatively close Samos and Kenchreai. At Samos, the only description of the excavated sediment upon and adjacent to the outer slope of the great mole is that it is a layer of organic material created by the constant sedimentary action of the sea (Simossi 1991: 288). However, Simossi's illustration (FIG. 8) demonstrates that it was possible to excavate a trench with straight baulks. Regarding Kenchreai, the description of the stratigraphy within one harbor basin trench (4B) is more explicit: "Beginning at the sea bottom, thick eel grass with intertwined roots that had to be removed by chopping with knives. Below this point, there was a very thick, black accumulation of mud, most likely from silting and root decay" (Scranton *et al.* 1978: 135). The qualification of mud in describing the matte is possibly due to the heavy amounts of silt extruded from the matte while the divers attempt to excavate through it. Ultimately, although *P. oceanica* matte is not specifically identified for Samos and Kenchreai, the descriptions of the sediment are congruent with this material.

Surprisingly, marine geoarchaeological studies describing ancient Mediterranean harbor sediments have also been limited regarding the ubiquitous *P. oceanica* matte. For instance, Marriner and Morhange's (2006a, 2007) "Ancient Harbor Parasequence" is based primarily upon sedimentological profiles from Alexandria, Caesarea, Kition, Marseilles, Sidon, and Tyre, sites largely outside the primary growing regions of the phanerogam. The sedimentological definition of their "Harbor Abandonment Surface (HAS)" of a "Transition from fine-grained harbor silts and clays to course sands and gravels" (2007: fig. 31) should be reconsidered for the Mediterranean coastlines where *P. oceanica* is present and where matte formation is following mole submergence. *P. oceanica* matte has also not been considered in the recent geoarchaeological investigation at the Liman Tepe site where clastic sediments are emphasized (Goodman *et al.* 2008, 2009). Goodman and colleagues (2008: 1271) were misled, as they excluded macrobiological material from their analysis, apparently unaware of the principles of matte formation.

Harbor silts, Archaic *P. oceanica* matte sea floor, and the situation of the anchor arm

Beneath the *P. oceanica* matte layer adjacent to and covering much of the middle talus boulders of the moles (FIGS. 3, 5: layer A), a ca. 1 m thick layer of particularly fine silt and clay sediment appears somewhat abruptly (FIG. 5: layer B). This is believed to be the siltation resulting from the construction of the enclosed harbor basin, which created a lagoonal environment and therefore rapid fine sediment deposition (cf. Goiran and Morhange 2001: 655; Marriner and Morhange 2007: 175–177). At the same time, the increased turbidity caused by harbor activity generally halted the growth of *P. oceanica* (cf. Pasqualini *et al.* 1998: 363–365). This hypothesis is supported by the observation that the lowest point of the silt is at the same level as the basal mole stones (–5.0 m), as observed in Area A3, illustrating that the silt deposition commenced immediately after the smaller mole's construction. The excavation trenches elsewhere within the harbor basin (Areas A1/2 and E/F; FIG. 2) reveal that this silt/clay layer extended throughout the enclosed area. In Area E/F, an area

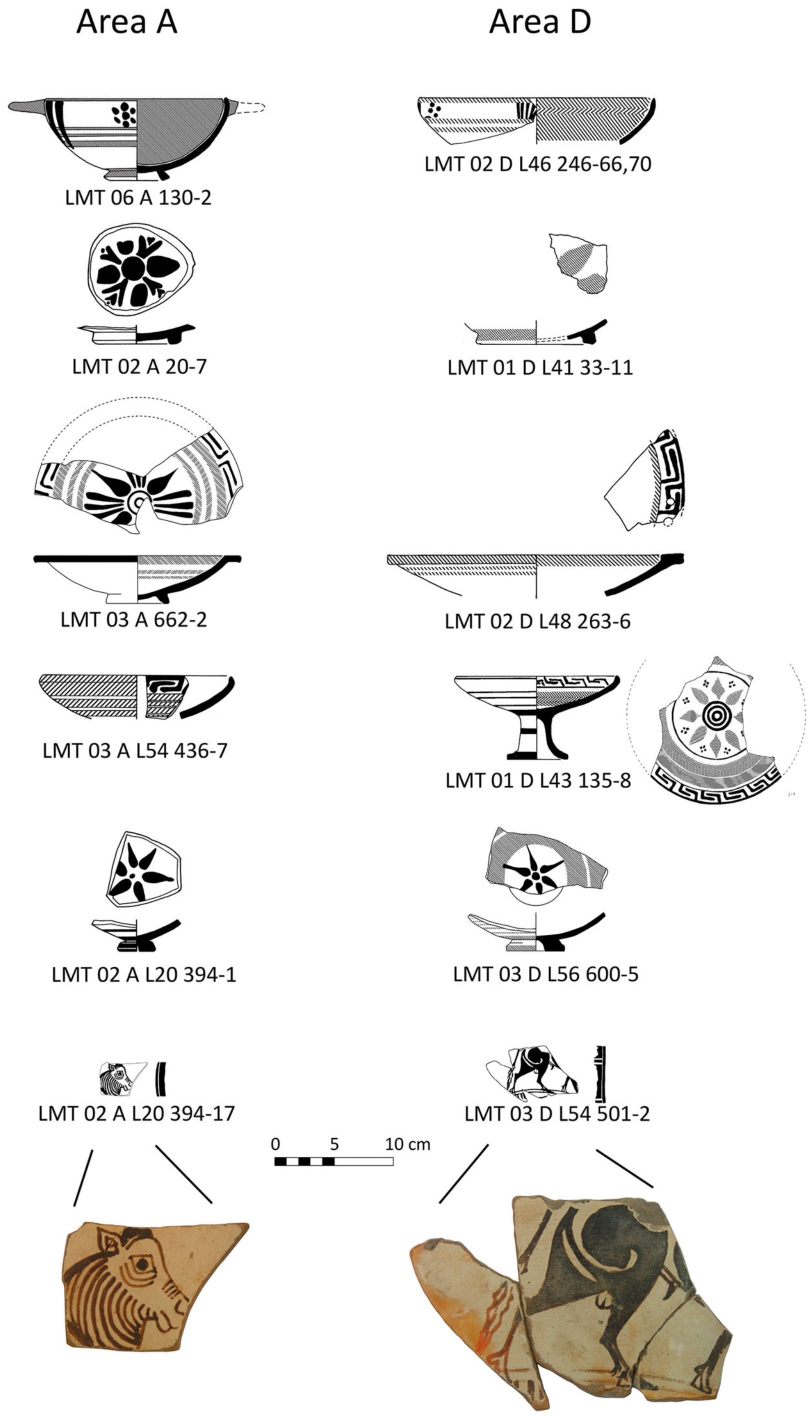

Figure 8 Examples of ca. 600 B.C. pottery found in the Areas A and D excavations. Those from Area D derive from the middle and lower stones of the larger breakwater. Those from Area A were exposed either on top of or within the Archaic *P. oceanica* layer. The lower two are identified as Chian. Compiled by M. Artzy; drawings by S. Zagorski.

closer to the center of the harbor, a considerable number of ceramic fragments were found within the silt layer. The abundant 6th century B.C. material reported within the lower section of this silt layer in Area E/F, at ca. –4.70 to –5.0 m (Erkanal *et al.* 2014a: 504), indicates a date within this century for the functioning of the harbor as an enclosed basin. The same date as a terminus ante quem can therefore be applied to the lower architectural stones of the small breakwater as this silt layer covers the lower section, which is at the same elevation (FIG. 3). Also in Area E, near the upper portion of the silt stratigraphy, at ca. –4.3 to –4.5 m, a dense deposit of 4th century B.C. material was exposed, including metal parts of anchors (Votruba and Erkanal in press; see also Erkanal *et al.* 2012: 481). This confirms that the harbor had several periods of use, as earlier identified in the excavation of Area D (Erkanal *et al.* 2010: 363–364, 2011: 452–453, 2012). That ceramics were absent within the silt stratigraphy in Area A3 and that no significant finds were made in Area A1/2 must demonstrate that ships did not regularly moor in the immediate vicinity of this smaller mole after it was constructed. There is no obvious indication of dredging, which may primarily have been a phenomenon of the Roman period (cf. Marriner and Morhange 2006b, 2007: 179), during which the harbor appears to have been inactive.

A second *P. oceanica* matte layer appears beneath the silt at ca. –5.0 m, in all of the inner basin trenches, upon which the stones of the smaller mole stand (FIGS. 3, 5: layer D). On its surface, there is a horizon of dense ceramics dating to the late 7th and/or early 6th centuries B.C. which is particularly conspicuous in Area A3. The ubiquitous material is presumed to be the result of activity that occurred when ships were at anchor (Artzy 2009). That ceramics continue beneath the smaller mole stones, and therefore predate them, may make the concept of an "anchorage" instead of a "harbor" more appropriate for this phase. The *P. oceanica* matte sea floor may have been ideal for anchoring with stock anchors, a design common from the Archaic Period onward (cf. Gianfrotta 1977; Kapitän 1984: 37–38). An angled and pointed arm would set relatively easily within the matte but remain embedded even during heavy winds due to the dense and consolidated nature of the sediment. Stable holding ground is one of the most important factors for safe anchorage.

The earliest architectural stones of the larger mole may have been contemporary with the anchorage level since the ceramics found among the lower stones at Area D are similar, including contemporary Chian figural sherds (FIG. 8). Therefore, the larger mole may have existed before the construction of the smaller mole, which would have provided an incompletely enclosed anchorage area, too far exposed to allow silt accumulation. It also remains to be determined whether an earlier feature, such as an island, may have formed the framework for the larger mole, such as its unexcavated seaward end (Goodman *et al.* 2009: 102). In either case, it is apparent that significant anchoring activity occurred around Area A3 immediately before the construction of the smaller mole.

Similar to the Medieval ceramics, these partially encrusted Archaic ceramics also continued to appear below the clearly defined ancient sea floor level, in this case for perhaps 15 cm beneath the surface, with the sterile sediment below presumed to be the pre-anchorage sea floor. This again demonstrates the overall trapping of ceramics and sediment by the ancient *P. oceanica* seagrass roots and the rise of the sea floor via matte production, as particularly indicated by ubiquitous leaf sheaths and roots that are fragmentary but still clearly visible throughout the excavated portion (FIGS. 6, 7). This process in addition to multiple penetrations of anchor arms would result in the appearance of ceramics below the sea floor level.

This lower Archaic matte may not, however, have been of precisely the same formation as the upper Medieval/modern matte. Possibly, the Archaic *P. oceanica* matte had contained greater amounts of trapped silty sediment in relation to the organic fraction than the post-harbor matte. Such a distinction could be attributed to the construction of the causeway to the east of the harbor site that caused changes in the ecology of the area (FIG. 2). It is apparent from the bathymetric survey and aerial photographs that sediment input is greater on the eastern side of the causeway (eastern bay) than on the western side (Şahoğlu *et al.* 2008: 77; Goodman *et al.* 2008: 1278). It should be emphasized that all the significant seasonal stream outlets run into the eastern bay. It is possible that, before the late 4th century B.C. construction of the causeway, the sediment-carrying prevailing current was westerly, as is the case for the eastern bay today. The orientation of the moles of the harbor would have effectively served to deflect such prevailing current-carried sediment away from the harbor entrance and basin (unlike the opposite orientation of the modern marina located only 150 m further to the west). Thus, the Hellenistic causeway may have performed a secondary parameter of damming the carried silt extruded from the streams, restricting it to the eastern basin. As a result, in the area of the artificial harbor, the sediment deposition regime may have been greater in the Archaic Period than it was during the period of the post-breakwater submergence matte formation. Greater sediment deposition may have made the earlier matte somewhat softer but, if so, not as much as to prevent the fracture of the set anchor arm.

This is the Archaic matte sea floor that the anchor arm had penetrated. This occurred before the construction of the small mole since the object is sealed by the mole's architecture. The arm is preserved up to 97 cm, including its protective metal tooth fitted to the end (Votruba and Artzy in press). It was found embedded at a ca. 25-degree angle, as appropriate for a stock anchor (e.g., the wooden anchor found with the ca. 400 B.C. Ma'agan Mikhael shipwreck; see Rosloff 1991, 2003), and oriented with its tooth pointing toward the southeast (130 degrees). The upper end commences at ca. –5.0 m, and the lower end reaches –5.6 m. The upper face and the eastern side were exposed through excavation to allow in situ preservation but also sufficient to enable plan and profile recording (FIGS. 6, 7). The anchor arm is currently preserved beneath sandbags and a thick overburden of sediment, for future investigation.

In addition to the loss of the upper superstructure, the upper face of the anchor's arm had split along the run of the grain (FIGS. 9, 10). Consequently, the upper surface appears flat, stripped, grainy, and uneven (FIG. 6, 10). This is in contrast to the visible side and the lower portion, which was preserved to show its original worked convex shape. Apparently, the anchor was subject to strong and abrupt stress, in the direction of the ship, creating the fracture, at the shoulder, that followed the run of the grains along the upper arm (FIG. 9). This was perhaps the result of powerful, sustained storm winds. Soon after the upper portion of the anchor arm split away, two small sherds from the rubbish strewn on the sea floor fell into the created gap. They were found some 10 cm lower than the deepest exposed ceramics elsewhere in the trench, lying directly on top of the stripped portion of the timber.

The anchor arm is sealed by the stones placed as late as the 6th century B.C. However, the dating is refined by the ubiquitous, ca. 600 B.C., ceramic fragments strewn upon and embedded in the ancient sea floor in which the arm survives in its inserted ("set") position (FIGS. 3, 8) (see also Erkanal *et al.* 2008: 362, fig. 2). The presence of ceramics assigned to the Late Wild Goat Style restrict the date of the anchorage floor to the last quarter of the 7th century, and or the first half of the 6th, according to the prevalent dates used by Coldstream (1977), Cook and Dupont (1998), and others. There are also several sherds, likely of Chian provenance, decorated with bulls which are usually dated, at the latest, to the first quarter of the 6th century (Lemnos 1991) (the lower two sherds of FIG. 8). No Geometric pottery or Bird Bowls have yet been identified to suggest any activity in the area earlier than ca. 600 B.C. This is in contrast to the substantial numbers of the subsequent Rosette Bowls. The fine silt accumulated in the enclosed harbor, immediately above the anchorage layer, contains ceramics characteristically dated from the second quarter of the 6th century B.C., particularly those including deer in a two-legged running pose, black-figure technique, the Fikellura style, and a Siana cup (Erkanal *et al*. 2014b: fig. 4, 2014c: 30, figs. 6, 7, 9). We therefore preliminarily assume a date for the anchorage floor of the last quarter of the 7th to the first quarter of the 6th century B.C.

Teredo worm damage on the arm's highest portion indicates that it was, for some period, exposed at the same level as these ceramics (FIGS. 9, 10) (see Steinmayer and Turfa 1996 for information about *Teredo navalis*). The level of the *Teredo* damage being only at the upper surface of the ancient sea floor leads the authors to assume that the damage occurred after the superstructure had fractured away. The *Teredo* boring occurred on the remaining wood left exposed to the water column. Radiocarbon dating of wood sampled from the central upper face of the arm does not contradict the chronology of the ceramics (2560 ± 50 B.P., ETH-34604). Because the

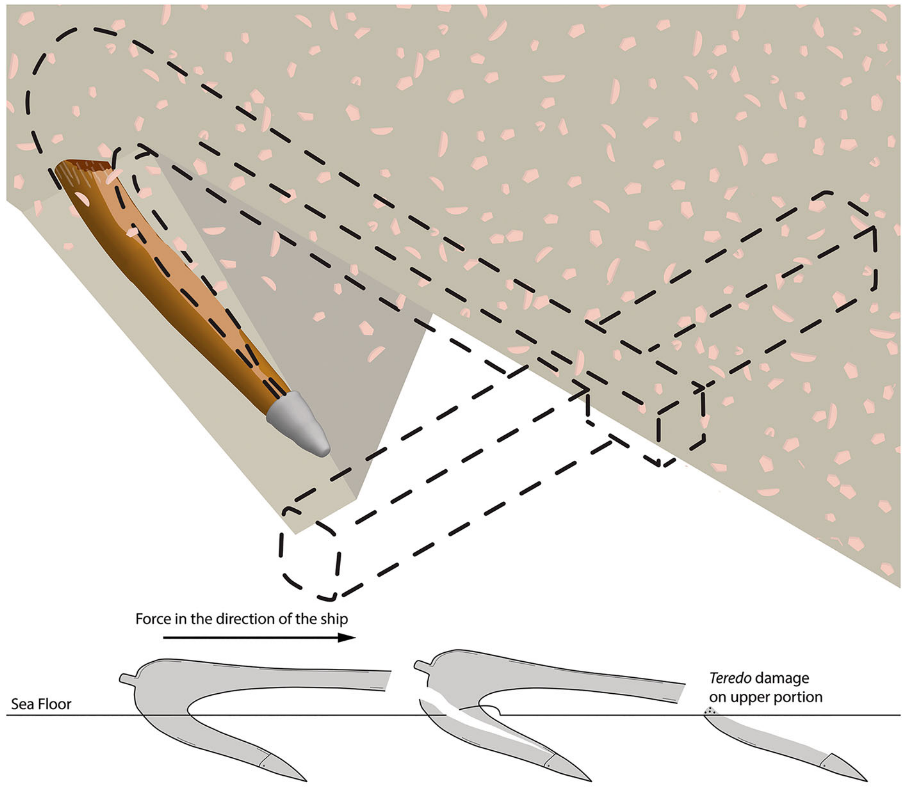

Figure 9 Hypothesized set situation of the anchor before fracturing, alongside the proposed means of breakage. Here a one-armed anchor is taken as a model, but it just as well could have been two-armed. Illustration by G. Votruba.

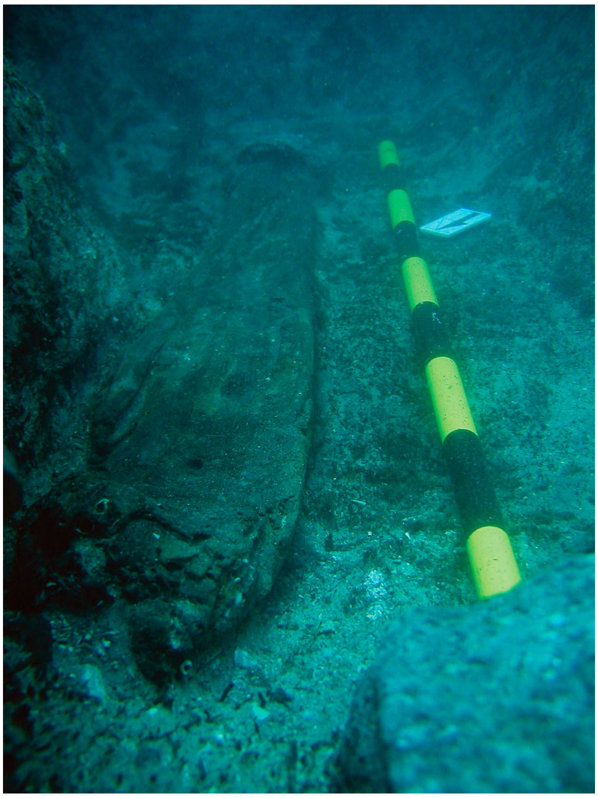

Figure 10 View of the anchor from its upper end during excavation. The *Teredo* damage at the broken end is visible, as is the grainy split face on the upper surface. Photograph by G. Votruba.

date range of 820 to 520 CAL B.C. (95.4%) is wider than the half-century definition provided by the ceramic and stratigraphic dating, it is relevant merely as an independent check on the latter.

We should also directly address the potential interpretation that the anchor arm was cast from a ship as rubbish after having fractured, instead of being an in situ find. This is a reasonable hypothesis considering the heavy jetsam activity that occurs within anchorage areas. However, this possibility is problematic due to the arm's deep penetration within once dense and consolidated sea floor matte sediment, so dense in fact, that the arm could remain embedded while the superstructure fractured away. We believe such sea floor piercing may have been possible only through the force and trajectory resulting from a functioning (canted and set) stock anchor, and the position and orientation of the object are consistent with this scenario. Had the anchor arm merely been thrown from a ship, we would have expected it to have laid flat upon the sea floor along with the ceramics, probably turned on its side according to its curve, if the anchor had not simply floated away due to the buoyancy of the wood. Furthermore, deliberately throwing away the arm is unlikely due to the value of the metal tooth. It is reasonable that salvage divers, who must have been commonly employed in ports throughout the ancient world (Frost 1968), would have attempted to find the anchor, but because the fractured timber projected only slightly from the sea floor, the anchor arm was not identifiable.

Conclusion

The excavation at Area A3 at Liman Tepe has demonstrated a number of important principles for marine archaeological fieldwork. The excavation exemplifies that the terrestrial method of stratigraphic excavation is possible underwater, particularly due to the existence of *P. oceanica* matte. This material allows for well-preserved strata several meters thick protecting identifiable ancient sea floors datable by the ceramics exposed. These materials provide information about the past geological situation and the anthropological circumstances. *P. oceanica* matte, as a stratigraphic coastal sequence, should receive greater attention within the discussion of ancient harbor sea floor sedimentology in archaeological investigation. *P. oceanica* matte is a difficult material for archaeologists to have to work with, but its careful recording can be rewarding, and ultimately, its study is essential for understanding the littoral of the Mediterranean basin.

P. oceanica stratigraphy can also protect the silt sediments of constricted harbors, which are particularly informative for understanding the history, economy, and long distance interactions of associated settlements. The strata further allow for novel discoveries, such as in situ parts of anchors found embedded in their original position within the ancient sea floor, ship assemblages and harbor architecture. What imbeds itself within the matte, or otherwise becomes covered by the rising accumulation, remains well preserved for archaeological investigation. Because *P. oceanica* is a species common throughout most of the Mediterranean, matte will undoubtedly prove to be a repository of significant historical and geological information and is particularly important for archaeologically rich regions such as the western coast of Turkey.

Finally, the holding strength of matte sea floors, solid but easily penetrable by stock anchor arms, is among the beneficial characteristics unique to the Mediterranean. It complements the stock anchor's sea floor–piercing design, enhancing mooring security and contributing to the Archaic period's particular growth in maritime activity.

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Haifa were the dive masters, and Yossi Salmon produced the bathymetric map. Members of the Israeli and Turkish teams used common equipment. At first, RIMS shipped their equipment from Haifa, but later, the teams used that of the subsequently established Ankara University Research Center for Maritime Archaeology (ANKÜSAM). The excavation was directed by Michal Artzy and Hayat Erkanal, with the active participation of Avner Raban in the first seasons.

Gregory Votruba (Ph.D. 2015, University of Oxford) was the area supervisor of Area A3. His main research interests include coastal architecture, landscapes of maritime cultures, and humankind's interaction with the sea in pre-industrial periods. His doctoral thesis examined anchoring and mooring techniques and technology in the ancient Mediterranean.

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