

HULL REMAINS FROM THE PABUÇ BURNU SHIPWRECK AND  
EARLY TRANSITION IN ARCHAIC GREEK SHIPBUILDING

A Thesis

by

MARK EDWARD POLZER

Submitted to the Office of Graduate Studies of  
Texas A&M University  
in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

August 2009

Major Subject: Anthropology

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Approved by:

Chair of Committee,	Cemalettin M. Pulak
Committee Members,	Shelley Wachsmann
	Christoph F. Konrad
Head of Department,	Donny L. Hamilton

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## ABSTRACT

Hull Remains from the Pabuç Burnu Shipwreck and Early Transition  
in Archaic Greek Shipbuilding. (August 2009)

Mark Edward Polzer, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Cemalettin M. Pulak

In 2002 and 2003, the Institute of Nautical Archaeology excavated the remains of an East Greek ship that sank off the coast of Pabuç Burnu, Turkey, sometime in the second quarter of the sixth century B.C. The scant remains of the vessel's hull have provided the first archaeological evidence for laced shipbuilding in the Aegean. The diagnostic features preserved in the hull fragments are consistent with those of Greek laced construction, as evidenced in other shipwrecks from the same period found in the western Mediterranean. The planking joinery included edge inserts, or coaks, between the planking strakes and ligatures laced through oblique holes drilled along the sides of the planks through tetrahedral notches. The ship's framing consisted of pre-fashioned made-frames alternating, on the upper sides of the hull, with top-timbers. The frames had trapezoidal sections, were notched over the planking seams on their underside, and were lashed to the hull. The top-timbers had rectangular sections and were both lashed and treenailed to the planking. Notable in this vessel's construction is the use of tenons as coaks in its original construction, the earliest example of tenon usage in Greek shipbuilding. The hull's construction features are virtually identical to those of the Cala

Sant Vicenç wreck in Majorca, and mostly similar as well to those of wreck 1 at Gela. The Pabuç Burnu and Cala Sant Vicenç ships are further similar in the use of traditional cylindrical dowel coaks for making repairs to the hull, wherein they are inserted obliquely along one side through the face of the replacement plank. These features testify to a critical phase in Greek shipbuilding when tenons replaced dowels as coaks in laced construction, paving the way for the eventual supplanting of lacing by pegged mortise-and-tenon joinery. Furthermore, examination and comparison of numerous construction details of these and other Greek shipwrecks from the sixth through fourth centuries B.C. suggest that mortise-and-tenon technology could have evolved naturally within the Greek tradition of laced construction, rather than being incorporated directly from some foreign—most likely Phoenician—shipbuilding method.

To my parents,  
who have given me everything.

## ACKNOWLEDGMENTS

As with any such work that represents at least partial culmination of years of fieldwork and research, there are myriad people to thank for making it all possible. Numerous institutions generously funded my education at Texas A&M University and my fieldwork and research in Turkey, upon which this thesis is based. I would like to thank the Department of Anthropology at Texas A&M University for scholarships and graduate enhancement awards, the Nautical Archaeology Program and Cemal Pulak for a graduate research assistantship, and the Institute for Nautical Archaeology (INA) for an academic award and study grant. The majority of my researching and writing was made possible with a Mary A. Tooze Scholarship and Mr. and Mrs. Ray H. Siegfried II Graduate Fellowship in Nautical Archaeology. My work also benefited from a number of travel grants from the Department of Anthropology that enabled me to present and discuss my research at various international conferences.

Of course, none of this would have been possible without the shipwreck material itself, which I excavated at Pabuç Burnu with project director George F. Bass and co-assistant director Elizabeth Greene in 2002 and 2003. The excavation was generously supported by the Institute of Nautical Archaeology and Texas A&M University, the National Geographic Society, the Smothers-Bruni Foundation, the Eugene McDermott Foundation, and Turkish Airlines. INA director Claude Duthuit deserves special mention for bailing out the expedition financially both years, and also for living and excavating with us—always a special treat. Oğuz Alpözen and Yaşar Yıldız, of the

Bodrum Museum of Underwater Archaeology, facilitated the excavation and research by providing conservation and storage for the artifacts and access to the material for study. Yaşar also represented the Turkish Ministry of Culture and excavated with us during our months in the field. Fond thanks especially are due to all of my team members with whom I was privileged to work: Don Frey, Zafer Gül, Faith Hentschel, Timothy Kane, Volkan Kaya, Bayram Kosar, Orkan Koyağasıoğlu, Xila Matthews, Asaf Oron, Robin Piercy, Corioli Souter, Deniz Soyarslan, Feyyaz Subay, Jon Swanson, Murat Tilev, Ioannis Triantafillidis, and Evren Türkmenoğlu. The INA staff in College Station—Claudia LeDoux, Michelle Chmelar, and Chasity Hedlund—and at the Bodrum Research Center—Tufan Turanlı, Marion Felder, and Özlem Doğan—provided exceptional assistance throughout with finances and logistics. Documentation of the hull remains was aided by my dear friends Asaf, Volkan, and Orkan, who spent countless hours with me in the wet and smelly confines of the wood lab and provided moral support and good cheer throughout. Çok teşekkür ediyorum!

I am especially grateful to my graduate committee members, Cemal Pulak, Shelley Wachsmann, and Christoph Konrad. All are exceptional teachers and generous colleagues, and share a contagious enthusiasm for their particular fields of study. As my committee chair, Cemal displayed a patience that apparently knows no end. He has been a mentor and example scholar, both inspiring and challenging me with his passion for knowledge and understanding, his humility towards the shipwrecks he studies, and the tremendous sense of responsibility he feels to do the best possible job in excavating, conserving, studying, and sharing all that he learns from them. Shelley has been a

constant source of motivation with the enjoyment and excitement he brings to his and others' work, and by being so generous in providing me with material to study and publish all throughout my years in the Program. Dr. Konrad's lectures on ancient Greek and Roman history bring to life those events of so long ago like few others I have experienced, and provided some of the most entertaining moments of my graduate studies.

I have had the great privilege as well to learn from professors Donny Hamilton, Kevin Crisman, and Wayne Smith, each of whom has made me a better researcher and archaeologist. I am especially grateful to Donny and Kevin, as Program head and President of INA, and as head of the INA archaeological committee, respectively, for their tremendous patience, faith, and support for my work.

Special thanks and affection go to George Bass, who encouraged me from the beginning to apply to the Program, and who ever since has been a mentor and friend and provider of so many opportunities. He took me on as part of the archaeological team that excavated the Classical shipwreck at Tektaş Burnu—my very first underwater excavation; he invited me to excavate with him at Pabuç Burnu and to study the hull remains of the ship; and he has been a charitable reference for so many successful project proposals and funding applications. I also need mention Dick Steffy, who inspired me from the beginning to study ancient ship construction, and from whom I learned so much from our discussions in the Ship Lab and department hallway, at various symposia, and anywhere else the opportunity to share in his amazing and generous knowledge presented itself.



My years in College Station would have been so much poorer if not for my dear friends and second family, Filipe, Siaska, Leanor, Filipino, and Julia Vieira de Castro, who provided me with refuge from long hours of study, and with whom I shared so many wonderful meals, music, foreign films, and stimulating conversations, usually well into the late hours of the night. I owe a tremendous personal debt to Filipe, who, first as fellow student and then as professor in the Program, has been a true God-send; inspiring, encouraging, coaxing, and assisting me in my studies, fieldwork, and research.

For Wendy van Duivenvoorde, my best friend and confidant, fellow student and colleague, excavation mate, and so very much more, words can never express sufficiently the heartfelt gratitude that I feel. Her companionship made life in College Station and the Program so much more enjoyable, and her encouragement, support, and example have always inspired me to do better. Thank you Wendy!

Finally, I am so very grateful to my wonderful family for supporting and encouraging my venture back to academia and into the sometimes murky depths of nautical archaeology; especially my sister, Julie, and brother-in-law, Brian Jordan, who helped make my career-changing decision an easier one with their personal insights and experiences in the Nautical Archaeology Program. But most importantly, I thank my amazing parents, Ben and Florence, whose unconditional love and support and boundless generosity made possible my studies, research, and many adventures in nautical archaeology—and, indeed, all good things in my life. I owe you everything, and I love you both so very much!

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## CHAPTER I

### INTRODUCTION

The Institute of Nautical Archaeology at Texas A&M University (INA) has conducted underwater surveys for ancient shipwrecks along the Aegean and Mediterranean coasts of Turkey since 1973.<sup>1</sup> The 2001 survey followed the conclusion of the final field season at Tektaş Burnu, where INA excavated a small classical merchantman.<sup>2</sup> Early in October, the survey team investigated a potential shipwreck site off Pabuç Burnu, a small point some 25 km east of Bodrum. The site was discovered a week or so earlier by Department of Fisheries employee Selim Dinçer, who immediately told his friend Aşkın Cambazoğlu.<sup>3</sup> A former archaeologist with the Bodrum Museum, Aşkın now owned a diving center and school at the Sea Garden hotel not far from the site. After inspecting the find himself and recognizing its potential as a shipwreck, he notified INA and suggested that the survey team investigate. On October 9, following a meeting at INA's Bodrum Research Center with INA Founder George Bass, INA staff member Donald Frey, and Ministry of Culture representative Yaşar Yıldız, Aşkın lead the team on board INA's research vessel *Virazon* to Pabuç Burnu for a quick dive to the site. There they found a sloping sandy bottom with a scattering of broken and intact

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This thesis follows the style and formatting of *American Journal of Archaeology*.

<sup>1</sup> Bass 1974. These surveys became annual events beginning in 1980, and for the subsequent 17 years were conducted by Cemal Pulak. Since 1997, the surveys have continued on a more sporadic basis, and have been directed at various times by Tufan Turanlı, George Bass, and Faith Hentschel.

<sup>2</sup> Bass 2002; Greene and Bass (forthcoming). In this survey, the submersible *Carolyn* was used for the first time. INA purchased *Carolyn* in 2000 from SEAmagine Hydrospace Corporation of Claremont, CA, with a generous donation from Malcolm Weiner, founder of the Institute for Aegean Prehistory (Bass 2001). For INA's excavation at Tektaş Burnu, see Carlson 1999, 2001, 2002, 2003.

amphoras, some lying exposed on the seabed, while others were half buried in the sand. They were not able to make any clear determination of the true nature of the site.<sup>4</sup> A more extensive second dive by the full team was made the following day, during which divers photographed and videotaped the area while others hand-fanned around exposed amphoras to see if there was any evidence of additional material underneath. The team did indeed find intact pottery buried deeper in the sand, which indicated that this was likely a cohesive shipwreck. They also recovered an amphora and pitcher for dating and provenience study (fig. 1.1). Back in the conservation laboratory in Bodrum, the two pieces of pottery were photographed and drawn, and copies of the records were sent to Mark Lawall at the University of Manitoba, an expert on Greek amphoras. He identified the pieces, respectively, as a transport amphora of the southeastern Aegean from the sixth century B.C., and a common plainware oinochoe of Ionian production from the same century.<sup>5</sup> No wreck of the Archaic period had been excavated in the eastern Mediterranean, and so the site was chosen for INA's next archaeological investigation.<sup>6</sup> On November 4, Bass submitted an application to the Turkish Ministry of Culture to conduct an archaeological excavation and study of the Pabuç Burnu site beginning the

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<sup>3</sup> Both men had worked on previous INA excavations in Turkey.

<sup>4</sup> Bass 2002, 5–6.

<sup>5</sup> Bass 2002, 6; Greene et al. 2008, 686.

<sup>6</sup> Parker (1992, 10) lists 23 known wrecks from the sixth century, but only three are from the eastern Mediterranean, none of which has been excavated. Two of these, curiously enough, are located in the Gökova Gulf east of Pabuç Burnu. The first is a scatter of ceramics including looped-handle amphoras and a bowl on a shallow reef near Kepeç, dated to the seventh–sixth centuries B.C. (Bass 1974, 335; Bass 1975, site L, n. 4; Parker 1992, 226 n. 542); the second is another shallow water site close by at Çökertme (site A) and includes scattered 'basket jar' amphoras dated to the seventh–fifth centuries B.C. (Rosloff 1981, 279–80; Parker 1992, 148 n. 324). The third site is an amphora wreck at 35-m depth off Lindos (site B), dated to the sixth century B.C. (Catling 1983, 60; Parker 1992, 243 n. 599).

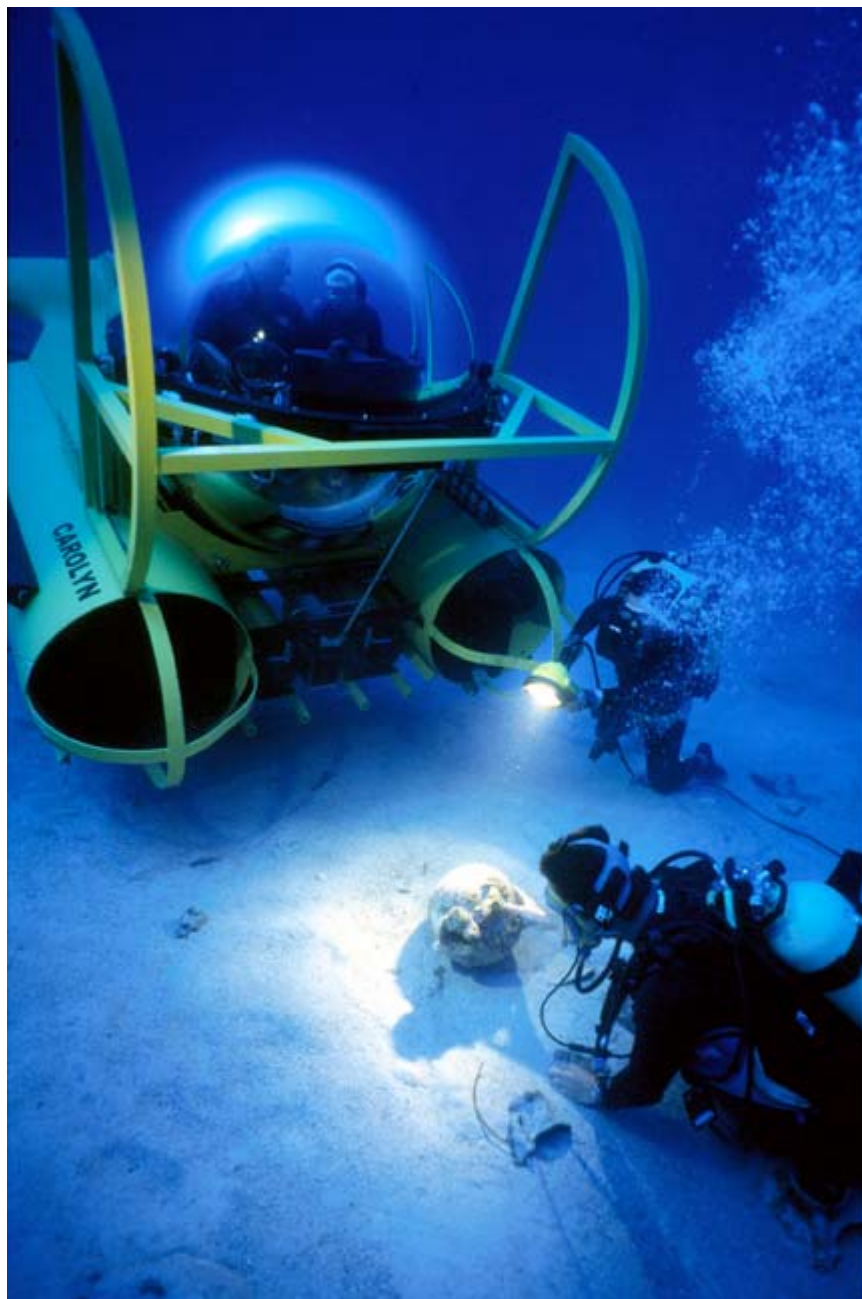


Fig. 1.1. Archaeologists from the 2001 survey team recover an amphora from the Pabuç Burnu wrecksite, while survey and excavation director George Bass observes from inside the submersible *Carolyn* (D. Frey).

following summer. In the intervening six months, he and his assistants secured the necessary funding, assembled a team of archaeologists, divers, graduate students, and ships' crew, and procured and prepared the necessary equipment.<sup>7</sup>

### *Site Location*

The Bodrum Peninsula is the third major promontory of the southern Aegean coast of Turkey, following north from the Lorimar (Chersonesos) and Datça Peninsulas (fig. 1.2a). The ancient city of Halikarnassos (modern Bodrum) sits at the head of a protected bay on the southern side of the peninsula's narrowest point (fig. 1.2b). The southern coastline of the peninsula and mainland stretches nearly 100 kilometers from east to west along the thirty-seventh latitude and forms the northern confines of Gökova Körfezi (Gökova Gulf), known in antiquity as the Sinus Kerameios. At the wide mouth of the gulf towards the west sits the island of Kos of the Sporades. At its eastern limit, near where the gulf culminates in the narrow inlet of the Sinus Cedreaticum, is the ancient town of Idyma. The gulf is bounded to the south by the Datça Peninsula, at the westernmost tip of which lie the ruins of ancient Knidus (Nova) and its double harbor on either side of the Triopion Promunturium (Cape Krio). Less than 100 km south and east from there lies Rhodes.

Pabuç Burnu is the first of numerous low projecting points that define the northern shoreline of the gulf. The small, forked headland takes its name (Shoe Point),

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<sup>7</sup> Funding and other support for the Pabuç Burnu excavation was generously provided by Texas A&M University, the National Geographic Society, the Smothers-Bruni Foundation, the Eugene McDermott Foundation, INA director Claude Duthuit, and Turkish Airlines.



Fig. 1.2a. Location of the Pabuç Burnu shipwreck site.

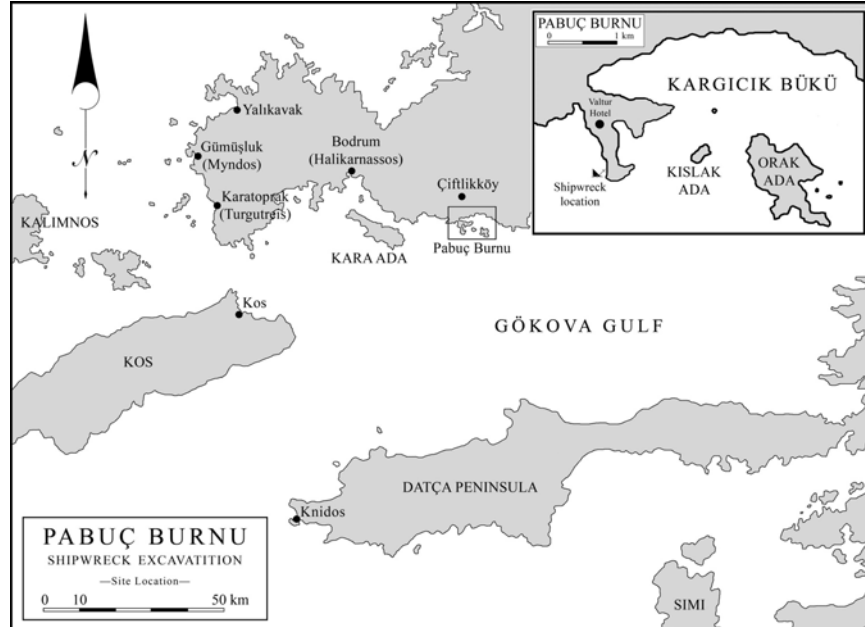


Fig. 1.2b. Pabuç Burnu shipwreck site location (detail).

quite appropriately, from its boot-like shape. Just beyond it lies a broad bay called Kargıcık Bükü, which is formed to the east and west by Orak Burnu and Pabuç Burnu, respectively, and is partially sheltered to the south by Orak Adası and several small islets. It is well protected from the northwesterly *meltem* winds, which develop with regularity during the afternoons and can be rather forceful. The point is covered with maquis scrub, while the mainland is wooded and backed by mountains.

The shipwreck site lay at a depth of 30–50 m off the western side of Pabuç Burnu, just before the tip of the promontory.<sup>8</sup> That the ship sank here suggests that it struck the point in a failed attempt to round the headland and find shelter within the bay beyond. The seabed where the wreckage lay begins at a depth of approximately 30 m then drops abruptly another 10 m or so down several rock outcroppings. From there the bottom consists of deep sand and falls away into deeper water with about a 25-degree slope.

### *The Excavation*

The Institute of Nautical Archaeology began full-scale excavation of the Pabuç Burnu shipwreck in 2002 under the direction of George Bass and assistant directors Elizabeth Greene and Mark Polzer. The Smothers-Bruni expedition conducted two campaigns of excavation, the first lasting from June through October of 2002, and the second from June through July of the following year.<sup>9</sup> Since the wreck was located so

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<sup>8</sup> Site coordinates are 36.9755° N, 27.5625° E.

<sup>9</sup> Greene 2003; Polzer 2004.

close to Bodrum, INA's Research Center there was designated the official excavation house. A majority of the team resided and dined in the Center's dormitory, and the Nixon Griffis Conservation Laboratory served as temporary storage depot for all recovered artifacts. There, during evenings and non-diving days, the team catalogued and photographed all recovered artifacts before ultimately transferring them to the Bodrum Museum of Underwater Archaeology for conservation and permanent storage. Each morning, the team drove to Içmeler harbor on the eastern side of Bodrum Limanı and boarded *Virazon* for the 45-minute trip southeast past Kara Ada to Pabuç Burnu. A permanent mooring was established over the site to hold *Virazon* against the prevailing *meltem* winds and the occasional southerly *lodos*.

*Virazon* served as the expedition's excavation and diving platform. The ship is fully outfitted for such work and houses a galley and bunks for eight or more people, generators, low and high pressure air compressors, a recompression chamber, diving gear and excavation equipment, and computer facilities. In 2003, the team rented a diesel-powered road compressor and set it on the rocks of Pabuç Burnu to better power the underwater airlifts.

The team prepared the site for excavation and mapping by first anchoring a Plexiglas dome known as the "telephone booth" to the bottom and positioning several auxiliary scuba tanks at the telephone booth and around the work area for diver safety. They assembled airlift pipes, erected a nylon rope grid demarking the site with 2 x 2-m

squares, and positioned 14 datum towers at strategic locations to serve as mapping control points. Precise relative locations of the datum points—the basis for all subsequent mapping—were established with measuring tape and Site Surveyor™, an iterative linear program that determines relative positions in three dimensions by trilateration. Thereafter, artifacts were mapped solely using digital photography and PhotoModeler Pro™, a mapping program that renders three-dimensional coordinates for objects using photogrammetry.<sup>10</sup>

All diving operations were conducted from *Virazon*'s forward deck. Each diver made two dives a day, separated by the requisite five-hour surface interval to allow for proper nitrogen off-gassing. The depth of the site limited bottom times to 20 minutes per dive, and required a decompression stop at 6 m during which divers breathed oxygen supplied from tanks onboard *Virazon*. Between dives, team members registered the day's artifacts on *Virazon*'s small stern deck, where they also emptied and sieved sediment from intact vessels to look for clues of their original contents.

At the end of each field campaign, all intact artifacts were transferred to the Bodrum Museum of Underwater Archaeology to undergo desalination and surface cleaning, conservation, and restoration. Wooden hull fragments, however, remain at the

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<sup>10</sup> Green et al. 2002. The process was developed and tested during INA's excavation at Tektaş Burnu, where it was employed alongside trilateration of manual tape measurements (Carlson 2003, 583). The Pabuç Burnu excavation represents the first INA project to use photogrammetry exclusively. See also Greene 2003, 4–6; Polzer 2004, 4–6; Greene et al. 2008, 686–7.



Nixon Griffis laboratory, where they are undergoing conservation with polyethylene glycol (PEG).

### *The Finds*

Some wreck material was found scattered on the rocks at the shallow end of the site, nestled in crevices and beneath overhangs, but the vast majority lay strewn across the sand below. The debris field extending over an area measuring almost 26 meters north to south and 14 meters east to west (fig. 1.3).

Little remained of the ship's primary cargo except the amphoras in which it was contained. The total number of transport amphoras recovered from the site is estimated at 260, of which less than 12% survived intact. Sieving of their contents yielded occasional grape seeds, olive pits, and nutshells, as well as fragments of their original tree bark stoppers. Some of the amphoras are lined with pine tar, which, along with the grape seeds, suggests a primary cargo of wine.<sup>11</sup> Three amphoras have small O-shaped stamps incised on their handles, as well as a rectangular device that may represent a partial monogram or palmette (fig. 1.4). Such marks are thought to have been a means of testing the hardness of clay before firing, but no completely satisfactory explanation for them has yet been offered.<sup>12</sup>

An assemblage of mostly plain wares—pitchers, bowls, mortaria, and cups—probably for shipboard use was found predominately in the upper regions of the site in

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<sup>11</sup> The tar was identified by Curt Beck at the Amber Research Laboratory at Vassar College as made from *Pinus* sp. (personal communication).

<sup>12</sup> Greene et al. 2008, 693–4; Dupont 1999b; Lawall 1995; Meyza 2004, 284.

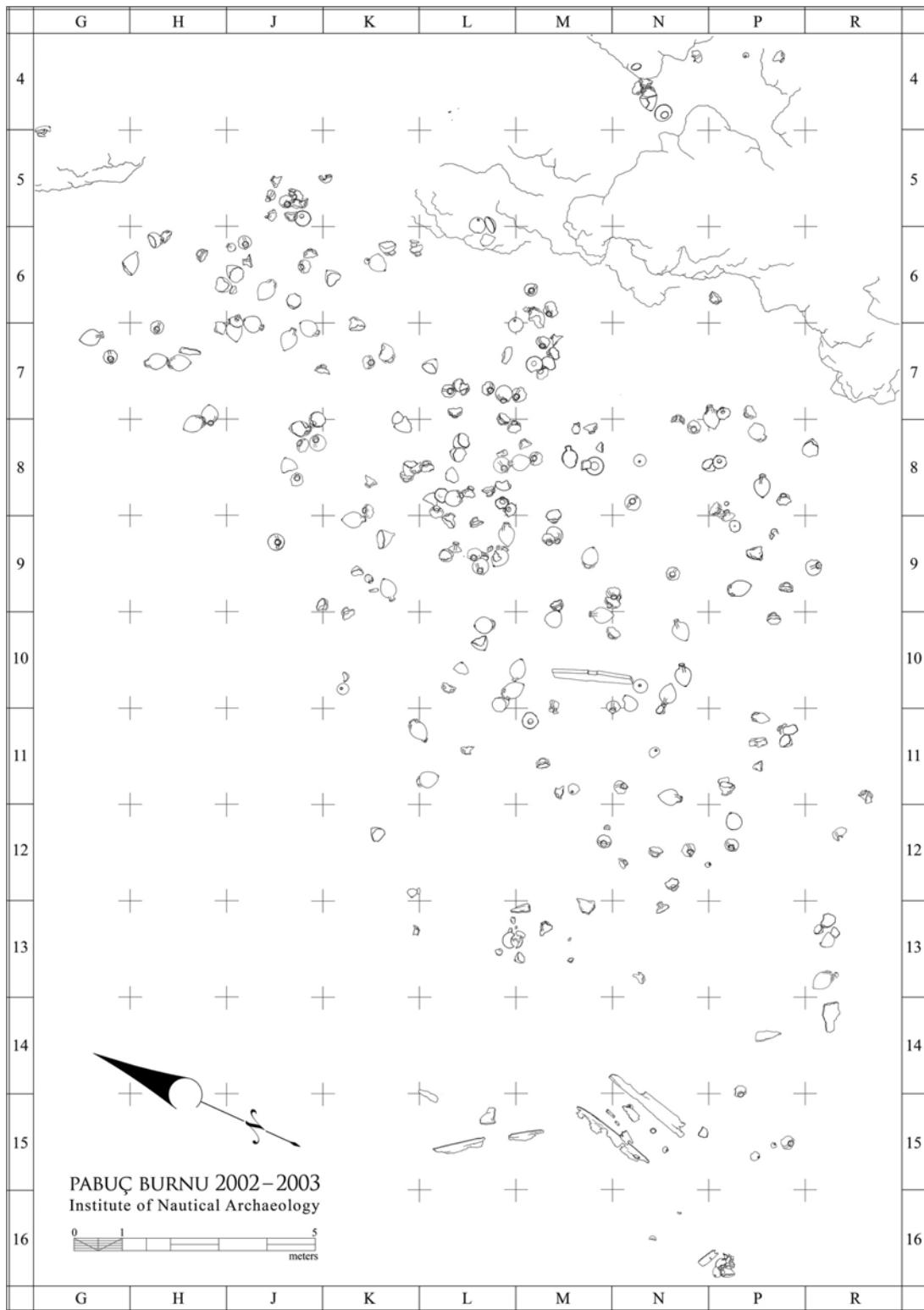


Fig. 1.3. Plan of the Pabuç Burnu shipwreck site (drawing by S. Matthews and M. Polzer).

sectors J4–N8, suggesting that the galley area at the stern of the ship was located there. Archaeologists also recovered a large, stone anchor stock from near the center of the site. The stock, which is 1.65 m long and weighs 115 kg, was chiseled from igneous rock and has a rectangular recess cut out around its midpoint (fig. 1.5). A similarly shaped stone, though much smaller and more crudely made, was found in 2003 some nine meters farther down slope at the intersecting corners of sectors L14 and L15. It measures 0.45 m in length, weighs 7.3 kg, and has a recess cut around its midpoint (fig. 1.6).<sup>13</sup> A heavy concentration of grape seeds in this lower region suggests that the ship may also have carried a bulk cargo of grapes or raisins, perhaps packed in perishable sacks or baskets, which did not survive the long centuries under water.



Fig. 1.4. Stamps found on three Halikarnassos(?) amphoras (V. Kaya).

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<sup>13</sup> Greene and Polzer 2004, 14–6.

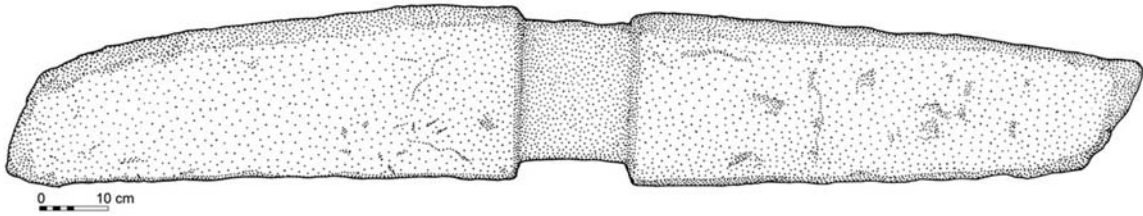


Fig. 1.5. Large stone anchor stock (drawing by B. Güneşdoğdu).

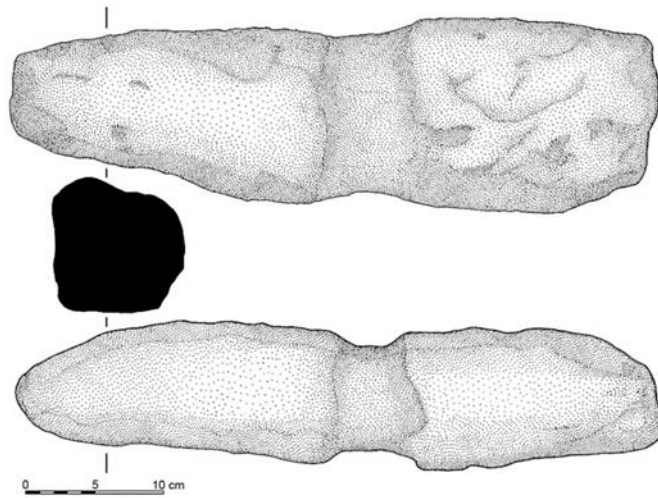


Fig. 1.6. Small notched stone weight (drawing by B. Güneşdoğdu).

### *The Ceramics*

The vast majority of objects recovered from the shipwreck are ceramic sherds and whole vessels constituting an assemblage of transport amphoras and another of mostly plain wares that includes pitchers of various types, mortaria, and an assortment of cups and bowls.<sup>14</sup> The team found only 30 amphoras that were intact, along with broken pieces of an estimated 230 additional jars. The majority of amphoras belong to two main types, but at least four other types are represented, in some cases by only a single example. The largest represented group consists of 21 complete jars and an estimated 150 broken ones, and are classified by Lawall as Halikarnassos(?) type (fig. 1.7A). They have one or two ridges around the neck just below the rim, and their shape is similar to jars attributed to Miletos, Samos, and Ephesos.<sup>15</sup> However, their dark brown fabric with various inclusions better resembles that of pottery from the region of Halikarnassos and Knidos.<sup>16</sup> Seven intact jars and an estimated 50–70 broken ones make up the second major type of transport amphora. These have a similar body shape as the Halikarnassos(?) type, but with slight variations in the rim and toe.<sup>17</sup> Their pale tan fabric has few inclusions and resembles material from Rhodes.<sup>18</sup> The only other type that has more than one or two examples is a group of perhaps four to 10 broken amphoras attributable to southern Ionia. They have two ridges below thicker rims, toes similar in shape to the Halikarnassos(?) type, finely micaceous fabric, and a grayish slip.

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<sup>14</sup> Greene 2003, 4–9; Polzer 2004, 6; Greene et al. 2008, 688–700.

<sup>15</sup> Greene et al. 2008, 688; Dupont 1998, 170–7; Dupont 1999a; Dupont 2001; Monakhov 2003, 30–4.

<sup>16</sup> Greene et al. 2008, 688–92.

<sup>17</sup> The smooth transition from rim to neck seen on these vessels is found also in examples from Histria (Dupont 2005, fig. 16c) and Ephesos (Kerschner and Mommsen 2005, fig. 7).

<sup>18</sup> Greene et al. 2008, 692.

Of the remaining jars, none of which are complete, one is attributed to Klazomenai and two have a form quite rare in the Archaic Mediterranean, Aegean, or Pontic regions.<sup>19</sup> The latter have a bulging neck with a single groove; flat, upturning strap handles; flaring pedestal toe; and fine fabric generally similar to that of the Halikarnassos(?) type. Pieces of two amphoras with typical gray fabric from Lesbos and the surrounding environs represent the most “distant” amphora found on the wreck.<sup>20</sup>

Excavation of the site yielded approximately two dozen plain, mostly undecorated vessels. The majority appear in one of the two fabrics of the main amphora groups—dark and coarse Halikarnassos(?) fabric, or paler tan Rhodian fabric—only here the latter is the more common. Six of eight oinochoai have tan fabric, a trefoil mouth, a double-reed handle, and a slight ridge between neck and shoulder (figs. 1.7C, 1.8).<sup>21</sup> Three *olpai* all have similar fabric and double-reed handle, but of the two with preserved tops, one has a trefoil mouth, while that of the other is simply everted.<sup>22</sup> Their form is rather nondescript, but finds general parallels in examples from Libya (Tocra), the Levant, and Cyprus (Marion), which are dated from the second to third quarters of the sixth century.<sup>23</sup>

Other plain wares in tan fabric include at least two decorated cups with slipped interiors, a reserved band between the handles, and thin horizontal striping around the

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<sup>19</sup> See Greene et al. 2008, 693, especially n. 30.

<sup>20</sup> Greene et al. 2008, 693.

<sup>21</sup> An oinochoe of Greek provenience with similar form but found on Cyprus is dated to the early sixth century B.C. (Gjerstad 1977, 35, no. 166, pl. 19.7).

<sup>22</sup> Greene et al. 2008, 696.

<sup>23</sup> The examples from Tocra are assigned to Rhodes (Hayes 1966, 66–7 n. 1; 70, nos. 848–51). See Greene et al. 2008, 696–7, n. 41 for additional bibliography.

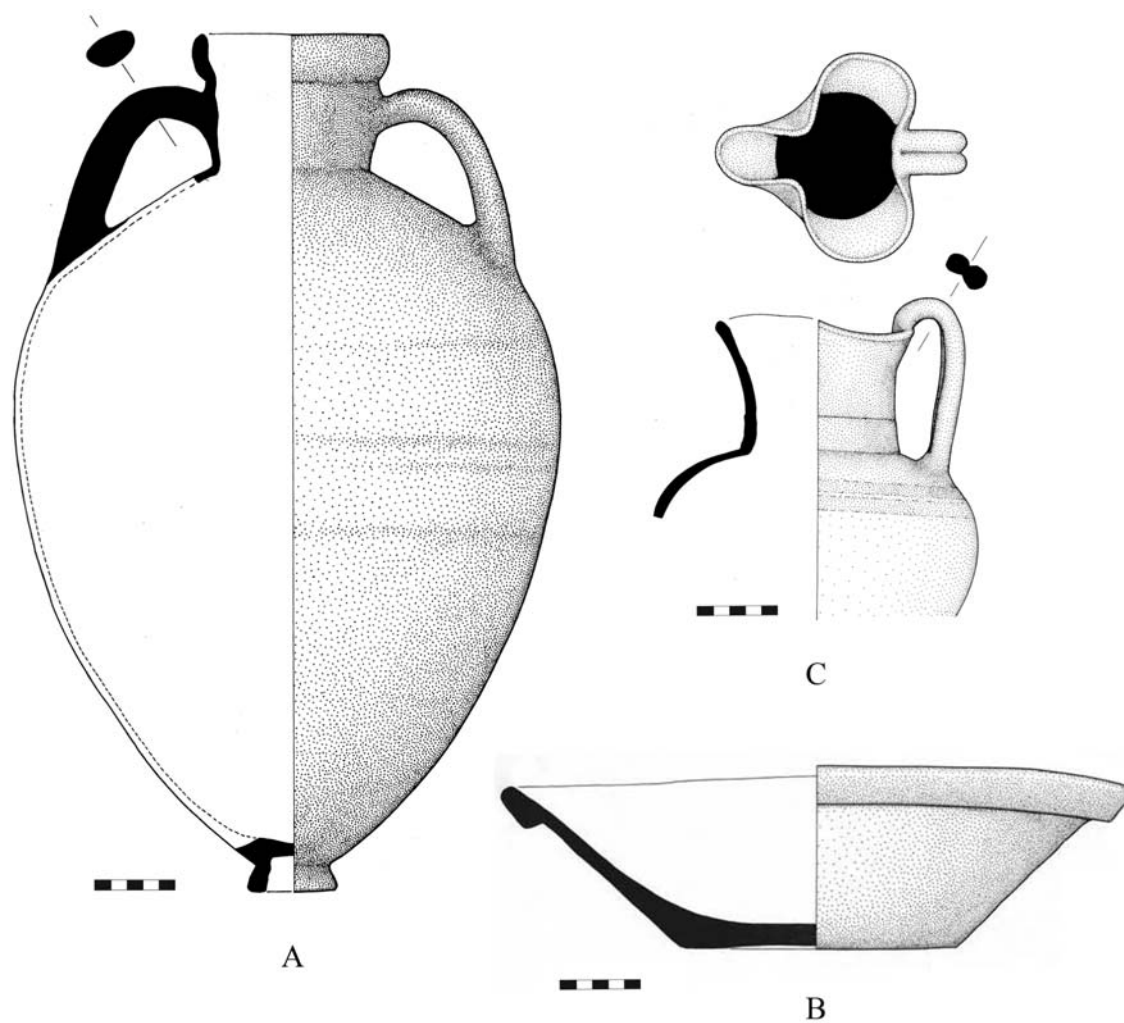


Fig. 1.7. Ceramic vessels from the Pabuç Burnu shipwreck: A—Halikarnassos(?)—type transport amphora; B—coarse tan-fabric mortarium; C—Halikarnassos(?)—fabric oinochoe (drawings by B. Güneşdoğdu).

outer face of the rim.<sup>24</sup> They are similar in form to Rhodian (from Tocra) and East Dorian examples, the fabrics of which are classified as either Knidian or Rhodian. Their decorative scheme resembles an East Dorian example from Naukratis.<sup>25</sup>

Three large mortaria, each with different profiles and rims, have tan fabric that is coarser than the other plain wares. Two of the mortaria have a flat bottom, while the other has a slightly raised foot (figs. 1.7B, 1.9).<sup>26</sup> A fourth mortarium has an even more coarse and micaceous fabric that may be attributable to Knidos.<sup>27</sup>

Two oinochoai, a pair of echinus bowls and another flat-based bowl exhibit the darker fabric of the Halikarnassos(?) amphoras. One of the oinochoai is undecorated and has a single-shaft strap handle, plain mouth, and offset ridge between the neck and shoulder. The second example, though not complete, has a trefoil mouth, double-reed handle, and is decorated with a relief band encircling the lower part of the neck, two bands of dark slip around the shoulder, and a wide, vertical band covering the outer face of the handle (fig. 1.7C).<sup>28</sup>

Two of three bowls recovered have incurving rims and plain ring bases.<sup>29</sup> The third bowl is undecorated, has a flat base and rounded rim, and its red-brown fabric is even darker. An iron bar was found concreted to the inside of the bowl; its length and

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<sup>24</sup> Greene et al. 2008, 697.

<sup>25</sup> Greene et al. 2008, 697, and n. 43 for bibliography.

<sup>26</sup> Greene et al. 2008, 697, 698 fig. 19.

<sup>27</sup> Greene et al. 2008, 697, and n. 44 for bibliography (especially Waldbaum and Magness 1997).

<sup>28</sup> Greene et al. 2008, 697, 699 figs. 20–1.

<sup>29</sup> Greene et al. 2008, 697; the bottoms of the bowls project slightly into their bases, and the rims are slightly thicker than the rest of the vessel walls. Bowls with similar rim features are found at Histria Archaic level 1 (Alexandrescu 1978, 120, no. 783, fig. 33).





Fig. 1.8. Coarse tan-fabric oinochoe (D. Frey).



Fig. 1.9. Coarse tan-fabric mortaria (D. Frey).

ends appear to fit the bowl's inner profile, though this may be mere coincidence (fig. 1.10). Its function has not yet been determined.



Fig. 1.10. Bowl with concreted iron bar (D. Frey).

Three solitary examples do not fit into the above groups. One such item is an Ionian cup typical of the sixth century B.C. It is decorated with black slip except for a narrow reserved band just below the rim, which incorporates the handles.<sup>30</sup> The cup was mended with staples in at three places. Another is a polychrome plate or shallow bowl with striped decoration typical of East Greek fineware. Lastly, a small juglet of pale-fabric with a flat base and horizontal ridging around the body has parallels from the late seventh and sixth centuries B.C. in Israel.<sup>31</sup>

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<sup>30</sup> Catling and Shipley 1989; Schlotzhauer 2000; Schlotzhauer and Villing 2006.

*Date and Provenience of the Wreck*

The ceramic assemblages have so far provided the best means for dating and proveniencing the shipwreck. All of the pottery from the wreck is datable to the sixth century B.C. The neck, handle, and toe morphologies of the southern Aegean amphoras date them generally before the middle of that century.<sup>32</sup> The two strap-handle amphoras with bulging necks put the date firmly in the first half of the sixth century, while the Klazomenian example refines it further to the second quarter. Likewise, the East Dorian cups, mortaria, and Levantine juglet all fit an early to mid-sixth-century date.<sup>33</sup> Reconciling the various overlapping chronologies, Lawall estimates the date of the shipwreck to be ca. 570–560 B.C.<sup>34</sup>

Many of the plain wares could have belonged to the crew and been used for preparing and eating meals or for measuring dry and wet goods. They are attributable by form and fabric to either Rhodes or the region of Halikarnassos and Knidos, and suggest an East Greek (Dorian?) provenience for the ship and its crew. The same applies for all but a handful of the transport amphoras from the ship's cargo. The exceptions come from further north along the coast, at Klazomenai and the vicinity of Lesbos. The Ionian cup and polychrome dish are typical East Greek pottery, whereas the lone intrusion to the assemblage is the Levantine juglet. All of these items could have been picked up at Halikarnassos, Kos, Knidos, Rhodes, or ports further north, and suggest a local nature for the ship's range of operation. The location where the ship sank indicates that it was

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<sup>31</sup> Greene et al. 2008, 698; Naveh 1962, 104 n. 19, figs. 6.10–6.11; Stern 1982, 120–4.

<sup>32</sup> Greene et al. 2008, 698.

<sup>33</sup> Greene et al. 2008, 699–700.

<sup>34</sup> Greene et al. 2008, 700.

sailing eastward into Gökova Gulf, perhaps returning home to Idyma or one of the small towns that dot the northern shore east of Pabuç Burnu. If so, the venture might represent that of one or more local farmers taking their excess agricultural produce to the markets of Halikarnassos or one of the other nearby cities. After selling much of their produce, then perhaps taking on a consignment of wine, the farmers/sailors may have headed back to sea with their ship under laden in order to arrive home before nightfall; lamps nor ballast was found among the wreckage. Once out in the gulf, a storm or even the normal meltem winds could easily have blown them towards shore. Hampered by poor response from their lightened ship, they were unable to navigate into the sheltered confines of Kargıcık Bükü and struck the rocks of Pabuç Burnu instead.

## CHAPTER II

### THE HULL REMAINS

Study of the site and the distribution of artifacts as work progressed and more material became exposed on the seabed indicated that after sinking, the ship initially touched bottom on top of the rock ledge at the eastern edge of the site before tumbling over it to the sandy and sloping seabed below and coming to rest in approximately a north-south orientation, roughly perpendicular to the shoreline.<sup>1</sup> The sand at the site is deep, and except at the base of the rock ledge, bedrock was never reached. For most of the 2002 campaign, only tiny fragments of wood, shipworm (*Teredo navalis*) tubes, and dark patches of sand hinted at wood or other organics now decomposed. Then, in early October, as the season was winding down, excavation revealed the first substantial wooden fragment (UM1) from the ship's hull in the downslope area of the wreck in sector N15 (Fig. 2.1).<sup>2</sup> Before inclement weather brought the underwater work to a halt, the team found and raised two more fragmentary pieces of hull (UM2 and UM3). On the season's final dive, during which the last piece was removed from the seabed, an additional piece was partially exposed beneath it. Divers covered it over with

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<sup>1</sup> Certain anomalies observed during the excavation of the wreck indicate that the site was disturbed on at least one occasion in the recent past, requiring that caution be exercised in drawing more than general conclusions based on the orientation and distribution of the finds. These anomalies include the vast number of broken amphoras and the scattered dispersion of the sherds, the lack of any recognizable pattern to the positions of the intact amphoras, the disarticulation of the hull remains, and the discovery of several modern bottles, cans, and other items in the wreck stratum. Trawling, dynamite fishing, sponge dragging, sponge diving, recreational diving, and natural phenomena such as earthquakes are all possible sources of disturbance.

<sup>2</sup> Polzer 2004, 3–5; Greene 2003, 9.

polyethylene sheeting and sandbags, then buried it under more sand and left it in place for excavation the following year.<sup>3</sup>



Fig. 2.1. Excavation of the first discovered hull plank, UM1 (S. Matthews).

The 2003 campaign started by relocating the hull fragment and airlifting around it. It turned out to be only a small fragment (UM4). Excavation proceeded outward from this location, to the west and east and downslope into deeper water. Two substantial pieces (UM5/1–2) were found in sectors M/L15 during the first week, and eventually the last fragment (UM6) was located in sector N16. Over the course of six weeks, the team fully excavated an area of nearly 150 m<sup>2</sup> from sectors L13 to S18, and a vertical trench on either side of this area to help determine where to concentrate its

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<sup>3</sup> Polzer 2004, 4.

efforts and to ensure that no remaining pieces of hull were missed. During the second week of work, after excavating the two pieces of plank UM5, divers trenched from sectors K14 to K18 to determine if any more of this plank or others continued to the north and west of the excavation area. There was no indication to suggest this was the case. During the last week of the campaign, a second trench was dug from grid squares T15 to T18 to look for evidence for more remains at that extremity of the site. Again, the trench revealed nothing to suggest any more of the ship had survived. Other than the seven fragmentary pieces raised during the two seasons of excavation, only tiny scraps of wood encountered around the site hinted at the presence of the wooden vessel that sank at this spot some two and a half millennia ago.

### *Fragment Catalogue*

The hull fragments are listed and described below in the order that they were excavated. At the time of their discovery, each piece was assigned an initial “UM” number, meaning simply “unidentified member”, since we had no way of locating these scanty fragments within the context of the original hull, which had long disappeared.<sup>4</sup> We quickly recognized the fragments as pieces of planking, but could not immediately assign them to the port or starboard side of the hull, nor to any particular area of the hull with any certainty. Since ultimately only seven pieces were found, it made little sense to change the labeling prefix to “P” for planking, and in this way all tags, registration and catalogue entries, and other records of the fragments remained unchanged and

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<sup>4</sup> Steffy 1994, 192.

consistent. The following catalogue entry for each fragment includes numbers for the photomosaics and drawings of each piece;<sup>5</sup> the sector(s) in which the fragment was found; the maximum preserved length (l.), width (w.) and thickness (th.) of the fragment; and the type of wood from which it was made.<sup>6</sup> Measurements are given in centimeters and are summarized in Table 2.1. The face of each plank that was oriented up when it was excavated is positioned uppermost in the photographs and drawings, and is described first in the text, followed by the other face. Directional orientations used in the descriptions are relative to the site and the remains as viewed in the wreck plan (fig. 1.3). The terminology used in describing the various parts of the planks follows that illustrated in figure 2.2.

UM1. Fig. 2.3; sectors M14–N14–N15; l. 223.8 cm; w. 30.5 cm; th. 4.5 cm; *Pinus nigra*.

The first piece of hull planking found proved to be the largest and best preserved, though its general condition is still only fair. It was found lying on its outboard face oriented at about 45 degrees to the slope of the seabed, angling down the slope from left to right with its longest preserved edge downslope. It extended from just within sector M14 through the corner of N14 and into sector N15, wherein most of its length was situated. The plank is widest at its right (downslope) end, which is broken and badly

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<sup>5</sup> The hull fragments were drawn at full size on acetate film. All notches, fastener and other holes, mortises, tenons, treenails, dowels, pegs, tool marks, and surface coatings were carefully measured and recorded. The length of both sides of each fragment was photographed in sections and these images were stitched together to make an overall photomosaic of each piece (Polzer 2004, 7).



Table 2.1. Maximum Preserved Dimensions of Plank Fragments

Plank	Length (m)	Width (cm)	Thickness (cm)	Wood Identification
UM1	2.24	30.5	4.5	<i>Pinus nigra</i>
UM2	2.84	15.2	4.2	<i>Pinus nigra</i>
UM3	1.86	27.8	4.1	<i>Pinus nigra</i>
UM4	0.38	17.4	3.8	<i>Pinus nigra</i>
UM5 <sup>7</sup>	1.72	20.2	3.2	
UM5/1	0.66	16.8	3.2	<i>Pinus nigra</i>
UM5/2	1.06	20.2	2.9	<i>Pinus nigra</i>
UM6	0.45	12.2	3.5	<i>Pinus nigra</i>

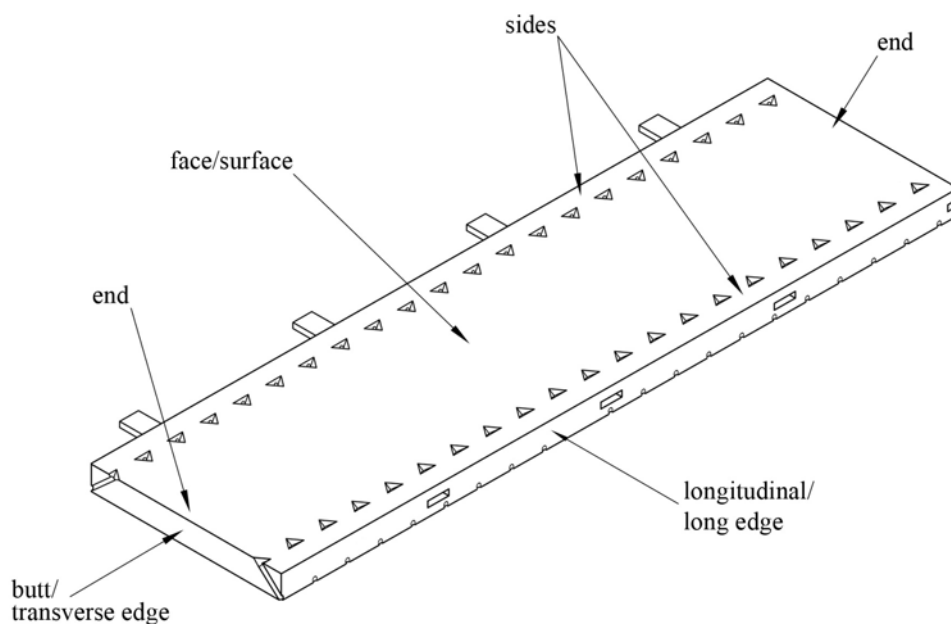


Fig. 2.2. Nomenclature used to describe particular areas of a plank.

<sup>6</sup> The wood identifications were made by Brian Jordan at the Kaufert Laboratory of the Department of Wood & Paper Science at the University of Minnesota, and subsequently confirmed by Nili Liphshitz at the Botanical Laboratory in the Institute of Archaeology at Tel Aviv University.

<sup>7</sup> These entries are the total combined length and maximum dimensions of the two preserved fragments, UM5/1 and UM5/2. The two pieces are from a single plank and thus, taking into account the 50 cm gap separating them, represent an original plank of more than 2.22 m length.

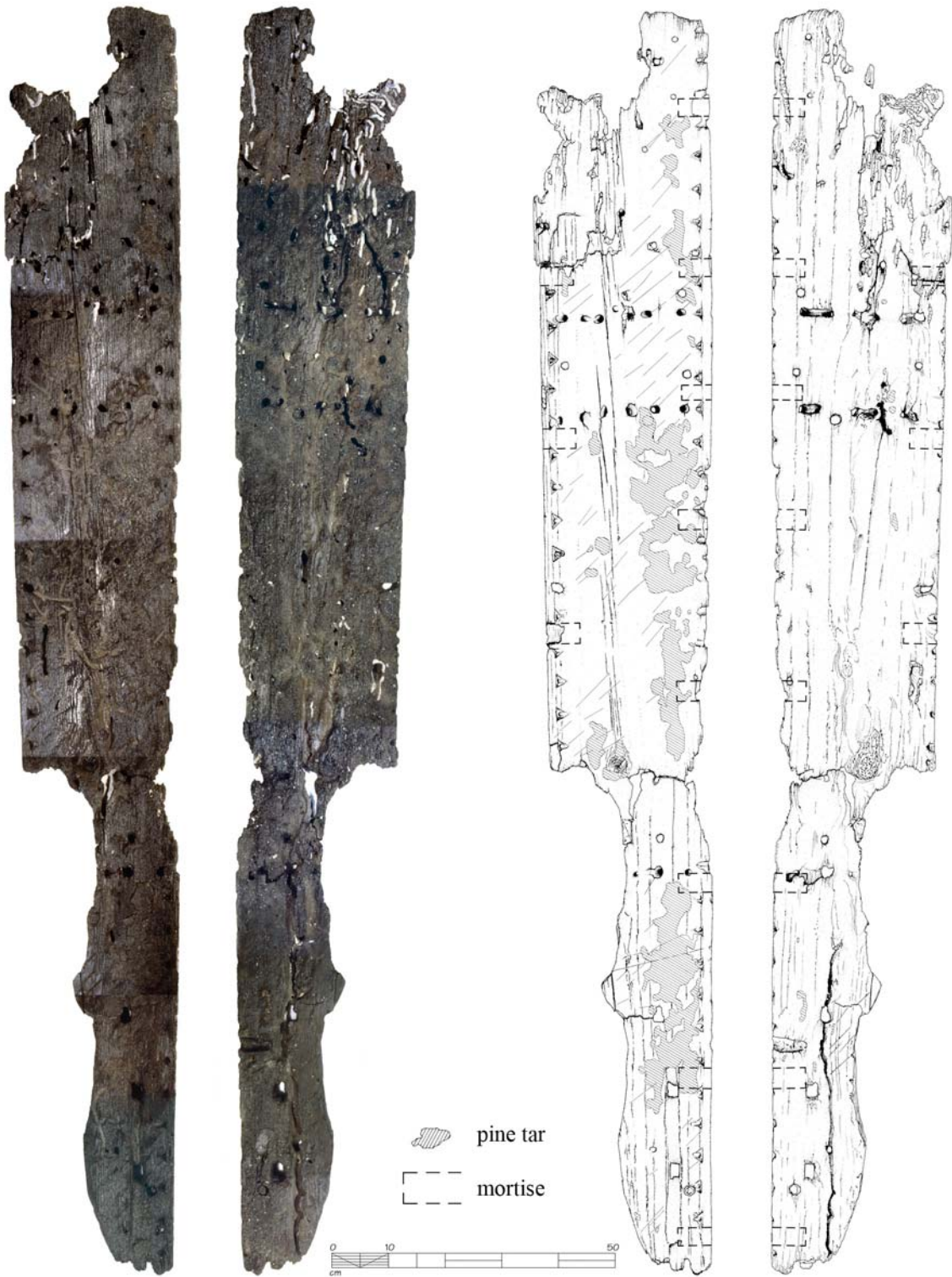


Fig. 2.3. Photomosaics and drawings of plank UM1.

deteriorated by shipworm borings. The opposite end is broken very near its original tip. Although it was found in one piece, the plank was cracked severely in several areas. These became full breaks during the plank's removal from the seafloor and desalination in the Nixon Griffis Conservation Laboratory at INA's Bodrum Research Center.

### General Description

The plank is made of *Pinus nigra* (Austrian pine, also commonly known as black pine), as are all of the recovered pieces of hull planking.<sup>8</sup> It retains most of its two original edges, including almost 70 cm of a curving scarf that forms the upper edge of its narrow end. Approximately 73 cm of its lower edge, extending outward from the break between the narrow and wide ends, has eroded away up to a maximum of 4 cm at the break. There is some exposed original surface on the inboard face, while the remaining surface is only slightly eroded, particularly between the distinct wood grains. The grain of the wood in general runs longitudinally along the plank and is denser towards the sides. A dark, amber-colored resinous material up to 4 mm thick in places is spattered across the plank surface and covers approximately 20 percent of the total surface area (fig. 2.4). The material was sampled and identified as pine tar made from *Pinus* sp.<sup>9</sup> Undoubtedly, additional original surface is preserved beneath it.

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<sup>8</sup> Jordan, personal communication. Samples from each plank were identified as pine, with a high probability of being *Pinus nigra*, based on their large resin canals and abrupt transition from earlywood to broad latewood. Due to variability within species, it is possible that the samples are *Pinus sylvestris* (Scots pine). However, the abrupt transition from earlywood to latewood and broad latewood regions are characteristics not usually found in *P. sylvestris*. Both types of pine are common around the Mediterranean, and *P. nigra* is found as well in Cyprus regions around the Black Sea.

<sup>9</sup> The samples were analyzed by Curt Beck at the Amber Research Laboratory of Vassar College. His identification is based on the presence of methyl benzoate that so far, in his broader and on-going study, he has found only in tars made from *Pinus halepensis* (Beck, personal communication). This material is referred to varyingly as resin, pitch, or tar. All three materials are plant-derived, and are not to be confused with petroleum-based products such as bitumen, asphalt, or oil tar. However, resin is the natural



Fig. 2.4. Remnants of pine-tar coating on the interior face of plank UM1.

The plank appears to be slightly concave across its width but, due to its structural fragility, it tends to form to the shape of the supporting surface upon which it lies, making it difficult to confirm its original shape. There are several large longitudinal

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secretion obtained by tapping pine trees or other coniferous plants, while tar and pitch are produced by heating the wood of such trees. When wood is burned in an anoxic environment, i.e., with insufficient oxygen for complete combustion, it produces charcoal and tar residue. Pitch is the heavy material left when the volatile components of tar are distilled off. Chemical analyses of tars can determine the source material and process (i.e., temperature) by which it was made (see, e.g., Beck et al. 2002; Kühn 1960). Unfortunately, tars from shipwrecks are not typically analyzed, and so whether they are tar or pitch is usually indeterminable. The term ‘tar’ is used in this thesis and follows Beck’s preference.

cracks running along the heartwood that may have resulted from the plank being pressed to the seabed and flattened during the wreck-formation process.

### Thickness

The plank is thinner towards its upper edge, especially along the length of the scarf. Planking thickness was measured every 10 cm, but in many cases the measurement was questionable due to granular collapse of the wood, especially in areas of heavy teredo concentration, erosion, and breakage. On average, the plank overall is about 3.5 cm thick, thinning from 3.6 cm along the bottom edge to 3.2 cm along the top edge. The difference in thicknesses is more pronounced along the scarfed end. Here the plank is 0.8–1.4 cm thinner along the top edge, with an average difference of about 1.0 cm. Along the full-width portion of the plank, the upper edge tends to be only 0.2 cm thinner, with differences ranging from 0.0–0.4 cm at similar locations. Table 2.2 lists maximum, minimum, and average thicknesses for each of the planks and fragments. These measurements are provided as well for the main portions of UM1 and UM5.

### Width

The width of the plank along its full-breadth portion widens from left to right. The bottom edge is straight, whereas the top edge of the plank angles upwards at about 1.2 degrees. The width of the plank thus increases from less than 26 cm after the scarf to almost 31 cm at the far right end, or about 3.8 cm per meter of length. Table 2.2 lists maximum, minimum, and average widths for each fragment. End scarfs are not included in overall average dimensions.

Table 2.2. Plank Thicknesses and Widths

Planking Fragment	Thickness (cm) <sup>10</sup>			Width (cm) <sup>11</sup>		
	Max.	Min.	Avg.	Max.	Min.	Avg.
UM1	3.5 4.5	3.0 3.1	3.2 3.6	30.5	26.8	29.2
Scarfed (left) portion	3.2 4.5	2.8 3.5	3.1 4.1	18.7	10.7	15.1
Full-width (right) portion	3.5 3.7	3.0 3.1	3.3 3.4	30.5	26.8	29.2
UM2/3	3.7 4.2	2.6 2.4	3.4 3.3	13.6	8.7	11.3
UM3	4.1 4.0	2.0 2.0	3.8 3.7	27.8	6.3	19.3
UM4	3.8 3.1	2.3 2.2	2.5 2.4	16.7	7.4	9.5
UM5	2.9 3.2	2.1 1.3	2.7 2.5	20.2	1.2	14.6
UM5/1	2.9 3.2	2.1 1.3	2.7 2.3	16.8	1.2	11.1
UM5/2	2.8 2.9	2.6 2.0	2.7 2.6	20.2	9.6	16.9
UM6	3.5 3.3	3.1 2.5	3.3 2.7	11.3	9.4	10.5

<sup>10</sup> Values provided for upper and lower edges of each plank, respectively.

<sup>11</sup> Measurements were taken at 10-cm intervals along the length of each fragment.

### Workings

The surface of the plank contains numerous tool marks and fastening holes that tell much about how it was made, its function, and its original location on the hull. These features are described here, but are interpreted and discussed within the technical aspects of the ship's hull construction in chapter IV.

The plank is plainsawn and the flat (tangential) wood grain is clearly visible running down the middle of the plank and flowing around a large knot located near the scarfed end. The knot's original surface preserves what appears to be fine saw tooth marks spaced about 1 mm apart and angled approximately 38 degrees to the run of the wood grain. Adze marks are particularly prominent across the full length and width of the inboard surface of the plank.<sup>12</sup> The marks generally overlap, but where complete marks are preserved with good definition, they appear to have been made by a well-honed adze with a blade 4–5 cm wide struck at an angle of 45–55 degrees.

As best as it can be determined, the longitudinal edges of the plank appear to be cut square with no beveling. If there is any beveling, it might be along the upper edge, slight and tapering from the upper to the lower face of the plank. The scarf edge, however, was dubbed with an adze and is multi-faceted. The scarf is generally S-shaped with a protrusion, or hook, at its approximate middle. The left scarf table (before the hook) is longer than the right table, which is now largely missing. The edge of the scarf is beveled, but the beveling changes direction from inward, near the key, to outward

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<sup>12</sup> The plank was lying on its outboard face when found, and most of that original surface has been scoured away by the sand, and with it most traces of possible tool marks.

towards the far left end of the plank (fig. 2.5). The edge is not particularly smooth or precisely crafted.



Fig. 2.5. Beveled edge of the curved scarf on plank UM1.

Both long sides of the plank are lined with tetrahedral notches, which from the surface appear triangular. They are aligned with their base side parallel to the plank edge. The notches were made using a chiseling tool. Slight cut marks are visible on the base of the better-preserved notches, extending beyond the intersection of each side cut, which probably means that a flat (rectangular) chisel was used. There is no visible damage to the inner sides of the notches (specifically, where the sides intersect each other), indicating that a corner of the chisel was used.<sup>13</sup> The notches are offset from the edge approximately 1.6 cm. The sides of the notches measure on average 2.0 cm, but

<sup>13</sup> Winters and Kahanov (2004, 38–9) assume that clean inner notch edges indicate the use of a pointed chisel. They note that notches made with a rectangular chisel were more uniform, but that the tool tended



the base is consistently the longest (averaging 2.3 cm), indicating that this side of the notch was made first. Within each notch is a hole measuring approximately 0.6 cm in diameter and drilled at approximately 42 degrees along the apex of the notch, into the face of the base side of the notch, and through to the outer (lower) corner of the plank edge. On average, approximately two-thirds of each exit hole penetrates the plank edge, while the remaining one-third exits the outer face of the plank. A few of holes, however, exit almost completely on the plank edge.

A limp, waterlogged segment of reed stem was found seated in one hole along the top side, extending beyond both faces of the plank (fig. 2.6).<sup>14</sup> The reed was identified as a monocotyledon, possibly a stem of *Phragmites communis* (common reed) or *Arundo donax* (giant reed) of the Poaceae (grass) family.<sup>15</sup> Three other holes along the top side and four holes directly opposite along the bottom side of the plank retain wooden pegs that were inserted to the outer corner of the plank edge and trimmed flush with the plank's inboard face (fig. 2.7). One of the pegs was removed and its wood identified as *Alnus incana* (grey alder).<sup>16</sup>

There are also series of aligned holes, ranging in diameter from 0.9–1.2 cm, running vertically across the width of the plank face. The dimensions and locations of

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to cut into the adjacent sides of the notch. It is possible that such cut marks have simply been worn away and are no longer detectable in the eroded notches of the Pabuç Burnu hull fragments.

<sup>14</sup> The collapsed reed was originally mistaken for a segment of ligature due to its limp appearance and the fact that it extended beyond the ligature hole on both sides of the plank (Greene 2003, 9).

<sup>15</sup> Liphshitz, personal communication. Due to the degradation of the sample, a definitive botanical identification was not possible, but the hollow stem looks like a reed section between internodes. The epidermis was degraded and the inner cells collapsed, but the remaining longitudinal fibers and phytolites, as well as silica bodies, point to the Poaceae (Gramineae) family (Watson and Dallwitz 1992 onwards).

<sup>16</sup> Jordan, personal communication. The size and degradation of the peg made identification problematic, but the morphology of the sample, especially the size of its rays, of which none were more than 30 cells in height, points to *Alnus incana* (grey alder).



Fig. 2.6. Reed peg in plank UM1.



Fig. 2.7. Wooden ligature pegs in plank UM1.

the holes are given in Table 2.3. The two best-preserved series, located approximately 153 and 170 cm from the left end of the plank, respectively, consist each of three pairs of holes. The holes of each pair are oppositely oblique, angling towards one another as they penetrate the plank's thickness. A small channel is cut out between the exit holes of each pair on the opposite face of the plank. There is no indication that they were drilled within tetrahedral notches, as were the holes along the sides of the plank. Neither series of holes is perfectly aligned, nor exactly perpendicular to the length of the plank, and the narrowest distance between their inner tangents is 15.3 cm.

A second set of holes is located near the middle of the plank, the two lines being approximately 71 and 88 cm, respectively, from the left end of the plank. Each series preserves only three holes. Those of the left series are fairly well preserved, whereas the holes of the right series, along which the plank is cracked and badly deteriorated, are difficult to make out. Where the exit holes are preserved, the plank is notched between them.

At the very left end of the plank fragment, again where it is broken, there are indications of two more holes. These, presumably, make up the lower pair of holes of the right line of another set of vertically positioned holes.

There are additional holes, also 1.2 cm in diameter, located between the middle and right sets of lined holes. There is a hole drilled within approximately 3.7 cm from each side of the plank between the right two series of holes, and a single hole situated approximately 7.2 cm from the lower side of the plank between the middle series of holes.

Table 2.3. Frame Lashing Holes in Plank UM1

Series	Diam. (cm)	Hole Angle <sup>17</sup> (degrees)	Distance from Near Edge of Hole to:				Distance Between Paired Holes	Distance Between Pairs		
			Ends of Plank		Sides of Plank					
			Left	Right	Top	Btm				
F1	Right	1.0	—	1.2	221.6	1.2	7.2	2.5	—	
		1.0	—	1.7	221.1	5.2	3.9			
F2	Left	1.0	35↑	70.5	152.3	1.1	12.9	—	3.3	
		1.0	42↓	70.8	152.0	5.4	8.4			
		1.0	21↑	70.8	152.0	10.4	3.4			4.0
	Right	1.0	32↓	87.2	135.6	-1.0	17.7	6.9	2.8	
		1.0	—	87.2	135.6	6.8	9.8			
		0.9	42↓	87.2	135.7	10.5	6.2			
		0.9	40↑	87.2	135.7	16.2	0.5			4.7
		1.2	46↓	150.7	71.9	2.5	26.4			
F3	Left	1.2	19↑	151.4	71.2	6.8	22.2	3.0	2.4	
		1.2	43↓	152.3	70.3	10.4	18.6			
		1.2	23↑	152.3	70.3	15.1	13.9			3.5
		1.1	36↓	152.6	70.1	19.4	9.7			4.0
		1.2	18↑	152.8	69.8	24.6	4.4			
		Right	1.2	38↓	168.9	53.7	3.6			25.7
1.2	20↑		168.8	53.8	7.3	22.0				
1.2	40↓		168.7	53.9	10.1	19.2				
1.2	20↑		169.2	53.4	15.4	13.9	4.2			
1.0	47↓		169.7	53.1	18.7	10.8	4.6			
1.0	17↑		170.1	52.7	24.3	5.2				

<sup>17</sup> The arrows indicate the direction of drilling relative to the upper side of the plank.

Three other holes penetrating the thickness of the plank, two of which are plugged with treenails that have been trimmed flush with the surfaces of the plank. The first of these holes is located approximately 14.1 cm from the left end of the plank and 3.1 cm from the bottom side of the plank. The treenails are irregular in cross-sectioned shape, though generally hexagonal, indicating that they were whittled by hand. Although the plugs and their holes are no longer the same diameter due to centuries submerged in the sea, the drilled holes still retain the original shape of the treenails, indicating that the latter were tightly fitted when originally inserted.



Fig. 2.8. Longitudinal groove and rectangular holes in scarfed end of plank UM1.

Finally, two rectangular holes penetrate the face of the plank 17.5 cm and 31.7 cm from its left end, respectively (fig. 2.8). The left hole measures approximately 2.0 x 1.5 cm, while right one is slightly smaller at 1.8 x 1.6 cm. The two holes are aligned roughly along the center of the plank and are separated by a space of 12.1 cm. On the

inboard face, the plank wood between the holes and to either side is gouged to form a recessed groove, the base of which slopes towards the holes from either end and from between them. The groove measures approximately 30.5 cm long and 2.4 cm wide. It extends towards the left almost 12 cm from the left hole (to within 6 cm of the end of the plank), but to the right of the right hole it extends just over 3 cm.

Rectangular mortises are cut into both edges of the plank, roughly staggered along one edge from those in the opposite edge. Three mortises are preserved along the upper edge, while eight penetrate the lower edge. There are no mortises along the scarf table. The first mortise in the lower edge still retains half of a tenon. It is broken flush with the edge, but is slightly damaged and missing part of its right side (fig. 2.9). The mortises are centered within the thickness of the edges and, where preserved, are



Fig. 2.9. Half-tenon preserved in its mortise in plank UM1.

precisely cut with sharp corners and straight sides. The mortises are on average 3.3 cm wide at the edge, 1.0 cm high (thick), and 5.9 cm deep, where their depth can be determined. The dimensions and positions of the mortises are given in table 2.4.

Table 2.4. Edge Mortises in Plank UM1

No. <sup>18</sup>	Edge	Distance From Left End of Plank to Left Edge of Mortise (cm)	Width (cm)	Height (cm)	Depth (cm)	Space (cm)	Room and Space (cm)
1	Upper	111.8	3.6	1.0	6.0	—	—
2		146.4	3.6	1.0	6.0	31.0	34.6
3		175.3	3.4	1.0	6.0	25.4	28.9
1	Lower	5.1	3.2	1.0	—	—	—
2		33.1	3.6	1.0	5.7	24.8	27.9
3		67.8	3.4	1.0	6.0	31.2	34.7
4		101.6	3.5	1.0	6.2	30.6	33.9
5		132.0	3.5	1.0	5.9	26.9	30.4
6		154.9	2.7	1.0	5.3	19.4	22.9
7		176.8	3.1	1.0	5.7	19.3	21.9
8		205.2	3.2	0.9	4.4 <sup>19</sup>	25.3	28.4
Min.			2.7	0.9	5.3	19.3	21.9
Max.			3.6	1.0	6.2	31.2	34.7
Overall Avg.			3.3	1.0	5.9	26.0	29.3

UM2. Fig. 2.10; sector N15; l. 28.4 cm; w. 15.2 cm; th. 4.2 cm; *Pinus nigra*.

Excavators uncovered the second hull fragment less than a meter to the west of UM1 and near the center left side of sector N15. Almost immediately thereafter, while

<sup>18</sup> Mortises are numbered from left to right along each edge.

clearing the sand from around it, a much larger plank (UM3) was revealed beneath it. UM2 lay directly overlapping the upper side of UM3.

All that remained of this plank was this one substantial piece and a few disarticulated scraps that were spread out over about a meter to the north of UM2. The run of the plank inferred from the alignment of these remains and their wood grain was skewed about 15 degrees to that of UM1, but was generally in the same direction. The scrappy wood fragments consisted mostly of teredo casings and a few millimeters of surrounding wood holding them together. They contained no diagnostic features and mostly fell apart upon recovery. A small piece of branch, identified as *Euphorbia* spp., was found stuck to the pine tar coating on its bottom face.<sup>20</sup>

### General Description

Fragment UM2 appears to be a preserved portion from the center of a plank; it retains no original edge. The upper surface is essentially original, with slight erosion between the wood grains and two teredo bore holes penetrating the upper right area. The bottom surface, however, is heavily scoured and damaged by teredo activity; several large burrow casings are visible.

### Thickness

The plank has a maximum preserved thickness of 4.2 cm (table 2.2), but this measurement comes from a damaged area of the plank and may slightly overstate the

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<sup>19</sup> A fragment of tenon remains within the mortise, preventing a measurement of the full depth.

<sup>20</sup> Jordan, personal communication. The hardwood has long pore multiples oriented in the radial direction and very small, possibly uniseriate, rays.



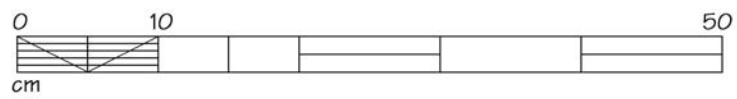
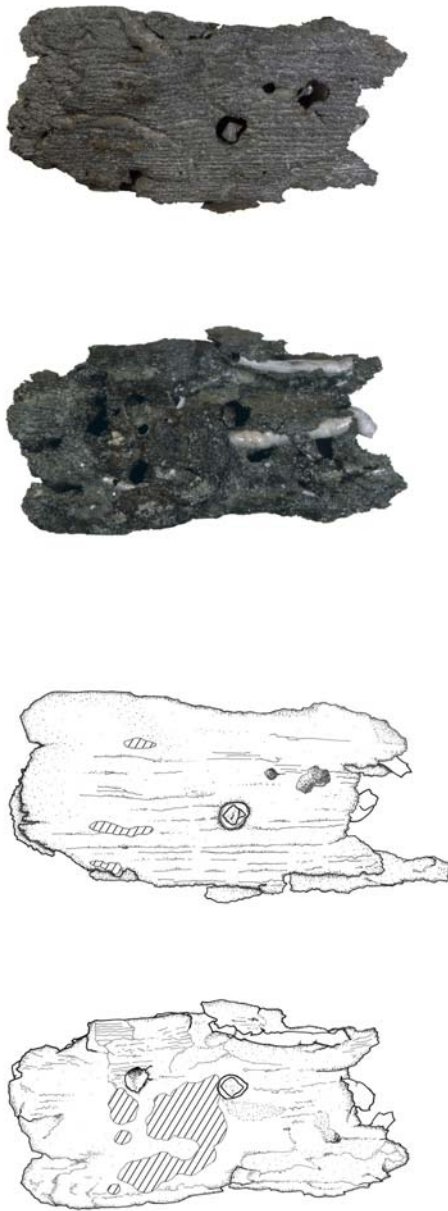


Fig. 2.10. Photomosaics and drawings of plank fragment UM2.

true original thickness. The fragment is up to 3.8 cm thick in other areas, so the original thickness was probably 4.0 cm or better.

#### Width

The fragment preserves up to 15.2 cm of the plank's original width (table 2.2).

#### Workings

The upper surface of the plank preserved no tool marks, and no original surface remains on the bottom face. The only diagnostic feature on the fragment is a through-hole near its center, in which remains a wooden plug; the hole is approximately 1.7 cm in diameter. The treenail used to plug the hole is made of *Pinus nigra*. It is approximately 1.2 cm square in section, no longer the same size as the hole, due to shrinkage.

UM3. Fig. 2.11; sectors M15–N15; l. 185.8; w. 27.8; th. 4.1; *Pinus nigra*.

Discovered while excavating UM2, this piece proved to be another large fragmentary plank similar in size to UM1. It was found lying on its outboard face approximately 80 cm west of UM1. The two planks were oriented parallel to one another and with both their extremities well aligned. UM3 extended from the upper right quadrant of sector M15 into the lower left quadrant of sector N15, with about half of its length situated in each sector.

The fragment is in poor condition. Both extremities and the entire lower side of the plank have been consumed by shipworms. Much of what remains of the plank, especially the lower portions, is thoroughly riddled with the telltale casings of these

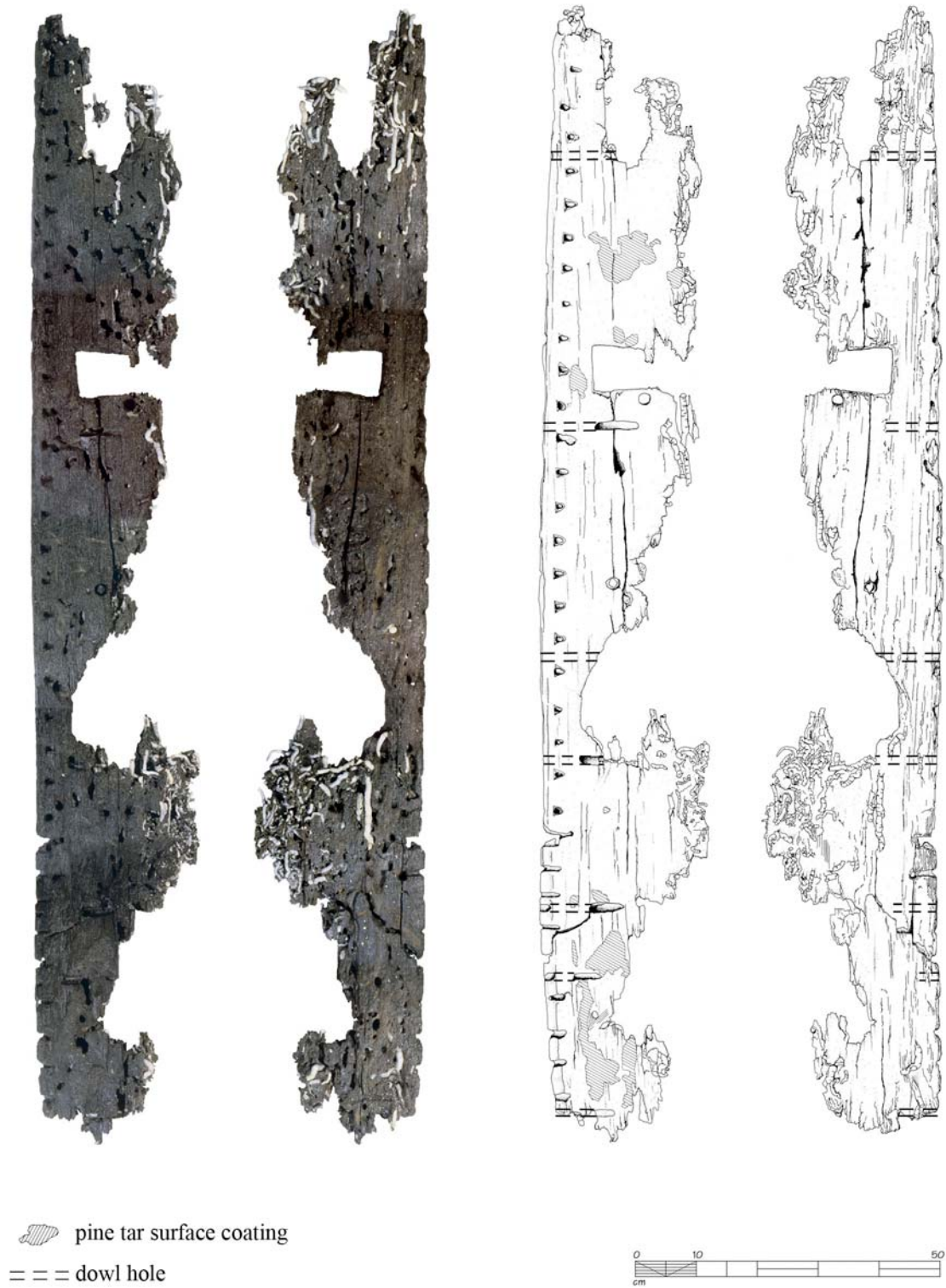


Fig. 2.11. Photomosaics and drawings of plank UM3.

marine wood-borers, making these areas particularly friable. There is also a large, longitudinal crack running down the center of the plank across its right and central portions.

### General Description

The fragment retains most of its original (or nearly original) upper edge, except for approximately the left 46 cm. That portion of the edge is missing its upper corner, which appears to have been sheered off, and as a result the plank has a deceptively curved appearance. This is exaggerated by the fact that at its narrowest point, approximately 70 cm from the left end, the remaining plank wood is only 6.3 cm wide. The plank ends tend to bend around this point, especially when the fragment is moved and handled. No other original edge survives. Neither is there any completely original surface on either face of the fragment, although the inboard face generally is in much better condition than the outboard. Several areas of the inboard surface—at the left end of the fragment, and another towards the right extremity, representing about eight percent of the total surface area—are covered with weathered, amber-colored wood tar, which is 3–4 mm thick in places. Original surface must survive beneath these patches of tar.

### Thickness

The plank appears to be fairly uniform in thickness. The top edge is approximately 4.0 cm thick along its better-preserved middle portion, but narrows to 2.0 cm at the right end where the wood is severely eroded and collapsed (see table 2.2). The maximum thickness along the edge is 4.1 cm. A maximum overall thickness of 4.4 cm

was recorded approximately 8 cm from the left end and 8 cm from the upper edge. However, this included 2–3 mm of a resinous material on the plank surface at that spot, and thus overstates the actual thickness of the wood.

### Width

The plank retains none of its full original width, as its entire lower side is missing. The preserved widths vary greatly across the length of the fragment, from a maximum of 27.8 cm at about 50 cm from the left end, to 6.3 cm at the 70 cm mark (table 2.2).

### Workings

The plank is plainsawn and cut parallel to the flat grain of the wood, which appears to be fairly uniform across the width of the plank. Fine saw tooth marks spaced about 2.5 mm apart and angled approximately 47 degrees to the run of the grain are visible about 20 cm from the left extremity (fig. 2.12). No other tool marks are visible, due to the poor preservation of the plank's surfaces and edges.

The upper edge of the plank appears to have a slight bevel of approximately 18 degrees from the outboard to the inboard corner of the edge along the right half of the plank, where the edge is best preserved. However, even this area has no original edge remaining, so this feature cannot be confirmed.

The preserved side of the plank is lined with 33 tetrahedral notches that have holes drilled through their base to the lower corner of the edge. Since 50 cm of the left upper corner of the side is missing, nothing of the first nine notches remains. All that is preserved is the bottom half of their oblique through-holes. Although none of the



Fig. 2.12. Saw marks preserved on the inboard face of plank UM3.

notches are well preserved, they appear to be identical to those on UM1. The only difference is that the notches on UM3 are not aligned as straight along the edge as those of the other planks. On average, the notches are offset 2.2 cm from the edge, but this distance varies from 1.1–2.7 cm. The actual variance may be somewhat less when the poor preservation is taken into account, but the workmanship or care evident on UM3 still does not seem to match that of the other planks. The sides of the notches measure on average 2.0 cm, with the base and sides about the same size. The loss of plank surface, however, means that the original size of the notches was slightly larger. The through-holes measure approximately 0.8 cm in diameter and were drilled at an angle of approximately 46 degrees.

There are two holes penetrating the thickness of the plank, one of which is plugged with a treenail. The first of these holes is located approximately 91 cm from the left end and 11 cm from the top edge of the plank, and has a hexagonal shape. The treenail within it is now roughly pentagonal in shape, and has shrunk to about 75 percent of its original diameter. The treenail was obviously shaped by hand, and was trimmed flush with the plank surfaces after being driven into the hole. The second such hole is situated another 30 cm to the right and 15 cm from the top edge. While its shape is more circular, it still retains the impression of the facets of the treenail that once plugged it.

Less than a centimeter to the right of the hole is a large rectangular—or, more precisely, trapezoidal—opening cut out of the plank. The upper edge of the opening is slightly longer than the lower edge, of which about two-thirds is missing. The hole has sides measuring approximately (clockwise, starting with the upper edge) 7.2 x 8.3 x 6.2 x 8.1 cm, and its upper edge is 8.2 cm from the edge of the plank.

Finally, there are seven circular holes drilled obliquely into the edge of the plank such that they exit through the inboard face. The diameters of the holes average almost 1.3 cm. The angles of the holes vary from 8–16 degrees (relative to the face of the plank) and, therefore, the distances from the edge of the plank to where the holes penetrate the surface vary as well, from 6.3–12.0 cm. Scrappy remains of the dowels that were inserted originally into two of the holes survive, the better preserved one

measuring 5.6 cm in length. The dowel scraps were recovered and identified as *Nerium oleander* (oleander).<sup>21</sup>

UM4. Fig. 2.13; sector N15; l. 37.7 cm; w. 17.4 cm; th. 3.8 cm; *Pinus nigra*.

This fragment was exposed on the last dive of 2002, when UM3 was lifted from the seafloor. There was no time to investigate the piece further, so it was reburied and left for excavation in the following season. Upon relocated the piece in 2003, the team excavated around it only to discover that it was a small fragment. It was positioned between UM1 and UM2, about 20 cm west of the former and oriented roughly parallel to it.

#### General Description

Like UM2, this fragment is poorly preserved. The upper face is essentially original, but suffers from erosion, especially between the wood grains. There are splotches of tar-like material on both surfaces, although on the top face it appears mostly as a discoloration of the wood. The coating is best preserved towards the right end of the bottom face, where it is up to 4 mm thick and contains many small shell inclusions. There is a small and partially loose knot at the middle right end of the fragment, and shipworm bore holes pit the surface, especially in the central area. The only near-original edge remaining is a straight 14-cm portion of the upper edge, which is aligned

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<sup>21</sup> Jordan, personal communication. Both samples were small and severely degraded, making positive identification difficult. One sample had some solitary vessels and many in radially oriented multiples of 2–4 vessels. The observable characteristics indicate *Nerium oleander* or *Euphorbia* spp., but the shorter pore multiples tend to favor the former. The second sample was similar, but had numerous long radial pore multiples of medium size combined with shorter pore multiples, which favor identification as *Euphorbia*.



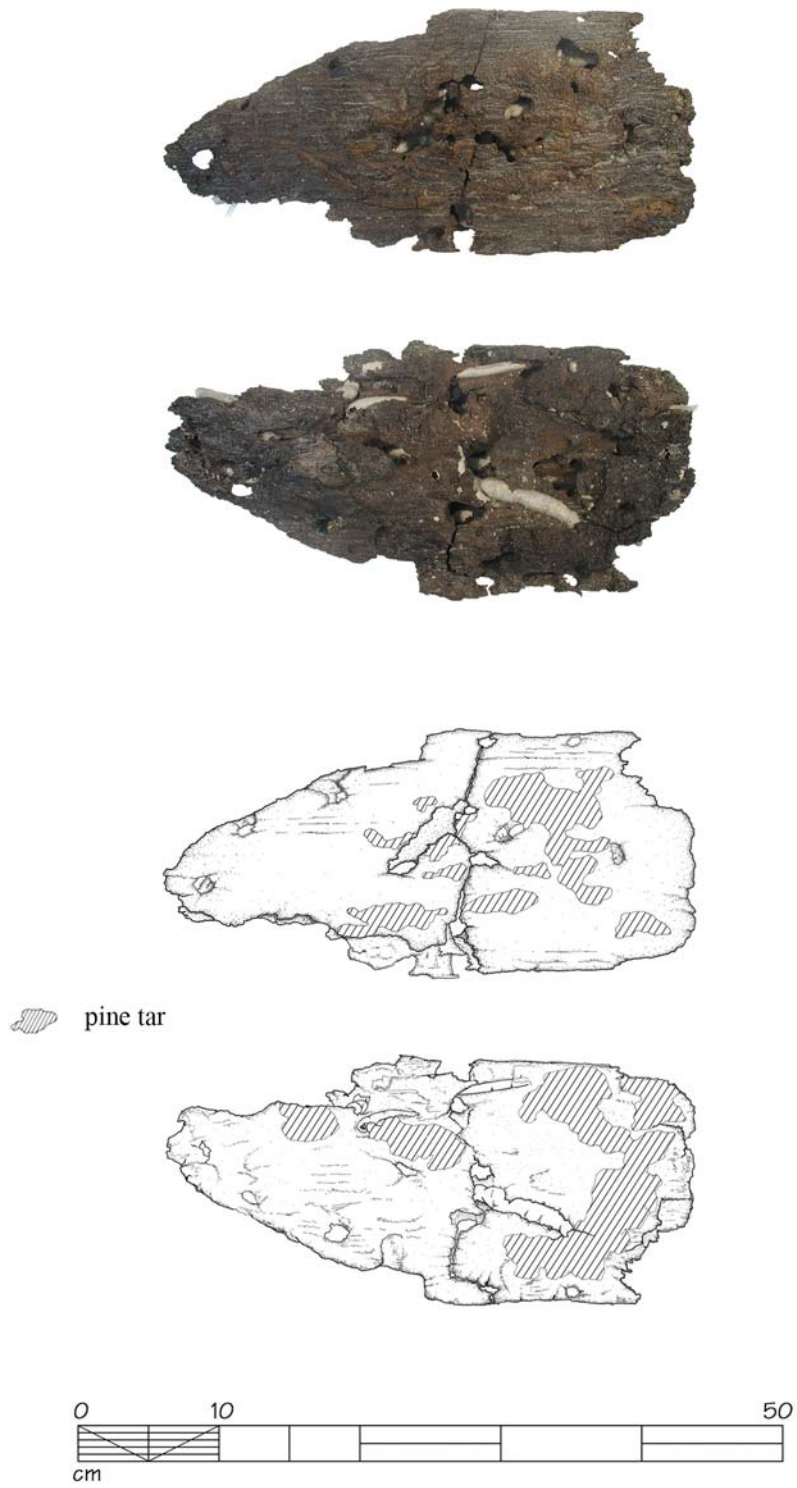


Fig. 2.13. Photomosaics and drawings of plank fragment UM4.

parallel to the run of the grain. However, even this is precariously preserved, as much of the interior wood behind it has been eaten away by shipworms. There is also a deep crack that runs from one side to the other down the middle of the fragment. The two halves are held together mostly by teredo casings. These casings are clearly visible on the underside of the fragment, which is in extremely poor shape due to heavy damage from scouring and boring. Surprisingly, a small section (4.5 x 3.5 cm) of smooth, original surface survives on the bottom face, located some 10 cm from the left (curved) end of the fragment. However, there should be additional original surface preserved under the wood-tar coating.

#### Thickness

The maximum plank thickness preserved in the fragment is 3.8 cm, measured along the upper surviving edge. The interior of the fragment measures 4.0 cm in spots, but always where there is wood-tar preserved; the thickness of the wood must therefore be several millimeters less. The lower, eroded edge is approximately 3.4 cm thick and diminishes to about 1.0 cm at the left end, which is the most deteriorated area (Table 2.2).

#### Width

The maximum preserved width of the fragment is 17.4 cm (see table 2.3).

#### Workings

The surfaces of the fragment retain no apparent tool marks, and the preserved portion of the upper edge is cut straight. Although no other original edge remains, the

left portion of the upper edge still retains the general curvature of its original shape and indicates that the fragment is the hood end of a plank.

The only features preserved in the fragment are seven holes penetrating the straight and curved portions of its upper edge. The wood surrounding the holes is highly eroded, which has enlarged the holes from their original dimension. As preserved, they measure from 0.9–1.6 cm in diameter and average 1.2 cm. There is no indication of the tetrahedral notches found on the other planks. Furthermore, the original angle of the holes is impossible to determine due to the poor preservation of the wood, but they do not seem to have been oriented to the corner of the edge as on the other planks.

UM5. Fig. 2.14; sectors L15–M15; l. 172.3 cm; w. 20.2 cm; th. 3.2 cm; *Pinus nigra*.

UM5/1. Sectors L15–M15; l. 66.3 cm; w. 16.8 cm; th. 3.2 cm. UM5/2. Sector L15; l. 106.0 cm; w. 20.2 cm; th. 2.9 cm.

This fragmentary plank was found during the first week of the second excavation campaign, the first and largest new piece of hull material discovered that season. It was found in two parts lying on its inboard face and oriented roughly perpendicular to the slope of the seabed, approximately 67 cm northwest of plank UM3. Working outward from where fragment UM4 was recovered, the team uncovered the smaller of the two pieces (UM5/1) first, in the upper left quadrant of sector M15. Continuing to airlift along this line into sector L15, the larger piece (UM5/2) was excavated shortly thereafter. A half-meter gap separated the two pieces, but it was readily apparent from the perfect alignment of the upper edges, wood grain, and smooth, dark limb wood

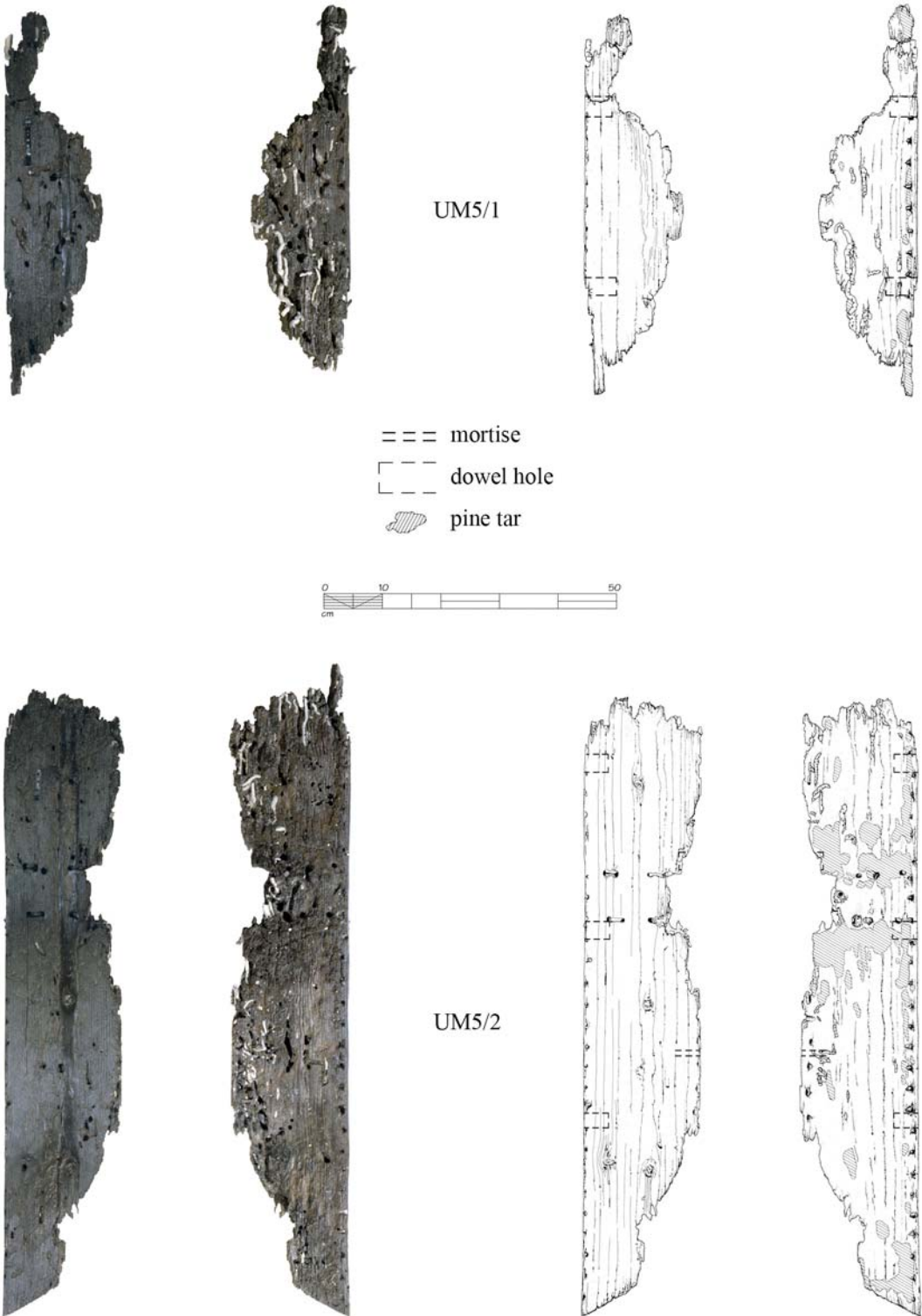


Fig. 2.14. Photomosaics and drawings of plank UM5 (in two parts, UM5/1 and UM5/2).

running down the center of each piece that the two fragments belonged to a single plank. The narrow, protruding right tip of UM5/1 was cracked along its juncture with the main portion of the fragment, and held there only by the bore casings of the shipworms that had eaten away the surrounding wood. It became dislodged during handling.

#### General Description

What is left of this plank is in fair condition, especially along its upper half. The lower portion, however, is mostly missing. Fragment UM5/1 preserves approximately 36 cm of original upper edge, but none of the plank's lower edge. Its maximum width of 20.2 cm is preserved near the middle of the fragment, from which point the remaining wood diminishes in either direction towards narrow, scrappy ends. Fragment UM5/2 is in somewhat better condition. The preserved long, upper edge is essentially all original, as is the near 11 cm remaining of the left transverse edge, which was cut diagonally. The fragment also preserves a portion of the original lower plank edge—23 cm to the left of middle and a few centimeters at the right end. However, large portions of the lower left corner of the fragment and that of the lower right half are missing. The right end of the fragment is roughly vertical, but eroded and eaten away by shipworms.

The upper face of the plank is fairly well preserved and is mostly original, but is marked with numerous wormholes and bore grooves, particularly on UM5/1. The flat wood grain is apparent and runs parallel to the length of the plank. It is fairly even, but becomes slightly larger toward the edges. Running down the center of the plank is a vein of dark, smooth limb wood that flows around three knots on UM5/2 and another on UM5/1. A fifth knot is located towards the upper side and near the left end of UM5/2.

The outer surface of the plank shows greater wear from scouring and shipworm activity. The wood surface is eroded slightly between the longitudinal wood grains, and numerous wormholes and bore casings are visible, especially along the lower side. Splotches of tar-like material remain on this face of the plank, particularly on UM5/2, and cover about 14 percent of the total surface area. Presumably, original surface is preserved beneath the tar.

### Thickness

The preserved plank remains tend to thin from the upper to the lower side—on average from 2.7 to 2.5 cm, respectively—due to the poorer preservation of the lower portions of the plank. In areas of better and more consistent preservation across the full width of the plank, the thickness actually increases towards the lower edge by approximately 0.1 cm. Furthermore, the maximum thickness of both fragments—3.2 cm for UM5/1 and 2.9 cm for UM5/2—was recorded along their lower edge. In any case, it seems that the plank originally had a fairly uniform thickness of around 3 cm.

### Width

Similarly, the plank appears to have been fairly uniform in width, with its maximum preserved dimension of 20.2 cm only slightly less than the original dimension. The upper edge appears to curve up slightly towards the tip of the scarfed end, but otherwise seems to have been cut fairly straight. The lower edge would appear to be straight-cut as well. The left end preserves a portion of a diagonal scarf cut at an angle of 62 degrees relative to the upper edge.

### Workings

No saw marks could be discerned on either face of plank UM5, and the distinct adze marks so prevalent on UM1 are virtually absent here as well. There are faint traces of adze marks, angled at about 45 degrees to the run of the plank, on the outboard face near the left end. In addition, the better-preserved edges bear telltale facets from adzing, and the uneven surfaces of the plank testify that it was indeed shaped with an adze (Fig. 2.15). The upper edge may be slightly beveled towards the inner face of the plank.



Fig. 2.15. Adzed edge of plank UM5.

Small holes whose diameters average 0.6 cm line both long sides of the plank, but are absent along the scarfed transverse edge. The holes exit at the upper corner of the edge and are drilled through tetrahedral notches aligned along the sides of the bottom face of the plank. The notches and holes are similar in all ways to those on planks UM1 and UM3, except that they are slightly smaller. The sides of these notches measure on

average 1.3 cm, with the base averaging 1.6 cm. The notches are offset from the edge approximately 1.1 cm and the holes have an average angle of almost 51 degrees. One hole contained the badly degraded remnant of a peg, which was removed and identified as a monocotyledon of the Poaceae (grass) family.<sup>22</sup>

Two lines of holes run vertically across the width of the plank some 67 and 75 cm, respectively, from the left end of UM5/2. Their arrangement resembles that of the lines of holes in UM1. Here, however, each line is comprised of only two pairs of closely-spaced holes connected by a groove between them. The lower hole of each second pair is largely missing, but its location can be determined by the preserved groove that connected it to its partner hole. The holes of the two upper pairs are separated by a space of 1.6 and 1.2 cm, respectively, while those of the lower pairs are 2.9 and 1.9 cm apart. The space between the pairs in the first line is 4.0 cm, while between the pairs in the second line it is 5.0 cm. The holes were drilled from the opposite face of the plank and are oppositely oblique. As such, the entrance holes are spaced farther apart. The holes were drilled directly into the plank without the use of tetrahedral notches. These holes are more precisely aligned than those on UM1, and the two lines are spaced closer together; the narrowest distance between their inner tangents is 7.0 cm. The dimensions and locations of each hole are given in table 2.5.

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<sup>22</sup> Jordan, personal communication. Due to the degradation of the sample, no gross or macroscopic features were observable and thus a definitive botanical identification was not possible. In cross-section, the sample's surface lacks typical wood morphology, and no rays are observed on the radial/tangential sections. There is spiral thickening in vessels with secondary walls, which is common in monocotyledons, but rare in dicotyledons. The larger openings may be intercellular canals, common in water plants such as *Phragmites* (reeds of the Poaceae family), and their location near the outer surface would seem to support this identification.



Table 2.5. Frame Lashing Holes in Plank UM5

Series	Diam. (cm)	Hole Angle <sup>23</sup> (deg.)	Distance from Near Edge of Hole to:				Distance Between Paired Holes	Distance Between Pairs	
			Ends of Plank		Sides of Plank				
			Left	Right	Top	Btm			
F1 <sup>24</sup>	Left	0.8	74↑	67.4	37.8	2.9	14.1	4.0	2.0
		0.9	59↓	67.4	37.7	7.6	10.2		
		1.0	79↑	67.5	37.4	10.3	6.8		
		0.8	54↓	67.4	37.8	16.3	1.5	5.3	
	Right	0.7	70↑	75.7	29.6	2.2	13.4	3.5	2.4
		0.7	61↓	75.4	29.9	6.4	10.0		
		0.7	66↑	75.2	30.1	9.5	6.2		
		0.7	53↓	75.3	30.0	15.2	1.2	5.0	

Table 2.6. Edge Holes in Plank UM5

No. <sup>25</sup>	Piece	Edge	Distance From Left End of Plank to Left Edge of Mortise (cm)	Width (cm)	Height (cm)	Depth (cm)	Space (cm)	Room and Space (cm)
1	5/2	upper	32.4	2.5	0.7	4.5	— <sup>26</sup>	—
2			64.6	3.1	0.7	4.5	29.7	32.2
3			93.0	3.2	0.7	4.3	25.3	28.4
4			17.5	3.0	0.6	5.6	—	—
5			48.0	3.0	0.6	5.0	27.5	30.5
1	5/1	lower	45.0	3.0	0.9 <sup>27</sup>	—	— <sup>28</sup>	—
2			76.7		0.7	4.2	30.8	32.7
3			34.9		0.7	5.5	—	—
Minimum				2.5	0.6	4.2	25.3	28.4
Maximum				3.2	0.7	5.6	30.8	32.7
Overall Average				3.0	0.7	4.9	28.3	31.0

<sup>23</sup> The arrows indicate the direction of drilling relative to the upper side of the plank.

<sup>24</sup> Measurements were taken on the inboard face of plank.

<sup>25</sup> Mortises are numbered from left to right along each edge.

<sup>26</sup> Distance from left end of plank to first mortise in upper edge is 32.4 cm.

<sup>27</sup> Dowel hole with diameter of 0.9 cm.

<sup>28</sup> Distance from left end of plank to dowel hole in lower edge is 45.0 cm.

No other holes are preserved in the surfaces of the plank, but there are a number of holes cut into the edges of the plank (table 2.6). Preserved in the upper edge are five rectangular mortises, three in UM5/2 and two in UM5/1 (fig. 2.16). Along the bottom edge there is an additional mortise in each fragment, although in both cases little of the



Fig. 2.16. Small mortise cut into the edge of plank UM5 between two ligature holes.

surrounding wood survives and only their approximate location and size can be estimated. The better-preserved mortises measure on average 3 cm wide at the edge and 0.7 cm high. The depths of the mortises range from 4.2–5.6 cm, and average 4.9 cm. Two mortises retain portions of their original tenons and so the full depths of those holes

could not be measured. One tenon fragment was sampled and identified as *Quercus* (oak) subgenus *Sclerophyllodrys*.<sup>29</sup>

A third hole is preserved along the lower edge of fragment UM5/2, in the best-preserved portion of the edge just left of middle. This hole is slightly hexagonal in shape and has a diameter of approximately 0.9 cm. Part of its original wooden dowel remains within, so the depth of the hole past 1.8 cm could not be determined. The dowel was probably hand cut and is tightly fitted within the hole.

The edge holes are centered in the thickness of the plank and are roughly staggered along one edge from those in the opposite edge (see fig. 2.14). The average space between adjacent holes is 28 cm, while room-and-space averages 31 cm, with a range of 28.4–32.7 cm. Preserved corners of the mortises are sharp and precisely cut, with no evidence of pre-drilling. Where it can be determined, it appears that one side of each mortise is cut straight, while the opposite side is slightly angled, presumably to facilitate removal of the wood. A rough interior edge of one mortise is further evidence of this kind of chiseling action.

UM6. Fig. 2.17; sectors N16–P16; l. 45.1 cm; w. 12.2 cm; th. 3.5 cm; *Pinus nigra*.

This fragment was the last piece of the ship's hull to be discovered. It was situated on the boundary between sectors N16 and P16 lying next to a broken amphora at

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<sup>29</sup> Jordan, personal communication. Possible species are *Q. coccifera* (Kermes oak), *Q. ilex* (Holly oak), and *Q. alnifolia* (Cyprian oak), with Kermes oak the most likely. It was not possible to distinguish with certainty between species within the subgenera based on wood anatomy alone. Kermes and Holly oaks are found around the Mediterranean basin and in countries along the western coast of the Black Sea, while Cyprian oak is found in Cyprus.

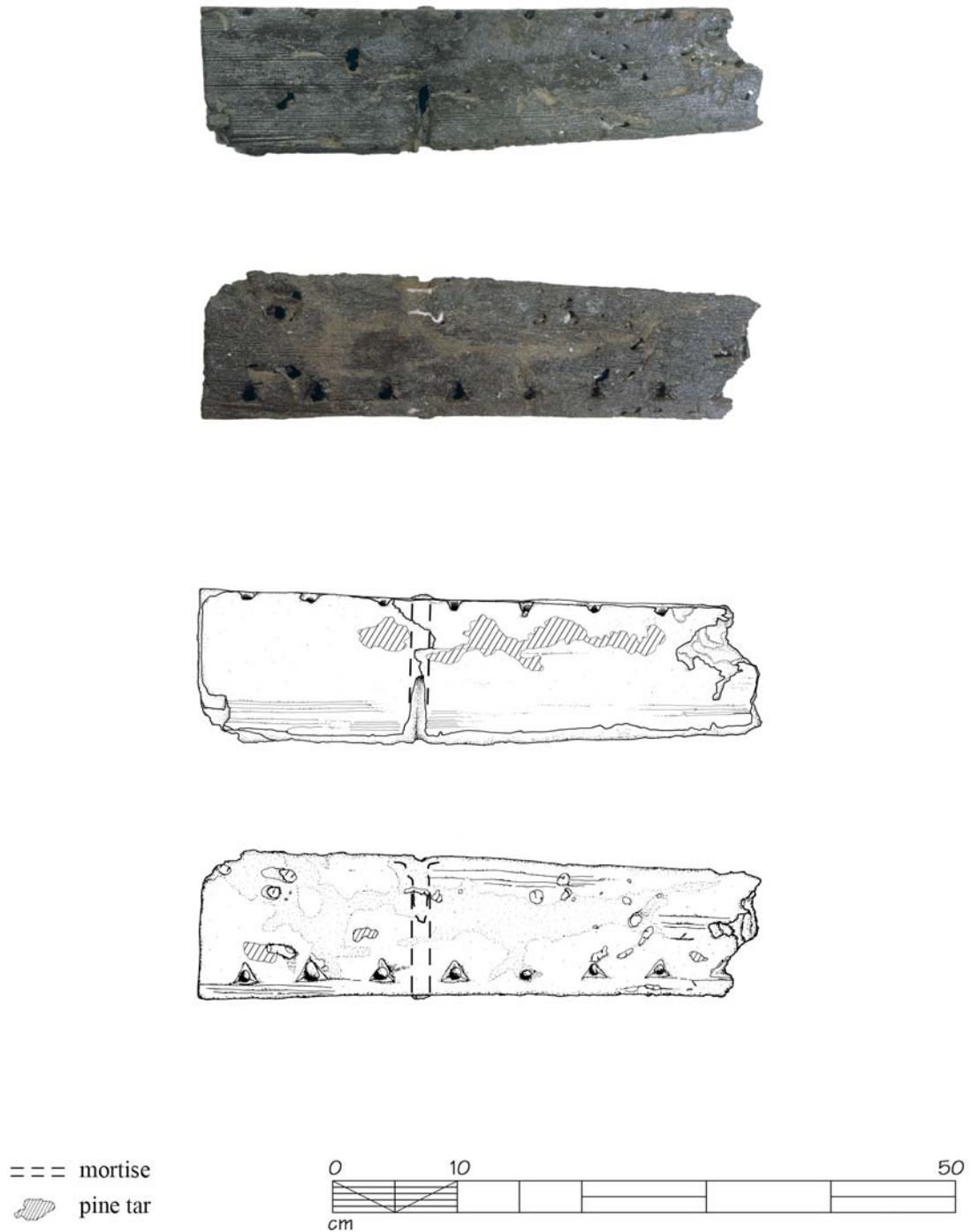


Fig. 2.17. Photomosaics and drawings of plank fragment UM6.

the lower extent of the site, approximately 2.24 m south of plank UM3 at a depth of about 46 m. Like plank UM5, this fragment was found lying on its inboard face and oriented roughly perpendicular to the slope of the seabed and to the other plank remains.

#### General Description

What little remains of this plank is in fair condition, with some shipworm bores penetrating its surfaces and numerous bore casings visible. Original surface is preserved along roughly 13 cm of the upper side and center of the fragment. The upper edge is original, as is approximately 10 cm of the plank's left transverse edge. The fragment is broken vertically at its right extremity and longitudinally along its length. Thus, little of the plank's width is preserved, and none of its lower original edge. The wood grain follows the length of the fragment and is fairly even.

The bottom surface of the plank shows greater wear from scouring and shipworm activity, but a small area of original surface is preserved to the left of center. This area measures approximately 5 x 3 cm, is smooth, and has a burnt umber color. A 2 x 2 cm blotch of wood-tar covers some of this area.

#### Thickness

The fragment is on average 3.3 cm thick along the top edge and 2.7 cm along the bottom edge, though the difference appears to be due to the poorer preservation along the broken portion of the plank. The thickness of the majority of the fragment seems fairly consistent at 3.3 cm.

### Width

Since the piece is broken longitudinally, there is no way of knowing the width of the original plank. Up to 12.2 cm is preserved towards the left end of the fragment, but only 4.6 cm at the right end. In a similar manner as on UM5, the upper edge appears to curve up slightly towards the tip of the scarfed end, but otherwise seems to have been fairly straight. The flat butt scarf at the left end has a slight angle of about 2 degrees relative to the upper edge.

### Workings

No distinct adze or saw marks are preserved on either face of the plank fragment. However, the unevenness of the surfaces and the preserved edges indicate that the original plank was probably shaped with an adze. The preserved edges are cut straight with no beveling.

Eight small holes with diameters averaging 0.7 cm line the corner of the upper preserved edge of the plank.<sup>30</sup> The holes exit at the corner of the edge and outer face and are spaced from 5.2–5.9 cm between centers, averaging 5.5 cm. They were drilled through tetrahedral notches aligned close to the side on the opposite face of the plank. The notches are similar in all aspects to those of the other planks, with an average base side 2.3 cm long and two other sides averaging 2.2 cm long. The notches are offset approximately 1.3 cm from the edge and the holes have an average angle of 44 degrees relative to the surface of the plank. Peculiarly, there is no tetrahedral notch associated with the fifth hole from the left, which was drilled directly into the surface of the plank.

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<sup>30</sup> The last hole is only partially preserved at the broken right end of the fragment.

A dowel remains seated within its hole in the edge, 17.2 cm from the left end of the plank (fig. 2.18). The tightly fitted dowel and hole are circular in section and have diameters of 1.5 cm. The hole was drilled obliquely from the center of the plank edge to the outboard face of the plank at an 8-degree angle. The dowel was broken almost flush with the edge, from where its preserved portion extends inward some 4.3 cm to where it was bored through by a shipworm. A burrow casing intersects the dowel inside the plank and nothing of the dowel is preserved beyond it.



Fig. 2.18. Dowel in situ in the edge of plank UM6.

This chapter has provided qualitative and quantitative descriptions of the recovered hull remains. The tool marks, notches, holes, fittings, and grooves on the planking and how they relate to the construction of the ship are investigated below.

## CHAPTER III

## GREEK SHIPWRECKS OF THE SIXTH – FOURTH CENTURIES B.C.

Despite their paucity, the hull remains recovered from the wreckage at Pabuç Burnu provide considerable evidence for the ship's materials of construction, scantlings, fastenings, and construction procedures and techniques. The tetrahedral notches and oblique holes lining the sides and edges of the fragments indicate that the remains are from a laced hull.<sup>1</sup> The practice of building boats using ligatures to fasten together the constituent pieces of the hull is very ancient and developed in coastal, island, river, and lake cultures throughout the world.<sup>2</sup> Yet while these boatbuilding traditions may share one or more individual features, the application of specific combinations of traits—materials, techniques, scantlings, fasteners, and details such as size, shape, spacing, and surface treatments—is unique to each system.<sup>3</sup> So far, the only evidence for tetrahedral notches in laced boatbuilding in the Mediterranean comes from a Greek context, and predominately from shipwrecks of the late Archaic period.<sup>4</sup> Interpretation of the sparse remains from the Pabuç Burnu hull will be fruitful only when viewed within this context

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<sup>1</sup> The terminology referring to hull construction techniques using cordage, or ligatures, is varied and, despite early recognition of the problem (McGrail and Kentley 1985a, xi), has yet to be standardized. As a result, terms are often used that are inappropriate and fail to reflect accurately the true nature of the specific technique to which they are applied. The term used most commonly to describe the type of construction employed in Archaic Greek boatbuilding is “sewn” or “sewn plank” construction. However, the technique is better described as “laced” construction, wherein matching holes are pre-fashioned along the edges of the fabrics to be connected and then ligatures are strung, or laced, through the holes to form the join. The latter terminology will be used in this thesis. For a general discussion of the descriptive terminology found in the scholarship of ligature-based boatbuilding, see McCarthy 2005; 15–21.

<sup>2</sup> The literature on the subject is vast, but a good starting point for a survey of the various boat types, construction techniques, fastening methods, and materials used will include Hornell 1970, McGrail and Kentley 1985b, Prins 1986, and McCarthy 2005.

<sup>3</sup> What Prins (1986, 23–4) would call the coherent and consistent application of a group of characteristic traits that defines a specific tradition.

<sup>4</sup> Pomey 1999, 150.



and compared with material from contemporaneous wrecks. The following is a brief synopsis of Greek shipwrecks from the sixth to the fourth centuries B.C. that exhibit some element of laced construction, with a summary of finds from their cargoes and equipment that establish the date and provenience of the ships, and what survives from their wooden hulls. The wrecks are addressed in order of their excavation, and the information is summarized chronologically in Table 3.1. The details of their hull remains and relevant construction features are dealt with in greater detail and compared to those of the Pabuç Burnu remains in the following chapter.

*Bon Porté (France)*

Tetrahedral notches were first revealed in a shipwreck discovered in 1971 in the Bay of Bon Porté, near St. Tropez, France.<sup>5</sup> Although heavily plundered, the wreck yielded some 40 amphoras, half of which are Etruscan type 3A and the rest Greek, including Graeco-Massaliot, Chian, Klazomenaian, and Corinthian examples; a single Massaliot *oinochoe* with painted black banding; a lead ingot; and a concreted spear point.<sup>6</sup> The ship's homeport is believed to have been the Phocaeen city of Massalia, and the ceramics date the wreck approximately to the third quarter of the sixth century B.C. (ca. 540–510 B.C.).<sup>7</sup>

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<sup>5</sup> Liou 1974; Liou 1975, 595–7; Joncheray 1976, 5. The absence of preserved ligatures in the hull remains mystified the excavators and led to several early misinterpretations of the vessel's joinery (Joncheray 1976, 28–31, 35–6; Basch 1976, 1978, 1981; Jestin and Carrazé 1980). Basch (1976, 1978) was the first to propose that the hull remains were indicative of laced construction, while Pomey (1981) correctly explained the details of the vessel's construction method and its laced joinery a few years later.

<sup>6</sup> Joncheray 1976, 13–23; Pomey and Long 1992, 191–2.

<sup>7</sup> Liou 1975, 597; Pomey and Long 1992, 192; and Kahanov and Pomey 2004, 14 for the ship's provenience; Liou 1974, 1975 and Pomey 2002, 113 for the date of the wreck.

Table 3.1 Shipwreck Provenience, Date, and Estimated Original Dimensions<sup>8</sup>

Shipwreck	Location	Provenience	Date (B.C.)	Length (m)	Capacity (tons)	Type of Joinery*
Giglio	Italy	Corinth/East Greece	600–580	25	—	lig., dc
Pabuç Burnu	Turkey	East Dorian	570–560	17–18	—	lig., tc
Bon Porté	France	Massalia	540–510	10	2–4	lig., dc
Cala Sant Vicenç	Majorca	Massalia/Emporion	520–500	20–22	30	lig., tc
Jules-Verne 9	France	Massalia	525–510	9.50	3.0	lig., dc
Jules-Verne 7	France	Massalia	525–510	15.65	15.2	(m&t), nails
César 1	France	Massalia	510–500	10	—	(m&t), nails
Grand Ribaud F	France	Greece/Massalia	510–490	25	30–38	m&t, nail
Gela 1	Sicily	Magna Graecia	500–480	20	—	lig., dc, tc
Gela 2	Sicily	Magna Graecia/Greece	450–425	18	—	(m&t), nails
Tektaş Burnu	Turkey	Ionia (Erythrae?)	440–425	14	6–7	(m&t), nails
Alonnesos	Greece	Greece (Athens?)	420–400	>25	>126	—
Ma‘agan Mikhael	Israel	Aegean or Cyprus	410–390	13.8	23	(m&t), nails
Porticello	Italy	Greece	400–385	16.6	—	(m&t), nails
Kyrenia	Cyprus	Rhodes	295–285	14	30+	m&t, nails

\*Principal types of joinery evident in the hull remains: “lig.” = ligatures laced through tetrahedral notches; “dc” = dowel coaks; “tc” = tenon coaks; “(m&t)” = pegged mortise-and-tenon joinery with ligatures in the extremities or repairs, or any other vestige of laced construction; “m&t” = pegged mortise-and-tenon joinery; “nails” = metal nails to attach the frames.

The poorly preserved hull remains from the wreck represent a central portion of the ship’s hull measuring almost 1.5 x 4 m. Preserved elements include approximately 2.8 m of the keel, fragments of both garboards, an additional starboard strake and two more on the port side, parts of five frames, and a mast step.<sup>9</sup> Planking joinery between the keel and garboards and between all strakes consists of dowel coaks inserted into the plank edges across the seams and lacing through tetrahedral notches. The frames are

<sup>8</sup> The information summarized in this table is fully cited in the text. As an aid to the reader, a fully referenced version of this and subsequent tables is provided in Appendix A.

<sup>9</sup> Joncheray 1976, 23–33.

lashed to the hull.<sup>10</sup> From the remains and spread of the wreckage, investigators surmise that the vessel was a small coaster or fishing boat about 10 m in length and capable of carrying 50–100 amphoras.<sup>11</sup>

*Giglio (Italy)*

For four years beginning in 1982, archaeologists excavated the remains of another looted shipwreck that had been discovered originally more than two decades earlier off the Tyrrhenian coast of Italy at Isola del Giglio.<sup>12</sup> Besides lead and copper ingots and various wooden objects, the ship carried a cargo of olives and olive oil, wine, and pine tar transported in Etruscan, western Phoenician, East Greek, Samian, and possibly Laconian and Corinthian type amphoras.<sup>13</sup> It also had a large consignment of Etruscan, Corinthian, Laconian, Samian and Ionian finewares.<sup>14</sup> Recovered shipboard items include half a dozen Greek lamps, two with charred spouts, indicating them to be the ship's lamps; two bronze Corinthian helmets and a group of bronze arrowheads believed to belong to the ship's crew; uncut amber, copper nuggets, and iron bars, or spits, that may have functioned as currency; a pair of wooden carpenter's calipers of Greek manufacture; and fishing weights and hooks.<sup>15</sup> The ceramics date the shipwreck

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<sup>10</sup> Joncheray 1976, 26–9; Pomey 1981, 225.

<sup>11</sup> Joncheray 1976, 23; Pomey 2002, 116.

<sup>12</sup> Bound and Vallintine 1983; Bound 1985, 1991a, 1991b.

<sup>13</sup> Bound 1991b, 22, 25–7.

<sup>14</sup> Bound 1991b, 14–21.

<sup>15</sup> Bound 1991a, 43; Bound 1991b, 21–7.

to the beginning of the sixth century B.C. (600–580 BC), while the shipboard items and tools indicate a Corinthian or East Greek port of origin.<sup>16</sup>

Two parts of the ship's hull survived: a three-meters section from the stern of the vessel that included parts of the keel, the garboard and two additional strakes on the port side, fragments of the starboard garboard, and traces of framing; and a second, larger section that was found later and deeper on the site but was never examined in detail.<sup>17</sup>

Construction was the same as that of the Bon Porté vessel, with dowel coaks between the keel, garboards, and planking, and ligatures laced across the seams through tetrahedral notches.<sup>18</sup> The wreck's excavator estimates the ship's original length to have been approximately 25 m, which would make it the largest of the fully laced vessels considered here.<sup>19</sup>

#### *Place Jules-Verne (Marseilles, France)*

Two more Greek shipwrecks from the sixth century B.C. came to light during the 1993 excavation at Place Jules-Verne, Marseilles, on the site of the ancient harbor of Massalia. The positions of the wrecks and the lack of any associated cargo led

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<sup>16</sup> The Early Corinthian *aryballoi* and Middle Corinthian Warrior ware are particularly diagnostic for the dating (Bound 1985, 50–1; Bound 1991b, 14–6). Cristofani's (1996) study of the cargo and personal items concludes that the ship came from Corinth, but Bats (1996, 577) argues that a Phocaeen origin cannot be ruled out. Mark (2005, 40–2) suggests an East Greek homeport, possibly on Samos.

<sup>17</sup> Kahanov and Linder 2004, 49–50.

<sup>18</sup> Pomey 1981, 55.

<sup>19</sup> Winters and Kahanov (2004, 49) obtained this estimate from Bound's unpublished manuscript, but report it without supporting data. Bound provides no estimate of the ship's size in his published works. If accurate, the vessel is considerably larger than any other laced vessel, save that at Cala Sant Vicenç, and similar in length to the Grand Ribaud F wreck (510–490 B.C.), which is estimated to have been 20–25 m long, sank with some 800–1,000 amphoras in its hold, and had an estimated capacity upwards of 38 tons (Pomey and Rival 2002, 119). It would also be of comparable length to the Classical shipwreck at Alonnesos, which had an estimated original length of 25–30 m, carried some 4,200 amphoras, and had a capacity of more than 126 tons (Hadjidaki 1996, 588–9).

excavators to surmise that the ships were abandoned at the same time in the last quarter of the century (ca. 525–510 B.C.), as determined by stratigraphic associations.<sup>20</sup> The hulls of both vessels were well preserved.

### Jules-Verne 9

The surviving portion of the smaller of the two wrecks, designated Jules-Verne 9, measures 5 m long and 1.5 m wide, and correspond to approximately one half of the boat from near midships to one extremity. It preserves the most complete set of features that define Greek laced-hull construction: parts of the keel, endpost, planking, and framing survive, along with all the various elements of its laced joinery.<sup>21</sup> Dowel coaks were inserted along the edges of the garboard and planking seams, wadding was placed over the inboard seams of the hull, and ligatures were laced around it and through tetrahedral notches and oblique holes to secure the joints. Ligatures lashed around the frames and through paired oblique holes in the strakes attached the frames to the hull. Small wooden pegs were driven into all the lacing holes to lock the ligatures.<sup>22</sup> Investigators believe the boat to have been a small fishing vessel and have reconstructed it with a rounded bottom and original dimensions of 9.50 m length (between perpendiculars; overall length is 9.72 m), 1.88 m beam, and 0.75 m depth of hold, giving it a deadweight capacity of approximately 2.3 metric tons and a total displacement of about 3 tons.<sup>23</sup>

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<sup>20</sup> Pomey 1995, 470–1.

<sup>21</sup> Pomey 1997, 195.

<sup>22</sup> Pomey 1995, 471–4.

<sup>23</sup> Pomey 2003, 64 (with precise values provided by personal communication), updating preliminary dimensions published earlier (Pomey 1999, 148). Winters and Kahanov (2004, 54) provide slightly different values.

### Jules-Verne 7

The second wreck, Jules-Verne 7, constitutes the remains of a merchant ship whose hull was preserved in a broken assemblage measuring 14 m long and 4 m wide. Reconstruction studies of the remains have yielded a ship with a round bottom and sharp, symmetrical extremities, measuring approximately 15.65 m long (between perpendiculars; overall length 16.55 m), 3.80 m at the beam, and 1.70 m deep, and having a deadweight capacity of approximately 11.8 tons and a total displacement of about 15.2 tons.<sup>24</sup> Although contemporaneous to wreck 9, this vessel was built much differently. The strakes of its shell were fastened with pegged mortise-and-tenon joints rather than with ligatures, and the frames were nailed to the hull rather than lashed.<sup>25</sup> Elements of lacing are still present, but relegated to specific and limited areas of the hull. The builders used the lacing technique to attach the hood ends of the strakes to the endposts, and the extremities of the garboards to the keel for about 1.0–1.5 m where the keel is rabbeted and starts its turn up into the posts.<sup>26</sup> There were also several areas on the hull where the builders had to make repairs, either to replace defective mortise-and-tenon joints between two strakes, or where a plank had cracked.<sup>27</sup> Typically, the carpenter would cut out the damaged section and insert a filler piece, which he then attached with ligatures in the typical way; that is, with dowel coaks and pegged lacing.<sup>28</sup>

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<sup>24</sup> Pomey 2003, 63 (with precise values provided by personal communication), updating preliminary estimates published earlier (Pomey 1999, 150). Winters and Kahanov (2004, 55) provide slightly different values.

<sup>25</sup> Pomey 1995, 476.

<sup>26</sup> Pomey 1995, 477; Pomey 1997, 198; Pomey 1999, 150–1; Pomey 2003, 62 fig. 11.7.

<sup>27</sup> Pomey 1997, 198.

<sup>28</sup> Pomey and Rieth 2005, 119.

The Jules-Verne 7 hull remains demonstrate clearly that a major shift took place within Greek boatbuilding no later than the sixth century, wherein the primary hull joinery changed from laced ligatures pegged in their holes to tenons pegged in mortises. The specifics of this development and its ramifications to our understanding of Greek shipbuilding will be dealt with in greater detail in chapter 5, but similar shipwrecks and their relevant hull features are included for comparison with the fully laced vessels.

*Place Villeneuve-Bargemon (Marseilles, France)*

The remains of another such wreck came to light only a few years later, at the end of 1997, in the same general area of Marseille at Place Villeneuve-Bargemon during excavation work for the ‘Caesar Museum’ project, from which the wreck takes its name, César 1. Based on site stratigraphy, the vessel is thought to have been abandoned at the very end of the sixth century B.C. (ca. 510–500 B.C.).<sup>29</sup>

The preserved vestige of the ship’s hull measures 6.1 m long and 0.9 m wide, but was cut in two by a small trench. The remains include the keel (complete between scarfs) and part of an end-post, as well as fragments of a garboard, five strakes, and two frames.<sup>30</sup> The vessel is estimated to be a modest boat with a rounded bottom similar in size to wreck 9 at Jules-Verne, but its construction parallels that of wreck 7. The primary type of joinery used in the hull planking is pegged mortise-and-tenon, but lacing

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<sup>29</sup> Pomey 2001, 425, 432 n. 9.

<sup>30</sup> Pomey 2001, 429.

is employed to fasten the hood ends of the strakes to the end-posts, and for making repairs. The frames are nailed to the planking.<sup>31</sup>

### *Majorca (Spain)*

In 2002 and 2004, Spanish archaeologists excavated an Archaic shipwreck off the northwest side of Cap de Formentor on the northern coast of Majorca.<sup>32</sup> The wreck takes its name, Cala Sant Vicenç, from the creek that flows into the small bay where the ship sank. The vessel was carrying a cargo of wine in 18 Ionian or Ionian-Massaliot amphoras, along with grinding stones, tin, glass beads, and Greek luxury goods including Chian and Thasian wine, Corinthian oil, and black-figure fineware pottery—type B2 cups, *oinochoai*, *lekanides*, mugs, and small *olpes*—that appear to have been produced in Magna Graecia.<sup>33</sup> It also carried 26 Iberian amphoras that are similar to examples found at Emporia, on the northeastern coast of Spain. The original contents are not known, but a lack of pitch lining suggests that they did not hold wine.<sup>34</sup> The excavation uncovered a number of personal or shipboard items including Ionian style lamps, Attic black-figure plates and eye-cups, black glazed pitchers and jars, Greek mortaria and cookware, and a small brazier.<sup>35</sup> Additional items include a wooden *pyxis* box lid and several items—a bronze Greek kyathos (ladle), a stamnoid vase, and a

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<sup>31</sup> Pomey 2001, 430. The nails are reportedly iron (Kahanov and Pomey 2004, 17).

<sup>32</sup> Nieto et al. 2002, 18; Nieto et al. 2005, 42.

<sup>33</sup> Nieto et al. 2004, 208–10. The shipboard ceramics and transport amphoras are discussed in greater detail in the final report; see Nieto and Santos 2009, 82–9 (Attic black-figure cups, pitchers, and jars), 89–92 (Ionian lamps), 113–9 (galley wares), 120–1 (brazier), 129–40 (Magna Graecia amphoras), 142–7 (Aegean amphoras), and 163–83 (Iberian amphoras).

<sup>34</sup> Nieto et al. 2004, 210–11.

<sup>35</sup> Nieto et al. 2004, 208.



krater—that might have been used for religious rituals onboard the ship.<sup>36</sup> Based on these collective objects, the vessel most likely hailed from Massalia or Emporion and was operating within Phocaeen trading circuits in the western Mediterranean that encompassed the southern coast of France, southern Italy and Sicily, the Balearic Islands, and the northeastern coast of the Iberian Peninsula.<sup>37</sup> The ceramics, and especially the eye-cups, one of which is decorated in the Chaldician style, date the wreck to the last third of the sixth century B.C., and no earlier than 520–510 B.C.<sup>38</sup>

A section of the ship's hull measuring approximately 6 m long and 4 m wide was preserved beneath the seabed and included part of the keel, five strakes to one side and four to the other, and four frames (along with the impression of a fifth).<sup>39</sup> The remains preserve details of planking, framing, and surface treatment, as well as all the elements of laced joinery. The garboards were fitted to the keel with oblique dowel coaks, but between the rest of the planking strakes the ship's builders utilized narrow, wooden tenons.<sup>40</sup> All of the planking was edge-joined with ligatures in the normal fashion through tetrahedral notches.<sup>41</sup>

### *Gela (Sicily, Italy)*

Two shipwrecks from Sicily proved to have laced hulls, or at least some elements of laced construction. They have an intriguing combination of features that could add

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<sup>36</sup> Nieto et al. 2004, 209; Nieto and Santos 2009, 267–70 (*pyxis* box lid), 223–8 (*kyathos*).

<sup>37</sup> Nieto et al. 2004, 208; Nieto and Santos 2009, 147–9, 316–7.

<sup>38</sup> Nieto and Santos 2009, 82, 85; revising slightly the date of 530–520 published earlier (Nieto et al. 2004, 209).

<sup>39</sup> Nieto et al. 2004, 198; Nieto and Santos 2009, 29 fig. 22, 28–30.

<sup>40</sup> Nieto et al. 2004, 202, 222 figs. 3 and 4; Nieto and Santos 2009, 27 fig. 22, 48–51.

<sup>41</sup> Nieto and Santos 2009, 53–7.

much to our understanding of the transition from laced to mortise-and-tenon shipbuilding. Unfortunately, their remains have not been well documented and published reports do not allow for a full evaluation of their construction.

### Gela 1

The first of these wrecks, discovered in 1988 off the southern coast of Sicily at Gela, was partially excavated over five seasons from 1989–1992.<sup>42</sup> The ship was carrying a cargo of mostly luxury items—high quality wine, oil, and ceramics from the Greek world—destined for the wealthy elite of central Mediterranean Greek colonies.<sup>43</sup> Of the 55 recovered amphoras, 31 were Chian (or Chian imitation), 6 were of various East Greek types, 10 were Corinthian (types A, A1, and B), 2 were Attic “à la brosse”, 4 were Greco-Massaliot (western Greek), and 2 were Punic.<sup>44</sup> These amphora types are datable to the late sixth or early fifth century B.C. The ceramic cargo consists of Attic, Laconian, and Ionian finewares, as well as copies of these types produced in colonial workshops. An Attic black-figure *oinochoe* with trefoil mouth is attributed to the Athena Painter of the early fifth century B.C., and three Attic red-figure *askoi* were painted by Epiktetos, who worked from 520–490 B.C.<sup>45</sup> The black-glazed Laconian wares are similar to terrestrial finds from around Gela and attest to such imports from the

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<sup>42</sup> Panvini 1993, 60.

<sup>43</sup> Panvini 2001a, 35.

<sup>44</sup> Panvini 2001a, 32, 64–75. The percentages of different types of amphoras provided in the text (p. 34) are not consistent with the entries in the catalogue (pp. 64–75).

<sup>45</sup> Panvini 2001a, 27, 28 fig. 26, 39; 28 figs. 27–9, 40–1.

late sixth to the early fifth centuries B.C.<sup>46</sup> These ceramics best date the wreck to the beginning of the fifth century, around 500–480 B.C.<sup>47</sup>

Other items recovered from the wreck include four terracotta altars, likely produced in the Peloponnesus or at Corinth; a pipe and small boar figurine, both of terracotta; a bone stylus and carved wooden arm; and a bronze tripod base used to hold a *dinos*.<sup>48</sup> Whether these items were for sale or for shipboard use is not certain, but the latter seems likely. Two lamps and an assortment of colonial pottery—jars, pitchers, bowls and pans, lids, and other plainwares—clearly did belong to the ship’s crew, as evidenced by traces of burning and wear.<sup>49</sup> All of these items indicate a Greek origin for the ship and its crew, probably somewhere in Magna Graecia, and a zone of operation that stretched from Sicily to the Aegean coast of the Greek mainland.

The ship’s hull was well preserved up to 18 m long and 6.8 m wide, and quite complete.<sup>50</sup> Portions of the keel, endposts, keelson and mast step survive, along with 17 floor timbers and planking strakes from both sides of the hull.<sup>51</sup> Several of the strakes retain their hood ends and are still joined along their edges by ligatures laced through tetrahedral notches.<sup>52</sup> Both dowels and tenons were used as coaks in at least some areas of the hull.<sup>53</sup> The frames were attached to the planking with double-clenched nails.<sup>54</sup>

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<sup>46</sup> Panvini 2001a, 29–31, 44–5.

<sup>47</sup> Panvini 2001a, 17.

<sup>48</sup> Panvini 2001a, 33–36, 60–2.

<sup>49</sup> Panvini 2001a, 31.

<sup>50</sup> Panvini 2001a, 19.

<sup>51</sup> Panvini 2001a, 18–20.

<sup>52</sup> Panvini 2001a, 21.

<sup>53</sup> Panvini 2001a, 21.

<sup>54</sup> Panvini 2001a, 20, 21 fig. 12. The nails are reported as copper or iron, but no definitive metals analysis is provided. See van Duivenvoorde (forthcoming) for the use of copper and iron in ship construction, and the misidentification of metal composition of nails.

Based on the remains, the ship can be reconstructed to an original length of at least 20 m and an original beam of around 8 m.<sup>55</sup>

### Gela 2

In 1990, the second shipwreck came to light in the waters off Gela, about a kilometer east of the previous wreck site and close to the ruins of the *emporion* of the ancient colony. A preliminary survey of the wreck was conducted in 1995, followed by a more extensive investigation in 1997.<sup>56</sup> The excavation yielded a collection of cargo and shipboard items rather similar to the first wreck. Cargo containers included Corinthian type-B transport amphoras, a few of type-A, and baskets most likely for foodstuffs. A consignment of ceramics for trade include two Attic *skyphoi*, one black figure and the other black glazed, a small black-glazed *olpe*, two Laconian kraters and a red-figure krater and column krater. Remains of cattle and chicken bones, peach and plum pits, grains of wheat, pine nuts, beans, and grape seeds testify to the provisions carried on board, while a wooden stylus (which excavators assume belonged to a merchant on board), globular jars, pitchers, *olpai*, *lekanai*, two-handle cups, and three lamps represent shipboard items.<sup>57</sup> The black-figure *skyphos* is attributed to the CHC Group and dated between 490–480 B.C., while the black-glazed example is similar to

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<sup>55</sup> Benini (2001, 104 n. 15) indicates an estimated original length of 17 m, but this does not concur with the preserved dimensions of the remains themselves. Winters and Kahanov (2004, 55–6) perpetuate this figure in reporting the estimated original length and beam as 17 and 7 m, respectively, but Long et al. (2001, 42) estimate the vessel's original length based on the preserved wreckage to be at least 20 m.

<sup>56</sup> Faccenna 1997, 143–6; Panvini 2001b, 81; Benini 2001, 99.

<sup>57</sup> Panvini 2001b, 81–3.

Type 257 from the Athenian Agora and dated to 450 B.C.<sup>58</sup> The column krater is believed to be the work of one of the Later Mannerist, perhaps the Duomo Painter, and is dated between 440–430 B.C.<sup>59</sup> Based on these finds, the wreck is best assigned a provenience of Magna Graecia or the Aegean coast of Greece, and a date of the third quarter of the sixth century B.C. (450–425 B.C.).<sup>60</sup>

Two sections of the ship's hull survived buried beneath a 1.5-m pile of ballast stone measuring 7.5 x 9.5 m in area. The main section includes 14 strakes (9 on one side and 5 on the other) and 4 floor timbers, while the smaller part consists of 4 fragmentary strakes and part of a frame. The strakes are joined together with pegged mortise-and-tenon joints, while the frames are fixed to the hull with double-clenched nails.<sup>61</sup> Three meters of a large timber that excavators believe to be the keel lay along the western side of the main hull section after apparently being ripped away during its wrecking. A small piece of timber tentatively identified as part of a keelson was found near the south end of these remains.<sup>62</sup> The hull has a wine glass shape, and based on the length (4.0 m) of one of the floors, the hull's investigator suggests the ship was originally about the same size as the Gela 1 vessel.<sup>63</sup>

A small section of the garboard and second strake seam contains what is assumed to be a laced repair, where five lacing holes with tetrahedral notches and surviving

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<sup>58</sup> Panvini 2001b, 83.

<sup>59</sup> Panvini 2001b, 83.

<sup>60</sup> Panvini 2001b, 81.

<sup>61</sup> Benini 2001, 104, 152–3 pls. XXXVI–XXXVII. The nails are described as bronze, but no analytical identification is offered and they may very well be of copper (see, *supra*, n. 54).

<sup>62</sup> Benini 2001, 101.

<sup>63</sup> Benini 2001, 104; see *supra* n. 55.

portions of ligatures are clustered around a mortise-and-tenon joint.<sup>64</sup> Judging from a photograph of the section, there may actually be six ligature holes (three sets of matching pairs), as well as what appears to be a seventh notch that was begun, but abandoned.<sup>65</sup> There is no obvious indication that this was a repair. It is doubtful, however, that these were reused laced planks, as one would expect in such a case to find lacing holes all along the length of the plank edges, and most likely not matched up with notches in the adjoining plank. Perhaps the vessel's builder was less than confident of the integrity of this particular mortise-and-tenon joint (the lower left tenon peg is rather close to the seam), and so reinforced it with a short run of lacing. In any case, just as on the Jules-Verne 7 hull, lacing is still present in this vessel's construction and still part of the builder's tradition, despite it being constructed primarily with mortise-and-tenon joinery.

#### *Grand Ribaud (France)*

In the spring of 1999, a submersible survey discovered a scatter of whole and broken amphoras on the seabed at a depth of 60 m near the small island of Grand Ribaud (Hyères, Var), off the peninsula of Giens, east of Toulon. Clearly a shipwreck, and containing Etruscan amphoras, the site was investigated in 2000 and 2001 using remotely operated vehicles and photogrammetry.<sup>66</sup> The cargo amphoras number an estimated 800–1,000 in total, and originally were stacked up four or five layers to a

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<sup>64</sup> Benini 2001, 104, 106.

<sup>65</sup> Benini 2001, 101 fig. 59.

<sup>66</sup> Long et al. 2002, 5–6.

height of 1.6 m.<sup>67</sup> They constitute a remarkably homogenous group of Etruscan Py type 4 wine amphoras.<sup>68</sup> Other ceramic vessels, most likely cargo items, include a banded black figure *askos*, an Attic black glazed *kylix*, Greek cups (Sparkes type C or perhaps colonial imitations from Sicily or Magna Graecia), a painted jug with Greek graffiti, and a pot of indeterminate origin.<sup>69</sup> A number of Greek and Etruscan plainwares were also recovered that may represent items used onboard by the crew. The Greek pieces include an undecorated *askos* with Greek graffiti on its base and a fragment of either an *olpe* or urn, while a shallow bowl (Rasmussen type 4), two *ollae* (urns), and two *mortaria* are all of Etruscan provenience.<sup>70</sup> Other recovered finds include five or six bronze discs with convex upper surfaces and raised, beaded borders; 32 bronze Etruscan basins; and five bronze fastenings from some wooden object.<sup>71</sup> The amphoras date the wreck to between 525 and 480 B.C., while the Greek ceramics narrow the range to 510–490 B.C.<sup>72</sup> The cargo items and find location place the ship within Greek-Etruscan trade circuits in the western Mediterranean, while the common wares provide a possible Greek origin for the vessel and its crew, though this is by no means certain.<sup>73</sup>

During the second season of investigation, after sediment and amphoras were removed, a 3 x 1.2-m section of the ship's hull was uncovered and recorded in situ.<sup>74</sup>

Investigators documented portions of hull planking (on one side of the keel), the keelson,

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<sup>67</sup> Long et al. 2001, 31.

<sup>68</sup> Long et al. 2002, 17–20; Py and Py 1974, 193–205.

<sup>69</sup> Long et al. 2001, 33–4; Long et al. 2002, 27–33.

<sup>70</sup> Long et al. 2002, 33; Long et al. 2001, 35–6.

<sup>71</sup> Long et al. 2001, 32–3; Long et al. 2002, 26–8, 34. The authors do not rule out that the bronze fasteners might be pins used for mounting chariot wheels.

<sup>72</sup> Long et al. 2002, 34.

<sup>73</sup> Pomey and Rival 2002, 119; Long et al. 2001, 41–3.

<sup>74</sup> Long et al. 2001, 37–8.

a stanchion, and two frames, but the keel could not be observed, as it was hidden by the keelson and other intact structure.<sup>75</sup> The planking was assembled with pegged mortise-and-tenon joinery, while the frames were attached to the hull with double-clenched iron nails.<sup>76</sup> The stanchion fragment was found in situ—standing in a mortise in the keelson, positioned precisely where it crossed over a frame—and presumably would have supported originally a transverse beam.<sup>77</sup>

Based on a reconstruction of the recovered frame fragment and an estimate for depth of hull based on the height of the amphora mound, investigators determined the beam of the hull at the corresponding frame station to have been 5.25 m. Allowing for a slightly greater width amidships, and assuming a length-to-beam (L:B) ratio of 4.5:1 based on the Jules-Verne 7 and Ma‘agan Mikhael reconstructions, they estimate the original vessel to have been at least 25 m long.<sup>78</sup> Capacity of the ship is estimated from the quantity and capacities of transport amphoras at 30–38 tons.<sup>79</sup> Judging from the shape of the recovered frame fragment, the hull had a slight wine glass shape.<sup>80</sup>

#### *Ma‘agan Mikhael (Israel)*

In 1985, a remarkably well-preserved and relatively complete shipwreck was discovered 70 m off the beach at Kibbutz Ma‘agan Mikhael in shallow water. After a preliminary investigation in 1987, the wreck was excavated from 1988–1989. The

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<sup>75</sup> Pomey and Rival 2002, 118.

<sup>76</sup> Long et al. 2001, 39–40.

<sup>77</sup> Long et al. 2001, 41.

<sup>78</sup> Long et al. 2001, 41–2. The estimated length is bolstered by comparison of the vessel’s larger frame dimensions to those of the Gela 1 wreck, which is estimated to be at least 20 m long.

<sup>79</sup> Pomey and Rival 2002, 19; Long et al. 2001, 31.

<sup>80</sup> Long et al. 2001, 40 fig. 44, 42 fig. 46.



wreckage lay under some 12 tons of stone and rock, which the excavators initially believed to be ballast. However, more than half of the rock is blue schist from the Aegean, which investigators now deem to represent a cargo of architectural/construction material.<sup>81</sup> Excavation yielded a modest yet varied collection of ceramic vessels. Different types of bowls, mortaria, cooking pots, jugs, pitchers, tankards, lamps, and decorated table amphoras make up the vessel's 'galley wares', while a pithos, a number of basket-handle jars, and several so-called Persian storage jars comprise the 'load wares'.<sup>82</sup> In addition, a small group of Greek or East Greek glazed bowls and *kanthroi* was recovered.<sup>83</sup> The wreck also yielded a well-preserved assemblage of carpentry tools, 18 in all, of which a dozen were found inside a basket. The collection includes chisels, awls, bow drills, mallets, a set square and measuring stick, a plumb bob, and a whetstone.<sup>84</sup>

The ship's hull was preserved in excellent condition. The entire bottom of the ship survived intact up to the third strake, including the keel and false keel, stem and sternpost (from their scarfs through their upward turn), a knee at each extremity, 14 frames, the mast step and related structure, and a keelson-like central stringer. Portions of eight more starboard strakes, including a wale, and four more port strakes survive from the sides of the hull, and four stanchions and possibly two fragments of carlings remain from internal support structure.<sup>85</sup> Sharp corners and clean surfaces, a lack of

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<sup>81</sup> Shimron and Avigad 2003, 153; Artzy and Lyon 2003, 198.

<sup>82</sup> Artzy and Lyon 2003, 183–96. Undoubtedly, not all the galley wares and storage jars were for shipboard use.

<sup>83</sup> Artzy and Lyon 2003, 197.

<sup>84</sup> Udell 2003.

<sup>85</sup> Kahanov 2003.

teredo damage and barnacle growth, and the remains of bark adhering still to some of the timbers testify to the newness of the vessel when it sank.<sup>86</sup> The planking shell was constructed using pegged mortise-and-tenon joints and reinforced with frames attached with double-clenched copper nails. The bow and stern assemblies were reinforced with stout knees fixed to the keel and endposts. Lacing with tetrahedral notches attached the ends of the bottom three strakes to the knees, and the ends of the upper strakes to the posts.<sup>87</sup> The ship's hull had a wine glass shape and reconstructed original dimensions of 13.8 m overall length, 4.27 m beam, 2.65 m depth of hull amidships, and 23 tons displacement.<sup>88</sup>

The ceramics provide the best date for the shipwreck of around the turn of the fourth century B.C. (410–390 B.C.).<sup>89</sup> The ship's homeport (or construction location), however, has proven more difficult to determine, though it can be situated within the Greek world. The consignment of blue schist, believed to have been part of the ship's initial load, came from the southern end of Euboea (Evia), while a secondary load of basalt ballast originated in southern Cyprus.<sup>90</sup> The provenience of the greatest part of the ceramic assemblage is the Limassol district or Amathus on the southern coast of Cyprus, while a secondary group is of East Greek make.<sup>91</sup> Foodstuffs—olive pits, fig seeds, and an acorn—came from the southeastern Aegean.<sup>92</sup> The species of trees that provided timber for the ship's hull all grow mainly in western and northwestern

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<sup>86</sup> Kahanov 2003, 53.

<sup>87</sup> Kahanov 2003, 64–8.

<sup>88</sup> Winters and Kahanov 2004, 131 table 2.

<sup>89</sup> Artzy and Lyon 2003, 197.

<sup>90</sup> Shimron and Avigad 2003, 168, 175–7

<sup>91</sup> Artzy and Lyon 2003, 197–8

<sup>92</sup> Kahanov 1996, 245.

Anatolia, and most likely came from along its Aegean coast, whereas the copper used for the ship's fastenings was mined in Cyprus.<sup>93</sup>

*Kyrenia (Cyprus)*

Another extremely well preserved shipwreck was excavated from 1968–1969 off the northern coast of Cyprus near Kyrenia.<sup>94</sup> The ship was transporting a cargo of wine, carried in over 380 Rhodian amphoras; more than 10,000 almonds packed in amphoras from Samos; and iron ingots.<sup>95</sup> Twenty-nine hopper-type millstones, many with mason's marks (single Greek letters), were stacked in three rows centered over the keel. The odd number, lack of matching pairs, and differences in size and finish indicate that the stones served as ballast, although undoubtedly they could have been sold opportunistically as replacements for broken pieces.<sup>96</sup> Excavators also recovered a collection of black-glazed pitchers and echinus bowls, casseroles, mixing bowls, plates, a pottery sieve, a bronze ladle and copper cauldron. Four sets of drinking cups, *gutti* (oil jugs), salt dishes, and wooden spoons suggest a crew of four, including the captain. Other finds used onboard the ship include a lathe-turned wooden bowl, a single lamp, lead fishing weights and net sinkers, a lead seal impression depicting Athena Promachos, seven bronze coins struck between 306–294 B.C., an inkwell, and a marble column pedestal and ceremonial basin. A spare sail and rope, 10 wooden bobbin-toggles, a wooden pulley, belaying pins, approximately 100 lead rail rings, and a quarter rudder blade provide evidence for the

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<sup>93</sup> Liphshitz 2004, 159; Linder and Kahanov 2003, 246.

<sup>94</sup> Katzev 1970, 1974, 1976, 1978.

<sup>95</sup> Katzev 1978, 295; Katzev 2005, 75–6. A total of 403 amphoras were recovered.

<sup>96</sup> Katzev 1978, 296; Katzev 2005, 76.

ship's rigging and steerage. A bow drill and other ship's tools were also found.<sup>97</sup> These finds suggest that the ship's homeport was most likely on Rhodes, where it was built in the last quarter of the fourth century B.C.<sup>98</sup> It sank after a long service life sometime between 295 and 285 B.C., according to the coins and styles of amphoras found onboard.<sup>99</sup>

About 60% of the hull's external area and more than 75% of its representative timbers, constituting some 6,000 individual pieces, survived in two sections beneath the cargo and sediment. The extant remains include the entire length of the keel; more than half of the stem from its scarf up; 10 planking strakes on the starboard side, including the lower wale, and 13 on the port side, including the lower and upper wales; 41 frames fastened to the hull with double-clenched copper nails; internal ceiling stakes; three cross-beams; and the mast step and two stanchion steps.<sup>100</sup> Unlike the Ma'agan Mikhael ship, this vessel was very old and well worn.<sup>101</sup> Wood sheathing covering the bow planking, lead sheathing over the entire hull, a relocation of the mast step, and removal of a frame to make room for a sump all testify to numerous episodes of maintenance and alteration. The keel itself was cracked and had to be repaired, and there are various repairs in the outer planking, wherein replacement planks were installed using specially shaped 'patch' tenons.<sup>102</sup> The original dimensions of the ship are reconstructed to a

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<sup>97</sup> Katzev 1978, 297–8; Katzev 2005, 76, 78 for the dates of the coins.

<sup>98</sup> Katzev 2005, 75.

<sup>99</sup> Katzev 2005, 76.

<sup>100</sup> Steffy 1985, 72, 77, 84.

<sup>101</sup> Steffy 1985, 77.

<sup>102</sup> Steffy 1985, 95–9.

length of 14 m, beam of 4.7 m, and displacement of over 30 tons.<sup>103</sup> The vessel was built by means of pegged mortise-and-tenon joints and there was no trace of lacing. However, at least some of the ship's internal ceiling consisted of reused planking from a small laced vessel; the edges of the planks were trimmed to remove the lacing holes.<sup>104</sup>

Three additional shipwrecks from this period should be included in the catalogue for completeness. None of them has produced much in the way of hull remains or evidence for their construction, but some conclusions might still be drawn in light of the collected data from the entire catalogue of shipwrecks considered here. Excavation of one of the shipwrecks remains incomplete, but if completed one day, it yet may yield new and useful information.

#### *Porticello (Italy)*

Remains from an ancient shipwreck were discovered and partially looted in 1969 near the town of Porticello, located on the Italian side of the Straits of Messina. Once Italian authorities became aware of the situation, apprehended the offenders and confiscated most of the material, the University Museum of Pennsylvania was invited to excavate the site, which they did in 1970.<sup>105</sup> The ship was carrying a cargo of Greek wines, salted fish from a Punic site, lead ingots from Laurion, and ink and bronze sculpture from unidentified sources.<sup>106</sup> The wine amphoras consisted of 13 Mendeian

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<sup>103</sup> Steffy 1985, 100; Katzev 2005, 75–6.

<sup>104</sup> Steffy 1985, 95.

<sup>105</sup> David Owen directed the excavation (Eiseman and Ridgway 1987, 4).

<sup>106</sup> Eiseman and Ridgway 1987, 107.

amphoras dated to the early fourth century B.C.,<sup>107</sup> two Solokha II type amphoras from Byzantion or the Bosphorus and dated to the fourth century B.C.,<sup>108</sup> and three Locrian amphoras dated to the end of the fifth or beginning of the fourth century B.C.<sup>109</sup> The salted fish or other fish products were packed in Punic amphoras of uncertain specific origin; 15 were recovered.<sup>110</sup>

An assemblage of ceramics for cooking and eating was found at the northern extremity of the site, which excavators assumed to be the location of the ship's stern storage area. The pottery included a pair of black-glazed bolsals with decorated interiors, two black-glazed lamps with flat band handles, and a black glazed cup-skyphos with impressed interior decoration and concentric circles decorating the underside.<sup>111</sup> Coarse wares include a chytra with a single strap handle; sherds from one or more lopades (lidded chytrai) with traces of dark slip on their exterior; a mortar with white slip on its exterior; and an oinochoe.<sup>112</sup> The bolsals, lamps, and cup-skyphos are all of Attic production, and the lamps show signs of usage. The bolsals are dated to between 420–380 B.C.,<sup>113</sup> while the cup-skyphos is dated to the same range, but earlier.<sup>114</sup> The lamps

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<sup>107</sup> Eiseman and Ridgway (1987, 37–42) originally published the Mendean amphoras as dating to the end of the fifth or beginning of the fourth century B.C., based largely on Brashinsky (1976), but Lawall (1998) argues convincingly for an early fourth-century date.

<sup>108</sup> Eiseman and Ridgway 1987, 50–1.

<sup>109</sup> Eiseman and Ridgway (1987, 48–50), tentatively identify them as Western Greek from southern Italy or Sicily. See Lawall 1998, 21; Barra-Bagnasco 1992, 212 for evidence from the kilns at Epizephyrian Locri; and Isserlin 1964, fig. 13.6 for a good parallel from Motya, dated earlier than 397 B.C.

<sup>110</sup> Eiseman and Ridgway 1987, 42–8.

<sup>111</sup> Eiseman and Ridgway 1987, 27–30.

<sup>112</sup> Eiseman and Ridgway 1987, 30–1.

<sup>113</sup> Eiseman and Ridgway 1987, 27.

<sup>114</sup> Eiseman and Ridgway 1987, 29.

are identified as Howard's type 23C Late Classic I (430–380 B.C.).<sup>115</sup> The coarse wares are of common and widespread types, and while the chytra and lopas have shapes similar to Attic examples, the mortar and oinochoe are definitely non-Attic.<sup>116</sup>

Other objects recovered from the storage area include two whetstones, a wooden bowl and an awl, lead fishing weights, four fragmentary lead cake ingots and 122 lead nuggets, and a small lead box; these objects, however, do little to help further refine the date or provenience of the wreck.<sup>117</sup> The utilitarian vessels and lamps from the wreck, as well as the cargo items, show that the ship was Greek in origin and was operating within eastern and central Mediterranean trade circuits. The lamps, bolsals, and cup-skyphos best date the wreck to between 415 and 385 B.C., while the transport amphoras would seem to narrow that range to the fourth century, or 400–385 B.C.<sup>118</sup>

Of the ship itself, only one small timber fragment, two tenons, two lead patches, and several dozen nails remained from its hull. The irregularly shaped timber measures only 21 cm long, 8 cm wide, and 6.5 cm thick, and has only one preserved original face. The fragment is probably part of a strake or wale that original was about 11 cm wide and 6.5 cm thick. It contains two mortises, cut into opposite edges (which were not preserved), that taper slightly in width as they penetrate the plank and have maximum dimensions of 5.3 and 6.3 cm.<sup>119</sup> The two presumably partial tenons show peg holes in their preserved ends. One tenon measures 9.5 cm long, 5.3 cm wide, and 0.5 cm thick,

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<sup>115</sup> Eiseman and Ridgway (1987, 29) suggest that their shape and dimensions point to a date in the first half of the range.

<sup>116</sup> Eiseman and Ridgway 1987, 31.

<sup>117</sup> Eiseman and Ridgway 1987, 33–6; the ingots and nuggets are predominately lead, but have silver contents of just over 12 and 23 percent, respectively.

<sup>118</sup> Eiseman and Ridgway 1987, 33; Lawall 1998, 21.

<sup>119</sup> Eiseman and Ridgway 1987, 10, fig. 2-1.

while the other is 5.9 cm long, 4.3 cm wide, and 0.4 cm thick.<sup>120</sup> Metal fasteners indicate that the frames of the ship were nailed to the hull with double-clenched copper nails.<sup>121</sup> The approximate original length of the ship's hull is estimated to have been 16.6 m. This was determined by comparing the distribution area of the nails across the site to that at Kyrenia and applying that ratio to the reconstructed length of the Kyrenia ship.<sup>122</sup>

#### *Alonnesos (Greece)*

A large shipwreck was discovered in 1985 by a Greek fisherman off the island of Alonnesos (ancient Icus), near Peristera, in the Northern Sporades. The wreck was investigated initially in 1991 and two small sections were partially excavated in 1992 and 1993.<sup>123</sup> The visible wreckage consists of a large mound of at least three or four layers of amphoras and a layer of fine wares on top of ballast stones. The ceramics are mostly intact and, except for the top layer of amphoras, still largely stacked as originally loaded into the ship. The mound measures approximately 25 m long and 12 m wide, and the total number of amphoras is estimated to be about 4,200.<sup>124</sup> The transport amphoras appear to be predominately Peparethian and Mendeian wine jars, but a Corinthian type amphora was also recovered.<sup>125</sup> Excavation recovered an assemblage of Attic pottery including black glazed bowls of various types and sizes; kylikes with stamped and

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<sup>120</sup> Eiseman and Ridgway 1987, 10–3, figs. 2-1–3.

<sup>121</sup> Eiseman and Ridgway 1987, 11, 13, 14–5 figs. 2-6–7.

<sup>122</sup> Eiseman and Ridgway 1987, 13.

<sup>123</sup> Hadjidaki 1996, 564–5.

<sup>124</sup> Hadjidaki 1996, 565.

<sup>125</sup> Hadjidaki 1996, 569–71.



engraved decorations; two lamps; and a plate, salt cellar, lekane, chytra, cup-skyphos and mug.<sup>126</sup> A mortarium of possible Corinthian make was also raised.<sup>127</sup> Besides ceramics, excavation yielded a bronze situla (wine bucket) of Ionian style, two bronze ladles, and the lead collar from an anchor.<sup>128</sup> A lead anchor stock was also found, but it was not recovered as it was concreted under a massive rock on the site.<sup>129</sup>

The ship was almost certainly Greek, and possibly Athenian, and would appear to have been involved in Aegean trade. Its final voyage likely began in Athens, where it took on a cargo of fine wares, and included calls at Mende and Peparethus, where it exchanged wares for wine. Its final stop—whether made or intended—was probably Icus, where it sank not far from the island’s main harbor.<sup>130</sup> The recovered transport amphoras have been dated to the last quarter of the fifth century B.C.<sup>131</sup> The salt cellar is assigned the earliest date of 450–425 B.C., while most of the Attic fine wares are datable to between 420 and 400 B.C.<sup>132</sup> The bucket and ladles are similarly dated to the very end of the century,<sup>133</sup> and radiocarbon analysis of some wood “chunks” recovered from beneath the fine ware layer provides a cutting date for the wood of between 480

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<sup>126</sup> Hadjidaki 1996, 570–2.

<sup>127</sup> Hadjidaki 1996, 569, 572.

<sup>128</sup> Hadjidaki 1996, 565. The collar was found some 25 m from the main wreck mound, so it is not certain if it belongs to the wreck or is intrusive. Analyses of the bronze (copper) and lead indicate that they were most likely mined at Laurion in Attica or on the Chalkidike Peninsula of Macedonia (Hadjidaki 1996, 585–6, 583, respectively).

<sup>129</sup> Hadjidaki 1996, 565.

<sup>130</sup> Hadjidaki 1996, 591.

<sup>131</sup> Hadjidaki 1996, 565.

<sup>132</sup> See the artifact catalogue entries (Hadjidaki 1996, 580–7) for dating of individual objects.

<sup>133</sup> Hadjidaki 1996, 585–7.

and 420 B.C.<sup>134</sup> Together, these dates suggest that the ship sank sometime during the final two decades of the fifth century B.C.<sup>135</sup>

The only object possibly from the ship's hull that was recovered is a single bronze nail, though it is likely that significant hull remains are preserved beneath the wreck mound.<sup>136</sup> Judging from the size of the mound, the ship's dimensions probably exceeded 30 m in length and 15 m in breadth. The vessel's cargo load, based on capacity measurements of the recovered amphoras, is estimated to have been more than 126 tons.<sup>137</sup>

#### *Tektaş Burnu (Turkey)*

The Institute of Nautical Archaeology excavated the wreck of a Classical merchantman from 1999–2001 off the Aegean coast of Turkey at a point called Tektaş Burnu, west of Izmir (ancient Smyrna) and east of the island of Chios. The ship's main cargo was a consignment of wine contained primarily in almost 200 pseudo-Samian amphoras.<sup>138</sup> Ten Mendeian amphoras, from the Middle Mendeian phase (400–425 B.C.), were recovered; one was packed with butchered cattle bones, while the other nine contained pine tar from a northern Greek species of conifer (likely *Pinus sylvestris*).<sup>139</sup> Additional transport amphoras from the wreck include two bulbous-neck type Chian jars, one dated to 450–440 B.C. and the other to 440–430/25 B.C.; a pair of Samian jars

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<sup>134</sup> Hadjidaki 1996, 590.

<sup>135</sup> Hadjidaki 1996, 590.

<sup>136</sup> Hadjidaki 1996, 572.

<sup>137</sup> Hadjidaki 1996, 588.

<sup>138</sup> Carlson 2003, 583.

<sup>139</sup> Carlson 2003, 587–90.

and a Samian-Milesian type dated to around 425 B.C.; and, finally, two jars from the northern Aegean.<sup>140</sup>

The ship also was carrying a cargo of East Greek pottery, including 13 table amphoras decorated with painted dots and polychrome bands and all but one lined with pine tar on the inside, a large domed askos with its upper portion dipped inverted in paint, and four standard East Greek banded olpai. Parallels of the table amphora are known from sixth- and fifth-century Mediterranean and Black Sea sites, while similar examples of the askos have been found in fifth-century levels at Miletus.<sup>141</sup> Additional wares include a dozen decorated kantharoi from Chios, nine large one-handled cups, and 12 handleless oil lamps with parallels from Chios.<sup>142</sup> Lastly, a small collection of cargo Attic wares were recovered from the wreck and include two Sessile type kantharoi, a shallow bowl, and single examples of a small askos, stone alabastron, and salt cellar.<sup>143</sup>

Items used onboard by the ship's crew include a group of undecorated coarse wares—a hydria and jug, plate, two shallow bowls, mortar, salt cellar with hanging holes, and four chytrai—as well as the ship's lamp, two bronze bucket handles and the shaft of a bronze kyathos (dipper), and two bone tile gaming pieces.<sup>144</sup> These objects were found in the downslope area of the wreck site, indicating that to be the location of the ship's stern area.<sup>145</sup>

As for the ship's hull, very little of it survived. Excavators recovered some 160

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<sup>140</sup> Carlson 2003, 590.

<sup>141</sup> Carlson 2003, 591.

<sup>142</sup> Carlson 2003, 591–3.

<sup>143</sup> Carlson 2003, 593.

<sup>144</sup> Carlson 2003, 593.

<sup>145</sup> Carlson 2003, 594.

metal fasteners and numerous small fragments of hull wood, mostly of pine and oak.<sup>146</sup> They also found two marble discs, each almost 14 cm in diameter and decorated with concentric incised and painted circles, that were used for the ship's symbolic eyes, or *ophthalmoi*. The discs were fastened to either side of the bow with lead spikes, one of which survives complete.<sup>147</sup> Their discovery at the upslope extremity of the site confirms the general orientation of the wreck and the location of the utilitarian objects as the stern area of the ship.

The ship was probably a modest merchant vessel engaged in local trade along the Ionian coast that sank during the third quarter of the fifth century B.C. (440–425 B.C.).<sup>148</sup> Its hull is estimated to have been about 14 m long originally, based again on the distribution of copper nails as compared to that of the Kyrenia wreck, and its cargo load was approximately 6–7 tons.<sup>149</sup> The transport amphoras from the ship's cargo best establish the date of the wreck and the route of the ship's final voyage, which would seem to have included stops at Erythrae and Chios and a next destination of Miletus or Samos, had the vessel not sailed into misfortune on route.<sup>150</sup>

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<sup>146</sup> Carlson 2003, 594; van Duivenvoorde (forthcoming).

<sup>147</sup> Nowak 2001, 86–7; Carlson 2003, 594–5; van Duivenvoorde (forthcoming).

<sup>148</sup> Carlson 2003, 596.

<sup>149</sup> van Duivenvoorde (forthcoming). Carlson (2003, 596) originally estimated the ship's length to be no more than 10–12 m, based on the general distribution of artifacts.

<sup>150</sup> Carlson 2003, 596.

CHAPTER IV  
ANALYSIS OF CONSTRUCTION FEATURES IN  
ANCIENT GREEK SHIPBUILDING

All of the shipwrecks catalogued in the preceding chapter with laced hulls were found in the central and western Mediterranean. The Pabuç Burnu shipwreck provides the first direct archaeological evidence for laced shipbuilding in the Aegean. Although these 12 shipwrecks provide hulls in multifarious states of preservation, excavation, and study, and exhibit a sundry of both common and dissimilar features, they provide rather fertile ground for examining aspects of hull construction regarding the Pabuç Burnu ship and boatbuilding in the late Archaic Greek world. Following is an analysis of the construction evidence—both preserved and implied—gleaned from the Pabuç Burnu remains and from comparison with that provided by the corpus of Greek wrecks. Construction features and techniques are dealt with in order of their application to the hull construction sequence.

*Keel-Stem-Sternpost*

When an ancient shipwright was ready to begin building a boat, he first laid down its keel and then affixed to it the stem and sternpost at either end. Excavation at Pabuç Burnu produced no trace of any of these timbers. However, a review of the evidence from other laced vessels should provide some idea of what the ship's central spine might have looked like and how it was assembled (table 4.1).

Table 4.1. Keel Design on Ancient Greek Ships

Shipwreck	Wood	Shape Sectional, Longitudinal	Rabbet	Pres. Length (m)	Sided (cm)	Molded (cm)	False Keel	Keel-Stem Scarf	Keel-Sternpost Scarf
Giglio	—	rectangular, rockered	at ends	2.76	15	22	no	—	chamfered and tongued
Bon Porté	<i>Pinus</i> sp.	slightly trapezoidal	no	—	6/6.4	9.6	no	—	—
Jules-Verne 9	<i>Quercus</i> sp.	rectangular	no	—	6.8	7	—	keyed box scarf	endposts rabbeted
Jules-Verne 7	<i>Quercus ilex</i>	rectangular	at ends	10.7	10.0	11.0	—	keyed box scarf and treenail	endposts rabbeted at lower length
Cala Sant Vicenç	<i>Quercus ilex</i>	rectangular	no	5.50	13	17	yes	—	—
Grand Ribaud F	<i>Quercus</i> sp.	—	—	—	—	—	—	—	—
Gela 1	<i>Pinus pinea</i>	rectangular	at ends	—	25	37	—	rabbeted	rabbeted
Gela 2		rectangular	—	—	—	—	no	—	—
Ma'agan Mikhael	<i>Pinus brutia</i>	rectangular, slightly rockered	at ends	8.62	11.0	16.0	yes	box scarf with vertical pegged tenon	rabbeted
Kyrenia	<i>Pinus brutia</i>	rectangular (slightly trapezoidal)	entire length	9.33	12.8	20.3	yes	wedged hook scarf inner/outer post assembly nailed/m&t	keel/sternpost knee

Less than three meters of the aft end of the keel was preserved in the Giglio wreck, but there may have been other portions in the deeper section of hull that was never well recorded. The keel had a rectangular cross-section and is sided about 15 cm and molded 22 cm along its more central portion, but towards its after end it has dimensions of 19.6 and 20.6 cm, respectively.<sup>1</sup> From that point, the keel diminishes in its molded dimension to 11.9 cm at its scarfed end.<sup>2</sup> Curiously, then, its sectional shape changes from vertically rectangular along most of its length, to horizontally rectangular

<sup>1</sup> Bound 1985, 53; Bound 1991b, 31. Kahanov and Linder (2004, 50) give maximum sided and molded dimensions as 21.3 and 22.1 cm, respectively.

<sup>2</sup> Bound 1991b, 33 fig. 76.

at its ends. It was “chamfered and tongued” at its aft end to connect with the sternpost, and near the scarf it had rabbets cut along its upper corners to receive the garboards.<sup>3</sup>

The preserved portion of the Bon Porté keel, made from pine, has slight dimensions (6–6.4 cm sided, 9.6 cm molded) and a slightly trapezoidal (inverted) cross-section, with its outer face broader than its inner one. The garboards butt flush against the sides and top of the keel at a 1.5-degree angle.<sup>4</sup>

The Jules-Verne 9 boat has a similarly diminutive keel (6.8 cm sided, 7 cm molded), but is more square in its dimensions. It is made of oak and was connected to the stem with a keyed box-scarf locked with a vertical peg. The boat’s endposts were rabbeted, but not the keel.<sup>5</sup> The keel of the Jules-Verne 7 wreck is made from two oak timbers joined with a box-scarf secured by a pegged tenon. It is joined to the endposts with similar box-scarfs and is rabbeted there to match those in the posts. As on the Jules-Verne 9 wreck, this keel is almost square (10 cm sided, 11 cm molded), but is larger, roughly in proportion to its greater length.<sup>6</sup>

The Cala Sant Vicenç wreck preserves 5.5 m of the ship’s oak (*Quercus ilex*) keel, but neither of its end scarfs where it joined the posts survived. The keel has a rectangular section sided 13 cm and molded 17 cm, is not rabbeted, and was fitted with a false keel.<sup>7</sup> The latter is made from the same type of oak and has a square section with

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<sup>3</sup> See Bound (1985, 53) for that part of the keel that has no rabbets (presumably being more centrally located); Bound (1991b, 31, 33 fig. 76) and Kahanov and Linder (2004, 50) for the keel’s rabbeted aft section.

<sup>4</sup> Joncheray 1976, 23–6.

<sup>5</sup> Pomey 1999, 148.

<sup>6</sup> Pomey 1999, 150–1; Kahanov and Linder 2004, 55.

<sup>7</sup> Nieto and Santos 2009, 28 fig. 23, 40–1; Nieto et al. 2004, 207; Nieto et al. 2003, 12.

13-cm sides. It was attached to the keel with pegged mortise-and-tenon joints.<sup>8</sup> Its molded dimension reduces gradually over the last half-meter of its south end until it reaches 10 cm, and was probably carved in this way to give it a curved shape to match the keel's profile as it curved up to meet the post.<sup>9</sup> The keel has rectangular mortises cut along its upper surface, which are thought to have been used to secure a mast step.<sup>10</sup> Investigators believe that the keel (and both garboards) were replaced during a major overhaul of the ship.<sup>11</sup> The main evidence supporting this is the presence of dowel coaks between the keel and garboard strakes, and the manner in which they were inserted—through oblique holes that open on the inboard surface of the garboards.<sup>12</sup> This and other evidence are discussed in more detail below.

The Archaic wreck at Gela has a rectangular pine keel with rabbets at its extremities to meet up with those in the endposts. What stands out about this keel is its large size. Sided 25 cm and molded 37 cm, it is the largest keel of any Greek wreck of this period. The Ma'agan Mikhael and Kyrenia ships both have keels made from single pine timbers that are similarly scarfed to the stem and sternpost. The Ma'agan Mikhael keel follows those of laced boats in that it is only rabbeted at the extremities where it joins to the posts. It has a false keel mortise-and-tenon joined to its bottom face.<sup>13</sup> The Kyrenia ship's keel is made from pine (*Pinus brutia*) and is slightly trapezoidal in section, similar to that from Bon Porté, but oriented instead with its narrower face out

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<sup>8</sup> See Nieto and Santos (2009, 27 fig. 22.4, 41 fig. 35).

<sup>9</sup> Nieto and Santos 2009, 41.

<sup>10</sup> Nieto and Santos 2009, 27 fig. 22.5.

<sup>11</sup> Nieto and Santos 2009, 48–9.

<sup>12</sup> Nieto and Santos 2009, 41–4.

<sup>13</sup> Kahanov 2003, 54–9.



and wider face in.<sup>14</sup> The keel is fitted with a thin false keel, less than 3 cm thick and made of Turkey oak (*Quercus cerris*), which was attached with square pegs.<sup>15</sup> At some point in the vessel's long service life, its keel cracked and had to be repaired. A section of the keel was cut out to either side of the crack and a repair block inserted. The block measures 84.3 cm long, 3.8–4.8 cm thick, and 10 cm wide like the keel. It was fitted to the keel with wooden tongues at both its forward and after ends, and secured with three copper nails.<sup>16</sup>

Small, rectangular (almost square) keels appear to have been the norm in Greek boatbuilding for a long while. The keyed box-scarf was a hallmark of the tradition as well, as it is found on all keels where keel timbers or keel and end-posts need to be joined and where those connections are preserved. These builders cut rabbets into the extremities of their ships' spines to help hold the strake ends to the posts, but butted the garboards flush with the top and sides of the keel throughout the main portion of the hull. This is not surprising, since the laced vessels all had rounded hulls. A quick look at keel dimensional proportions (table 4.2) would seem to indicate that there was a late trend towards deeper keels, as the ratio of molded to sided dimension increases over time from roughly 1.0 to 1.6. Keel size does seem to have had a general proportionality to hull size, but with so few data, and exceptions like the Gela 1 vessel, it is difficult to propose anything more than what one would expect from experienced shipbuilders knowing approximately how large a keel they needed to lay down for a particular size of hull.

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<sup>14</sup> Steffy 1994, 43, 45 fig. 3–24.

<sup>15</sup> Steffy 1985, 72, 75 ill. 3, 87.

<sup>16</sup> Steffy 1985, 76.

Table 4.2. Keel Proportions from Ancient Greek Shipwrecks

Shipwreck	Hull Length (m)	Keel Dimensions		Dimension Ratios		
		Sided (cm)	Molded (cm)	Molded/Sided	Sided/Length	Molded/Length
Giglio	25	15	22	1.47	0.60	0.88
Bon Porté	10	6.4	9.6	1.50	0.64	0.96
Jules-Verne 9	9.5	6.8	7	1.03	0.72	0.74
Jules-Verne 7	15.65	10	11	1.10	0.64	0.70
Cala Sant Vicenç	22	13	17	1.31	0.59	0.77
Gela 1	20	25	37	1.48	1.25	1.85
Ma'agan Mikhael	13.8	11	16	1.45	0.80	1.16
Kyrenia	14	12.8	20.3	1.59	0.91	1.45

### Planking

Having prepared the ship's spine, the next step was to install the bottom planking. Tool marks attest that the six surviving planks from the Pabuç Burnu hull were sawn from pine logs (*Pinus nigra*) and hewn to shape with an adze. The eastern variant of *Pinus nigra* ranges from Eastern Europe to the Black Sea and south through the Balkans, Anatolia, and Cyprus. In Anatolia, it is particularly prevalent in the west, towards the coast.<sup>17</sup> The tree is plentiful in the region, strong and durable, resistant to rot, and easy to work, making it a popular wood with ancient shipbuilders.<sup>18</sup> Virtually all known ancient Greek ships were built using pine planks (table 4.3).

<sup>17</sup> Davis 1965, 74.

<sup>18</sup> Steffy 1994, 258–9. Various ancient authors affirm the use of pine in shipbuilding: the fifth–fourth-century B.C. comedy writer Aristophanes (*Eq.* 1310) has a small galley describe itself as built of pine and timber; the fourth-century B.C. writer Theophrastus (*Hist. pl.* 5.7.1-3, 5.7.5) recommends pine, silver fir, and cedar; Pliny (*HN* 16.81.224) observes that pine and cypress most effectively resist rot and wood worms; and the Roman orator Dio Chrysostom (*Or.* 64.10) mentions a plank of pine three fingers thick (Fitzgerald 1994, 170–1).

Table 4.3. Hull Planking from Ancient Greek Shipwrecks

Shipwreck	Hull Length (m)	Primary Joinery	Width (cm)	Thickness* (cm)	Wood Type
Giglio	25	lacing	26	2.5–4.2	<i>Pinus sylvestris</i>
Pabuç Burnu	17–18	lacing	20.2–30.5	2.5–4.5 (3.7)	<i>Pinus nigra</i>
Bon Porté	10	lacing	12	2.4–2.6 (2.5)	—
Jules-Verne 9	9.50	lacing	15–20	2.7–3.0	<i>Pinus halepensis</i> , <i>Pinus pinea</i>
Jules-Verne 7	15.65	mortise-and-tenon	14–28	2.5–3.0	<i>Pinus halepensis</i>
Cala Sant Viçenc	20–22	lacing	30–45 (39)	4.5	<i>Pinus sylvestris</i>
César 1	10	mortise-and-tenon	—	—	—
Grand Ribaud F	25	mortise-and-tenon	—	3.5	<i>Abies alba</i>
Gela 1	20	lacing	—	—	<i>Pinus pinea</i>
Gela 2	18	mortise-and-tenon	25–30	4.5	<i>Pinus nigra</i>
Ma‘agan Mikhael	13.8	mortise-and-tenon	11.3–32.0	3.5–5.0 (4.3)	<i>Pinus brutia</i>
Kyrenia	14	mortise-and-tenon	18.5–31.5	3.2–4.1 (3.7)	<i>Pinus brutia</i>

\*Value in parentheses is an average for the range.

Preserved plank widths from Pabuç Burnu range from 20.2–30.5 cm, but the maximum original width of plank UM 3 may have been at least 35 cm. These widths are generally similar to those of the other Greek hulls, if perhaps on the larger side of the overall average. The Bon Porté and Jules-Verne 9 vessels tend to have narrower planks, while those from Cala Sant Viçenc are the widest of any recorded on Greek shipwrecks. Their widths range from 30 to 45 cm, and average about 39 cm.<sup>19</sup> Unfortunately, plank dimensions are poorly published, and the poor preservation of a number of these wrecks,

<sup>19</sup> Nieto and Santos 2009, 46 fig. 39.

including Pabuç Burnu, makes it difficult to draw any hard conclusions regarding sizes of planking. In addition, plank widths can vary tremendously within a hull. In the Kyrenia, Jules-Verne 7, and Ma‘agan Mikhael wrecks, the largest planks are well over twice the width of the smallest ones. This is to be expected, however, since ancient shipwrights used the design—width, thickness, edge beveling, placement location—of the planks themselves to control the shape of the hull, and so would have adjusted their plank dimensions as needed.<sup>20</sup>

Plank thicknesses are also generally similar, although the planks of the Bon Porté and two Jules-Verne wrecks seem to be slighter than those of the other wrecks. What is more interesting is comparing plank thicknesses of fully laced boats with those built predominately with pegged mortise-and-tenon joints. It has been suggested that laced vessels were built with thinner planking to enhance the flexibility of their hulls.<sup>21</sup> This, however, seems not to be the case. The vessels examined here range in length from about 10 to 25 m, and the average thickness of their hull planking varies correspondingly from 2.5 to 4.5 cm. The planking shells of the César 1 and Jules-Verne 7 hulls, constructed with pegged mortise-and-tenon joinery, are about the same thickness as those of wreck 9 at Place Jules-Verne. The Ma‘agan Mikhael, Kyrenia, Gela 2, and Grand Ribaud F wrecks all have similar planking thicknesses as the laced hulls from Cala Sant Viçenc, Pabuç Burnu, and Giglio. It would seem that the thickness of hull planking is related more to the size of a vessel than to the type of edge joinery used to fasten together its strakes.

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<sup>20</sup> Steffy 1985, 92.

<sup>21</sup> Mark 2005, 58–9, 62.

This is well illustrated in the hull of the royal ship of Khufu, the Fourth Dynasty funerary barge discovered alongside the Great Pyramid at Giza. Although of a much different type and build, it's hull is nonetheless held together primarily with ligatures. The vessel is large and heavy; made predominately from cedar, it stretches some 43.6 m long and 5.6 m wide, and weighs 38.5 tons.<sup>22</sup> The hull has no keel or endposts to serve as a structural spine. Rather, the bottom is constructed from eight planks each about 13 cm thick, while each side consists of 11 planks in 5 strakes measuring 12–15 cm thick.<sup>23</sup> The planks are aligned with tenon coaks and lashings at strategic locations, and then laced together with four or five strands of cordage running transversely from sheer to sheer through V-shaped channels cut into the interior surface of the planks.<sup>24</sup> The planks have joggled edges, which effectively lock them together and, along with the tenon coaks, prevent them from moving longitudinally. The hull is reinforced along its length by three upper girders, but the planking contributes the major portion of its longitudinal strength.<sup>25</sup> For this reason, it was made thick and strong.

The general relationship between ship size and planking thickness seen in Greek vessels of the Archaic and Classical periods appears to continue into Roman times, where moderate-size ships typically have planks between 2.5 and 4.5 cm thick, while much larger vessels have thicker planking and even double-layered planking.<sup>26</sup> This trend changes towards the later Roman period, when hull planking became thinner for

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<sup>22</sup> Lipke 1985, 29.

<sup>23</sup> Steffy 1994, 25.

<sup>24</sup> Steffy 1994, 25-6; Lipke 1985, 23.

<sup>25</sup> Steffy 1994, 28.

<sup>26</sup> Fitzgerald 1995, 128–31.

ships of similar sizes as shipwrights began placing greater emphasis on stronger internal structure and upper works.<sup>27</sup>

### Scarfs

The hull remains preserve parts of three planking scarfs: a butt joint on UM6; a diagonal scarf on UM5; and a curved (S) scarf on UM1 that is hooked near its middle (fig. 4.1). The last was shaped with an adze and its original length is reconstructed to almost 97 cm. Its edge is multifaceted and beveled, but the angle of beveling changes from inward near the hook to outward at its end (fig. 4.2). The scarf originally extended under two frames, which sat over the tips and attached to both planks at each end of the scarf with lashing and treenails. The lack of edge joinery along these scarfs is curious. In the case of the curved scarf at least, it would seem that the ship's builder compensated for this by reinforcing the joint longitudinally with the carved hook, or joggle, and transversely with an alternating beveled edge.

Ancient shipbuilders utilized long planking scarfs for shell-based hulls because edge joinery was incompatible with connecting square ended planks to each other to form strakes. This was particularly true for mortise-and-tenon joined planks. Laced joinery could, in fact, be used to join butted planks, but only if the coaks were omitted between the abutting ends. This clearly was the case with UM6, where no coaks or lacing was used. Butted planks were best joined by nailing or treenailing their ends to frames, but since most of the planking on Greek ships was erected before frames were

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<sup>27</sup> Steffy 1994, 78.

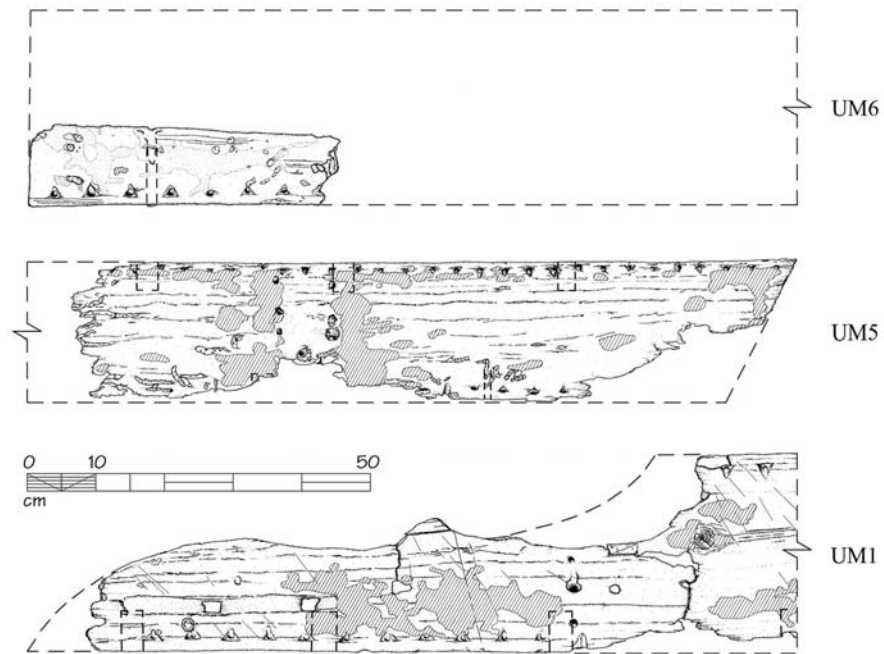


Fig. 4.1. Preserved planking scarfs.



Fig. 4.2. Beveled scarf edge on plank UM1.

installed, this was impossible. Ancient shipwrights solved the problem by angling (diagonal and three-planed/Z scarfs) or curving (curved/S scarfs) the butt to make it longer and more horizontal. Curved scarfs generally were more difficult to cut and fit than diagonal scarfs.<sup>28</sup>

Vestiges of the Giglio ship's hull preserved diagonal and three-planed (Z) planking scarfs, but none survived in the fragmentary hull remains from Bon Porté (table 4.4).<sup>29</sup> At least two strakes of the Cala Sant Vicenç wreck preserve curved scarfs,

Table 4.4. Planking Scarfs in Greek Hulls

Shipwreck	Type	Location on Hull	Bow-ward Angle	
			Forward	Aft
Giglio	diagonal, three-plane (Z)	lower	—	—
Pabuç Burnu	diagonal	lower	—	—
	butt	upper (above waterline)	—	—
	curved (S) with hook	upper (above waterline)	—	—
Jules-Verne 9	diagonal	garboard, strake 3	down	
Jules-Verne 7	diagonal	strakes 1–6	down	up
	three-planed (Z)	strakes 7–13	down	up
Cala Sant Vicenç	diagonal	garboards	—	—
	curved (S)	strake 3E, 5E, 3W?	—	—
Gela 1	diagonal	strake 4	—	up
Gela 2	diagonal	strake 2	—	—
		strake 10?	down?	—
Ma'agan Mikhael	curved (S)	strakes 2–5	down	up
	three-planed (Z)	strake 4	down	up
	diagonal	strake 6–11	down	up
Kyrenia	diagonal	all planking	down	up
	three-planed (Z)	wales	down	up

<sup>28</sup> Steffy 1999, 166–7.

<sup>29</sup> Kahanov and Linder 2004, 50.



located on the same side of the keel and between the same two frames, and separated by a single strake.<sup>30</sup> The scarf in strake 3E measures 1.25 m long, while that in strake 5E is about a meter in length. There also appears to be a preserved diagonal scarf in each garboard, located at the same spot on opposite sides of the keel, at the extreme south end of the remains.<sup>31</sup> Scarf edges are joined with tenon coaks and lacing in the same manner as the rest of the planking. The scarf in strake 5E was open when found on the seabed, revealing tenon coaks protruding along the preserved portion of the scarf. They were applied perpendicularly to the scarf edge (and thus at a different attitude than those in the seams), indicating that these planks were preassembled before the shipwright added them onto the hull.<sup>32</sup> Just as with the curved scarf from Pabuç Burnu, a frame typically sits over the scarf tips and is lashed to both planks of the strake.

The preserved portion of the Jules-Verne 9 hull contains two diagonal scarfs, one in the garboard and the other in the third strake. Both are situated on the port side of the hull near the bow, where the planking begins its inward curvature towards the stem. Their forward ends are angled down (towards the keel).<sup>33</sup> The Jules-Verne 7 hull remains preserve at least 22 planking scarfs, including six diagonal scarfs and two three-planed scarfs in the portside strakes, and 10 diagonal and four three-planed scarfs in the starboard planking. The diagonal scarfs are all located in the bottom of the hull up to the sixth strake, while above this point the scarfs are all three-planed.<sup>34</sup> A majority of the scarfs are located in the central portion of the hull, and are staggered so that scarfs in

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<sup>30</sup> Nieto and Santos 2009, 27 fig. 22 46.

<sup>31</sup> Nieto and Santos 2009, 27 fig. 22.

<sup>32</sup> Nieto and Santos 2009, 46. See Steffy (1994, 48) for the practice of edge joining scarfs.

<sup>33</sup> Pomey 1995, 472 fig. 7; Pomey 2003, 59 fig. 11.3.

<sup>34</sup> Pomey 1999, 149 fig. 3, 150.

adjacent strakes are never located next to one another.<sup>35</sup> However, in some places the scarfs of every other strake are aligned athwartship. All but three of the joints are situated under a frame. Planking scarfs in the forward half of the hull are oriented so that their boward end is angled down, while, with one exception, those in the after part of the hull are angled up.<sup>36</sup>

Wreck 1 at Gela preserves at least one diagonal scarf, located in the fourth strake on the port side and between two frames near amidships (one frame station aft of the mast step).<sup>37</sup> There are parts of at least two diagonal scarfs in the hull remains of the second wreck at Gela.<sup>38</sup> One extends under a frame, and its tip is reinforced with a lead patch that is fixed to the inside of the hull with small nails. The scarf seam is secured with pegged mortise-and-tenon joints, which are inserted at the same attitude as the planking joints, indicating that the planks were installed separately onto the hull.<sup>39</sup>

The planking strakes of the Ma‘agan Mikhael ship were made from two planks—one long and one short—joined together with diagonal, curved, or three-planed scarfs that range in length from 45.5–102.0 cm.<sup>40</sup> The boward angle of scarfs in the forward half of the hull is down, while in the after areas their angle is up. The scarfs are generally placed symmetrically, such that corresponding strakes on either side of the hull are scarfed in the same area, but staggered fore and aft with the scarfs of the adjacent

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<sup>35</sup> The exception is in the second and third starboard strake, where two diagonal scarfs extend continuously across the two strakes, and just forward of the tip of a diagonal scarf in the garboard. However, these are not original scarfs, but the seams of a replaced section of planking inserted during a later repair (see Pomey and Rieth 2005, 119).

<sup>36</sup> Pomey 1995, 472 fig. 7.

<sup>37</sup> Panvini 2001, 18 fig. 3.

<sup>38</sup> Benini 2001, 104 fig. 60, 152 pl. 36.

<sup>39</sup> Benini 2001, 104 fig. 60.

<sup>40</sup> This does not include the garboards, each of which was fashioned from a single timber (Kahanov 2003; Linder and Kahanov 2003, 71).

strakes. Strakes 2, 3, and 5 on both sides of the hull have curved scarfs, as does the fourth port strake. However, the strake 4 on the starboard side is joined with a three-planed scarf. Above the fifth strake, all planks are joined with diagonal scarfs.<sup>41</sup> It appears that most of the scarfed planks were erected individually, but at least one strake (S4) may have been preassembled with a three-planed scarf before it was added to the hull.<sup>42</sup>

Twenty planking scarfs from 42.5–81.0 cm long are at least partially preserved in the Kyrenia hull. All are diagonal scarfs except for those in the wales, which are three-planed scarfs. Strakes 4 and 9 consist of three planks joined by two scarfs, but the remaining strakes are all made from two planks. The scarfs are fairly evenly distributed across the hull and are symmetrically placed on either side, much like in the Ma‘agan Mikhael hull. With the exception of the forward scarf of port strake 9, all scarfs towards the bow are angled down. In the after part of the hull, the scarfs are angled up, except for the aft scarf of starboard strake 4 and that of port strake 8. Both of these scarfs are located centrally in the hull, just aft of amidships, and angled down.

### *Edge Joinery*

The laced joinery found in Archaic Greek shipwrecks consists of a number of complementary features that, when collectively applied, serve to form the best possible joining between the strakes and to ensure the watertightness and durability of the hull.

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<sup>41</sup> Kahanov 2003; Linder and Kahanov 2003, 72–3 fig. 36 for the planking plan, 78–81 for details of the scarfs.

<sup>42</sup> Assuming that the relative angle between the joint pegs is a true indication of the attitude of the tenons that they lock (Kahanov 2003; Linder and Kahanov 2003, 79 fig. 46).

The characteristics are remarkably consistent across all of the wrecks in questions and, when taken as a whole, form a unique, integrated system of hull joinery.

### Coaks

Coaks are wooden inserts let into the edges of adjacent planking strakes across a seam. They were an essential element of Greek laced joinery and served a dual purpose within the system. When a shipwright was ready to add a plank to his hull, he first fitted it onto coaks in the extant plank (or keel) to hold it in place while he laced the seam and secured the union between the two planks. After the hull was completed and the ship put into service, the coaks took on a significant role in maintaining the integrity of the seam joinery. They reinforced the planking connections longitudinally and helped prevent slippage between the strakes that would tend to work the lacings loose and open the seams. Details of edge inserts found in Greek shipwrecks are provided in Table 4.5.

The Giglio, Bon Porté, and Jules-Verne 9 ships all were constructed using dowel coaks, and establish the basic norm for Greek laced construction. To this group we might add the small vessel from which the Kyrenia shipwright salvaged hull planks for use as ceiling in his hull.<sup>43</sup> Although he trimmed the edges to remove the lacing holes and notches, traces of the holes and coaks remain to show that the vessel was lace-joined with dowel coaks. The dowels of all these vessels are similar in size, measuring about 12 cm long on average (seated 6 cm into each edge) and 1.0–1.5 cm in diameter. The

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<sup>43</sup> Steffy 1985, 95 ill. 17.

Table 4.5. Edge Inserts (Coaks and Joints) Employed in Ancient Greek Hulls

Shipwreck	Type	Function	Construction	Dimensions (cm)				Sp. (c-c) <sup>44</sup>
				Diam.	Width	Thk.	Length	
Giglio	dowel	coak	original	1.5	—	—	—	33
Pabuç Burnu	tenon	coak	original		3.2	0.9	11.1	29.8
	dowel	coak	repair (strakes)	1.0–1.4	—	—	17.4	26.5
Bon Porté	dowel	coak	original	1.0	—	—	12	15–16
Jules-Verne 9	dowel	coak	original	1.0	—	—	11	20.5
Jules-Verne 7	tenon	joint	original	—	3.0–3.5	0.5	14–15	23
	dowel	coak	original and repair	—	—	—	—	—
Cala Sant Vicenç	tenon	coak	original (strakes)	—	2.8–3.0	0.9	13.5	18–35 (28)
	dowel	coak	repair (keel)	1.5	—	—	20–25	20–45 (32)
César 1	tenon	joint	original	—	—	—	—	—
	dowel	coak	original and repair	—	—	—	—	—
Grand Ribaud F	tenon	joint	original		4.5	—	12	20
Gela 1	dowel	coak	original	1.0–1.2	—	—	—	18
	tenon	coak	original	—	—	—	—	—
Gela 2	tenon	joint	original	—	—	—	12	24.5
	dowel	coak	original and repair	—	—	—	—	—
Ma'agan Mikhael	tenon	joint	original	—	3.9	0.7	15.4	13.0
Kyrenia	tenon	joint	original	—	4–5	0.55	15–16	11.7
Kyrenia ceiling	dowel	coak	reused	1.5	—	—	—	14

spacing of the dowels along the seams, however, shows significant variation and ranges from 14–33 cm.<sup>45</sup>

The hull remains from Cala Sant Vicenç and Gela 1 both demonstrate the concurrent use of cylindrical dowels and rectangular tenons as coaks in the ships' construction. In the case of Cala Sant Vicenç, the shipwright assembled the hull's planking using narrow tenons for coaks between the plank edges. These he fashioned

<sup>44</sup> Value in parentheses is the average of the range.

<sup>45</sup> This range may be exaggerated by inclusion of the coak spacing on the Giglio ship, which was recorded only along the keel-garboard seams, which may not be representative of coak spacing in the hull planking. If Giglio is excluded, the average spacing would be about 18 cm (14–23 cm).

from dogwood (*Cornus* sp.), cutting them approximately 3 cm wide, less than 1 cm thick, and 12–14 cm long.<sup>46</sup> However, the coaks fitted between the garboards and keel are long, cylindrical dowels made from the same type of wood and measuring about 20 cm in length and 1.5–1.7 cm in diameter.<sup>47</sup> The peculiar aspect of these dowels is that they were not seated perpendicular to the seam, as is the normal fashion, but were inserted obliquely through holes that open onto the inboard surface of the garboard and extend through the garboard edge and into the side of the keel.<sup>48</sup> The ship's investigator believes that this atypical application is evidence that the ship underwent a major overhaul at some point in its life, during which the vessel's keel and garboards were replaced.<sup>49</sup> This hypothesis is supported as well by the presence of reused floor timbers for the vessel's framing,<sup>50</sup> the irregular treatment of the dowel coaks and lacing notches along the keel-garboard seams, especially when compared to the exceptional consistency of these features along the rest of the planking seams,<sup>51</sup> and the presence of more than two dozen plugged holes in the planking believed to have been attachment points for the shores or other bracing that propped up the ship during its overhaul.<sup>52</sup> More will be said on this in a below.<sup>53</sup>

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<sup>46</sup> Nieto and Santos 2009, 27 fig. 22, 51; Nieto et al. 2004, 202. The wood could not be identified to the species level, but it is most likely either common dogwood (*Cornus sanguinea*) or European Cornel (*Cornus mas*), both of which are native to most of Europe (though the latter is limited to the more southerly regions) and western Asia (Piqué-Huerta 2009, 332–4).

<sup>47</sup> Nieto and Santos 2009, 27 fig. 22, 42; Piqué-Huerta 2009, 332.

<sup>48</sup> Nieto and Santos 2009, 27 fig. 22, 42.

<sup>49</sup> Nieto and Santos 2009, 48.

<sup>50</sup> Nieto and Santos 2009, 31–2.

<sup>51</sup> Nieto and Santos 2009, 42–3.

<sup>52</sup> Nieto and Santos 2009, 49.

<sup>53</sup> See pp. 118–121.

Whereas the Cala Sant Vicenç shipwright appears to have used tenon coaks exclusively in his hull's original construction, the builder of the Gela 1 vessel took a somewhat different approach. Between the keel and garboards and some of the adjoining strakes, he inserted dowels in the typical manner. These are 1.0–1.2 cm in diameter and are spaced along the seams at intervals of 18 cm.<sup>54</sup> However, in certain other areas of the hull, towards the extremities between strakes 4 and 5, for example, he alternated the dowels with tenon coaks between the lacing.<sup>55</sup> Some reports claim that these tenons are pegged, which would identify them as joints rather than mere coaks.<sup>56</sup> It may be that inaccurately published usage of the term “mortise-and-tenon joint”, when freestanding tenon was intended, has contributed to this confusion, but the hull remains are not yet documented well enough to make a final determination.<sup>57</sup> In any case, it is apparent that dowels and tenons—whether freestanding or pegged—were inserted across planking seams that were also laced.<sup>58</sup>

### Tenons

The Pabuç Burnu shipwright utilized tenons for coaks in his hull, much like in the Cala Sant Vicenç ship. Planks UM1 and UM5 have rectangular mortises lining their edges. A single half-tenon, broken at the seam, is the only such coak to survive

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<sup>54</sup> Panvini 2001, 21, 22 fig. 13.

<sup>55</sup> Panvini 2001, 21, 25 fig. 20, 26 fig. 22.

<sup>56</sup> Kahanov and Linder (2004, 57–8) maintain that the first three strakes of the hull were joined with lacing and dowel coaks, whereas the fourth strake and those above were joined with pegged mortise-and-tenon joints (4 cm wide) fitted between dowel coaks. Although Panvini (2001, 26 fig. 22) does not show if the tenons are pegged or not, lacing holes are clearly visible and dowels and tenons are centered between them in the normal manner for coaks.

<sup>57</sup> Panvini 2001, 21. The preserved remains of the hull were raised from the seabed in 2008 and sent to Portsmouth for conservation and reconstruction by Mary Rose Archaeological Services (Italy Magazine 2008, 28 July, <http://www.italymag.co.uk/italy/sicily/2500-year-old-greek-ship-salvaged-sicily>).

<sup>58</sup> Panvini 2001, 26 fig. 22.

relatively intact (fig. 4.3). The right corner of the half-tenon, as viewed in the photograph, is damaged, but probing in the mortise indicates that the tenon is fairly tightly fitted. Deteriorated scraps of wood in several other mortises are all that remains of the other tenons. Being coaks, the tenons sat freely in their mortises and were never pegged.

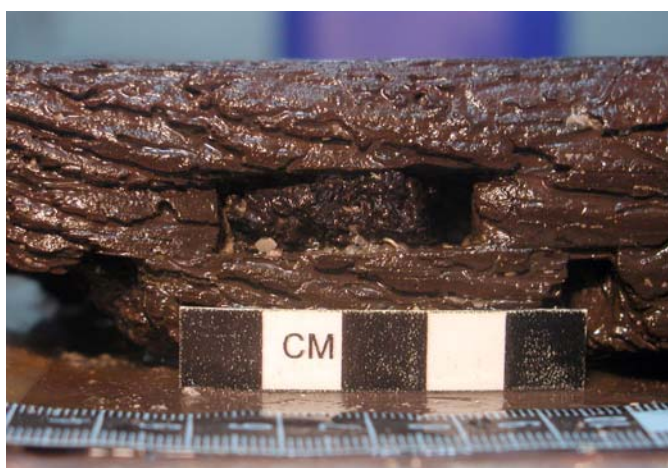


Fig. 4.3. Half-tenon seated in its mortise in plank UM1.

The tenons were made from oak, which was the hardwood of choice for tenons on most ancient Greek and Roman ships.<sup>59</sup> This particular species, Kermes oak (*Quercus coccifera*), is a large, evergreen shrub (or small tree) that has a wide distribution around the Mediterranean, including Portugal, Spain, and Morocco in the west, and Greece, the Aegean Islands, and western Anatolia in the east.<sup>60</sup> The presence of these coaks in the Pabuç Burnu hull represents the earliest archaeologically attested

<sup>59</sup> Fitzgerald 1994, 175–6; Steffy 1994, 258.

<sup>60</sup> Liphshitz 2004, 157.



use of tenons in Greek boatbuilding, and demonstrates that these builders were aware of the value of using edge fittings that were harder than the wood surrounding them. They needed to be hard and strong to endure the forces subjected upon them by the twisting and bending of the hull without distorting or breaking.<sup>61</sup> The mortises are centered within the thickness of the plank and staggered along one edge from those in the opposite edge, though their spacing is not consistent. Center-to-center spacing between mortises in UM1 averages 29.3 cm, with minimum and maximum distances of 21.9 and 34.7 cm, respectively. Mortise spacing on UM5 ranges from 28.4–32.7 cm and averages 31.0 cm. Mortises in UM1 are approximately 3.3 cm wide at the edge, 1.0 cm thick, and 5.9 cm deep, while those in UM5 are slightly smaller, measuring 3.0 cm wide, 0.7 cm thick, and 4.9 cm deep. Preserved corners of the mortises are sharp and precisely cut (fig. 4.4). Where it can be determined, it appears that one side of each mortise was cut straight, while the opposite side was cut at a slight angle, presumably to facilitate removal of the wood. The irregularly-shaped bottom of at least one mortise may indicate that it was cut with a mortising chisel without the use of pre-drilled holes, but the poor preservation of exposed mortises makes any determination tentative.<sup>62</sup>

### Dowels

The edges of planks UM3 and UM6 are bored with dowel holes of between 1.2–1.4 cm in diameter. The holes in UM3 are spaced irregularly, with distances between centers varying widely from 12–44 cm and averaging 26.2 cm. Degraded bits from original dowels remained in some of the holes, analysis of which indicates that the coaks

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<sup>61</sup> Steffy 1994, 46.

<sup>62</sup> Steffy 1985, 90 ill. 14.

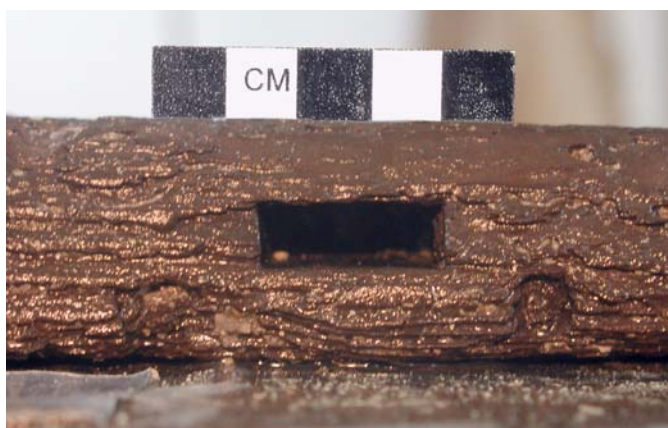


Fig. 4.4. Rectangular mortise in plank UM1.

were fashioned from branches of oleander (*Nerium oleander*), an evergreen shrub or small tree commonly found across the Mediterranean region. Plank fragment UM6 preserves a single coak hole, in which over 4 cm of the original wooden dowel was still fitted tightly (fig. 4.5). This dowel was made from oleander as well and broken at the seam. The significant characteristic of these dowel holes is that they were drilled obliquely through the face of the plank. In the case of UM3, the holes were drilled into the edge of the plank at angles of 12–16 degrees and penetrate the inboard face of the plank varyingly from 6 to 12 cm from the seam edge (fig. 4.6). The holes are offset slightly within the seam edge towards the outer corner. This likely was done to minimize the loss of resistance against the dowel from the inboard side of the plank.

The dowel hole in UM6 was drilled from the edge into the plank's thickness at an 8-degree angle, but this time through the outboard face of the plank, which it exits 6 cm from the edge.



Fig. 4.5. Extant dowel coak in plank UM6.



Fig. 4.6. Oblique dowel hole in plank UM3.

This treatment suggests that UM3 and UM6 are repair planks used to replace a damaged section of the hull. When installing edge-joined planking in situ, coak holes along one edge of the new piece had to be made obliquely and open at the plank surface, since the plank could not be fitted to coaks in both edges simultaneously. Here, for example, after the shipwright removed a particular damaged plank, he inserted the new piece (UM3) between the extant strakes and fitted its now vanished edge onto tenon coaks seated normally in the adjoining strake. Flushing up the plank on both sides, he then proceeded to drive in the repair dowels through the openings on the inboard face of UM3, across the seam, and into the thickness of the adjacent plank. The entire piece was then laced up tightly to complete the repair. The shipwright may have fashioned the repair dowels from oleander branches because their flexibility could better accommodate the bend from the oblique channels of UM3 into the straight holes of the existing strake. Or more likely, perhaps, he simply made use of whatever wood was available to him at the time. Furthermore, he preferentially penetrated the inboard face of the planks in order to prevent the introduction of new possible seepage routes for seawater. Where this was not possible due to the presence of a frame or some other obstacle, he had no choice but to drill to the outer face of the repair plank (as seen in UM6). This may explain as well the irregular placement of the repair dowels. Virtually the same repair procedure is seen in the Kyrenia hull, although there the replacement strakes were secured with specially shaped pegged repair tenons rather than with coaks and lacing.<sup>63</sup>

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<sup>63</sup> Steffy 1985, 97.

The Jules-Verne 7, César 1, and Gela 2 wrecks all show evidence of repairs in their hull remains. Cracked or otherwise damaged planking in the Jules-Verne 7 hull was cut out and fitted with new boards that were laced through tetrahedral notches to the surrounding planks. In other cases, defective mortise-and-tenon joints were reinforced with lacing to assure the integrity of the seam join.<sup>64</sup> There is no mention in published reports that coaks were used in the repairs, and a drawing of one mended area suggests that, indeed, they were not.<sup>65</sup> In general, the repair work does not exhibit the same level of care as the original construction, which mirrors what we see in the application of the repair dowels in Pabuç Burnu plank UM3.

Repairs in the hull of the César 1 ship were apparently accomplished with dowel coaks and ligatures strung through tetrahedral notches, but no additional details are available.<sup>66</sup> In the Gela 2 hull, there are three pairs of tetrahedral notches and lacing holes, some still with remnants of their ligatures, overlapping a particular pegged mortise-and-tenon joint in the seam between the garboard and second strake.<sup>67</sup> Although reported as a repair, there is no obvious indication that in fact it is.<sup>68</sup> Rather, it seems that the shipbuilder was dissatisfied with the integrity of the joint (the lower tenon peg is rather close to the seam), and decided to reinforce the seam with a short run of lacing. Typical of such rework, the notches are not particularly uniform or well aligned, and the original location of the lower middle notch was abandoned because it was too close to

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<sup>64</sup> Pomey 1995, 477.

<sup>65</sup> Pomey and Rieth 2005, 119.

<sup>66</sup> Pomey 2001, 430.

<sup>67</sup> Benini 2001, 101 fig. 59, 104. The report claims that there are only five notches.

<sup>68</sup> Benini 2001, 104.

the seam. This is further indication that the lacing was added after the planks were already joined.

The interpretation of Pabuç Burnu planks UM3 and UM6 as repair pieces, due to their oblique dowel coaks, is best supported by a near identical application of oblique dowels between the keel and garboards of the Cala Sant Vicenç wreck. This exceptional use of dowel coaks in a hull that, like the Pabuç Burnu ship, was otherwise lace-built with tenon coaks, is similarly attributed to repair work.<sup>69</sup> Thus, a review of the arguments and supporting evidence from Cala Sant Vicenç is in order.

The Cala Sant Vicenç hull remains provide a substantial section of a laced hull in which all the various elements of its laced joinery are preserved perhaps better than in any other Greek shipwreck. The size and spacing of the tetrahedral notches and ligature holes along the planking seams is remarkably consistent.<sup>70</sup> Spacing between centers of the notches along the seams of the strake averages 5.5 cm, whereas along the keel-garboard seams it is only 4.9 cm.<sup>71</sup> Nieto believes that this is a result of the work being done by a different carpenter and at a different time than the original construction.<sup>72</sup> It could also reflect the desire of the shipwright to create the strongest possible join between the garboards and keel, given the structural importance of this assembly to the overall strength of the hull. He was able to cut more notches and ligature holes—and

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<sup>69</sup> Nieto and Santos 2009, 48–9.

<sup>70</sup> Nieto and Santos 2009, 54–5.

<sup>71</sup> Nieto and Santos 2009, 47 fig. 41. The figure includes values of 77 cm (space occupied by 15 tetrahedrons) and 5.13 cm (corresponding distance between tetrahedron centers) for the seam between strakes 3E and 4E. However, a measurement of the notches along this seam in Nieto and Santos (2009, 27 fig. 22) yields respective values of 80 cm and 5.3 cm. These are more consistent with the spacing along the other strake seams, all of which agree with check measurements taken from figure 22. The average spacing assumes the corrected values.

<sup>72</sup> Nieto and Santos 2009, 47.

thus include more lacing “joints”—per length of seam because the dowel coaks (1.7 cm in diameter) he used in the repair were narrower than the tenons (3.0 cm wide) of the originally construction.

The shipwright could easily have cut the tetrahedral notches and drilled the lacing holes in the new garboards to match up with those in the original keel, just as he would have done during original construction, but not so with the coak holes. Thus, if he only replaced the garboards during the overhaul, the keel would have two sets of coak holes in its sides, those of the extant repair dowels as well as the mortises of the original tenon coaks. This, however, is not the case, which indicates that the shipwright must have replaced the vessel’s keel as well.<sup>73</sup>

To do this, the shipwright would have had to cut the keel away from the end-posts, since it would have been impossible to disassemble the keyed hook scarfs of the keel-posts assembly without dismantling the entire hull. Similarly, by whatever means the shipwright was able to scarf the new keel to the posts, the joints certainly would not have been as strong as the original scarfs, and so would have significantly weakened the ship’s spine.<sup>74</sup> In an attempt to mitigate this problem, the shipwright reinforced the new keel with a substantial false keel that would have extended beyond the ends of the keel to the posts, so as to support the weakened joints.<sup>75</sup>

Additional evidence for the overhaul comes from the presence of floor timbers that were clearly salvaged from some other vessel and modified to fit into the Cala Sant

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<sup>73</sup> Nieto and Santos 2009, 48.

<sup>74</sup> Nieto and Santos (2009, 49) assume that it would be virtually impossible to disassemble the keyed hook scarfs that almost certainly joined the ship’s posts to the keel. Unfortunately, neither end of the keel or its scarfs were preserved in the wreckage.

<sup>75</sup> Nieto and Santos 2009, 49.

Vicenç hull. The original notches in the base of the floors did not match up well with the planking seams of this hull, and so small blocks of wood had to be added and other areas of the floors notched out to make them compatible.<sup>76</sup> Furthermore, the only two floor timbers that preserve their central portion have a substantial horizontal section cut out from the center of their base where they crossed the keel. This cutout was fitted with a specially-shaped filler piece that was attached to the floor with oak treenails driven up through the bottom of the insert and others driven obliquely through the upper portion of its for-and-aft sides.<sup>77</sup> The inserts have a horizontal upper surface and vertical sides to match the opening in the floors. The base of the inserts is cut diagonally from each end towards the center, and is notched out on either side of its center where it overlays the keel-garboard seams.<sup>78</sup> These inserts give the hull a slightly deeper profile along the keel, which Nieto believes was intended to increase the ship's lateral resistance and reducing leeway.<sup>79</sup>

Effecting such an extensive renovation and replacement of the keel would have required that the hull be shored up and firmly braced after it was hauled up onto land. Evidence for this is found in the presence of 25 holes in the strakes, each 2.6 cm in diameter and sealed with a wooden plug.<sup>80</sup> The holes are centered between the frames in

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<sup>76</sup> Nieto and Santos 2009, 28 fig. 23, 31–2. Note that the added pieces are made from oak (*Quercus* subg. *quercus*), whereas the floors are pine (*Pinus* cf. *pinia*).

<sup>77</sup> Nieto and Santos 2009, 32.

<sup>78</sup> Nieto and Santos 2009, 28 fig. 23, 30 fig. 26. If this is true, one might say that the hull was modified to give it a proto-wine-glass shape.

<sup>79</sup> Nieto and Santos 2009, 31. If, indeed, this was the reason, then it is interesting to note that the addition of the large false keel further served this end. Together, the lowering of the keel by the floor inserts and its thickening with the false keel increased the effective area of lateral resistance by more than 170%.

<sup>80</sup> Nieto and Santos 2009, 49.



lines of one hole per plank that align roughly athwartships.<sup>81</sup> The bracing struts or cleats that would have been attached temporarily at these points to support the hull during its overhaul were positioned intentionally in this way so as not to interfere with the installation of the new frames. Taken as a whole, the evidence does indeed suggest that the ship was revised extensively at some point, during which its keel, garboards, and floors (if not the entire frames) were replaced. No other explanation reasonably accounts as well for the oblique application of dowel coaks in the critical keel-garboards assembly, when tenon coaks are employed in the typical orthogonal manner in the rest of the planking shell.

Comparing edge inserts—whether coaks or joints—in Greek hulls leads to some interesting observations. The Pabuç Burnu ship has the thickest tenons of the group, but also the shortest, although their lengths are generally similar to those of Cala Sant Vicenç, Grand Ribaud F, and Gela 2. The widths of the tenons in the Cala Sant Vicenç hull seem curiously narrow, only two-thirds larger than the dowels fitted between its keel and garboards. There does seem to be a generally consistent relationship between the length of inserts and the width of the corresponding planks into which they are introduced. This ratio varies from approximately 0.2 to 0.35 and averages almost 0.3 for the group. It may be that ancient Greek shipwrights used a simple rule of thumb to determine the appropriate length of their coaks or joints, making them approximately one-third the typical width of their planking.<sup>82</sup> It is tempting as well to see some

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<sup>81</sup> Nieto and Santos 2009, 27 fig. 22.7.

<sup>82</sup> Of course, the widths of hull planks can vary greatly depending upon where on the hull they are located, and the widths of individual strakes themselves vary along their lengths. If some type of rule of thumb was employed, it would have been applied to a representative plank width typical of the central portion of

relationship between tenon widths and the size of the vessels, but the data is too limited to be able to draw any firm conclusions. However, when the information is plotted chronologically, some obvious trends become apparent (fig. 4.7). Tenon size increases steadily over the three centuries that the evidence spans; length increases from 11 to 16 cm and width from 3 to 5 cm. This trend is more pronounced in the last third of the period, especially with respect to tenon length. If data from Ma'agan Mikhael and Kyrenia were ignored, both trend lines would be fairly flat for the earlier vessels. More

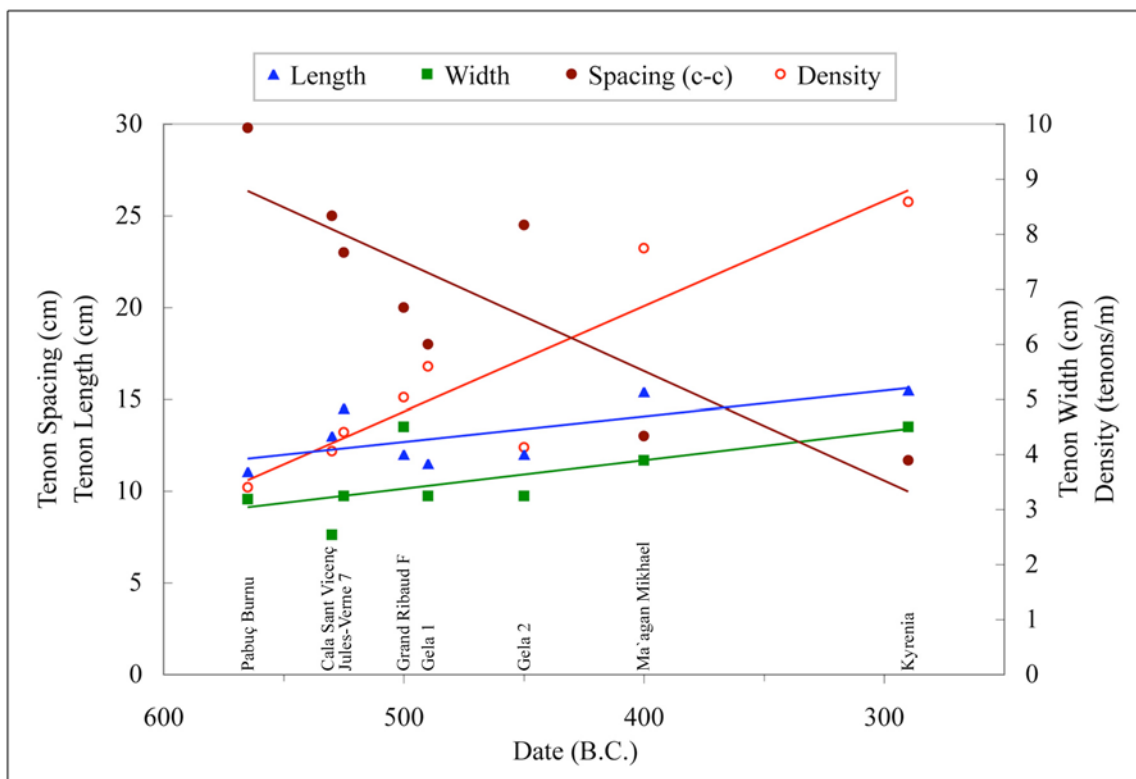


Fig. 4.7. Chronological plot of seam tenon dimensions and density in ancient Greek ships.

the hull. In the case of the Pabuç Burnu hull, the narrower plank UM5 has slightly longer tenons, relative to its width, than plank UM1. See as well, e.g., Yovel (2004, 109-10).

dramatic is the correlation of tenon spacing—or, conversely, tenon density—in the planking seams over time. Spacing between centers shows a clear decrease from almost 30 cm to less than 12 cm. This translates to an increase in tenon density by a factor of 2.5, from 3.4 to 8.6 inserts per meter of seam. The meaning of and reasons for these trends are dealt with in the next section, but suffice it to say that shipwrights continued to place an increasing emphasis on tenons as structural elements in their hulls.

### *The Lacing System*

Characteristics of the lacing systems found in Archaic Greek shipwrecks are remarkably similar. The Jules-Verne 9 and Cala Sant Vicenç hull remains preserve the most complete sets of features that establish the basic form of this system and demonstrate how each component contributes to the overall function and integrity of the joinery. The lacing elements observed in the Pabuç Burnu fragments are consistent with those of the other ships, which allows for broader interpretations of the finds.

### Lacing Notches and Holes

With the next plank to be added to the hull seated on the coaks, the shipwright scored the plank along its inner edge to mark matching locations for the lacing holes with the strake below. Removing the plank and using a chisel, he proceeded to cut out triangular openings centered on each mark to form a series of inverted tetrahedral notches. He cut the base of each opening first about 1.8 cm from, and parallel to, the plank edge. He then cut the two other sides—all with inwardly angled strokes—and split out the wood to form a notch about one centimeter deep (fig. 4.8). The bases of the



Fig. 4.8. Two lacing notches and holes in UM 6.

openings are consistently the widest and measure on average about 2.0 cm, while the other two sides each average about 1.8 cm (table 4.6).

He then placed the tip of his bit at the apex of the notch and, using it as a guide, drilled a hole obliquely through the side of the notch and the thickness of the plank to the outside corner of the seam edge (fig. 4.9). The diameters of these holes average 0.7 cm and their angles relative to the surface of the planks average 45 degrees. The exit holes intersect the outer corner of the seam edge such that about one-third of each hole opens on the outboard face of the plank and the remaining two-thirds opens within the seam (fig. 4.10). The external opening facilitated lacing the ligatures around the acute angle formed at the outer seam by the mated holes, while the cavity created within the seam kept the ligatures from protruding on the outer surface of the hull, protecting them from abrasion and possible breakage.

Table 4.6. Average Dimensions of Lacing Holes and Notches from Ancient Greek Shipwrecks

Shipwreck	Ligature Holes (cm)		Tetrahedral Notches (cm)					
	Diam.	Angle	Base	Side 1	Side 2	Offset from Edge*	Space between corners	Space (c-c)
Giglio	0.7	45–62°	2.1	1.6	1.5	1.5	3.4	5.6
Pabuç Burnu	0.7	45°	2.0	1.8	1.8	1.8	2.8	4.8
Bon Porté	0.6	45°	1.3–1.7 (1.5)			0.6	2.5	4.1
Jules-Verne 9	0.6	—	1.5–1.7 (1.7)			0.8	3.4	4.8–5.0
Jules-Verne 7	—	—	slightly larger than those of Jules-Verne 9 (1.7 cm)			—	—	—
Cala Sant Viçenc	0.8	—	2.0–2.5	slightly shorter than the base		1.5–2.0	2.5–3.0	5.0
César 1	—	—	similar to those of Jules-Verne 9 (1.7 cm)			—	—	—
Gela 1	—	—	1.5			1.5	3.0	4.5
Gela 2	—	—	1.5–2.0	1.0–1.5		—	—	—
Ma'agan Mikhael	0.6	42°	1.7	1.6	1.5	1.1	2.9	4.5

\*Distance from the base of the tetrahedral notch to the seam edge of the plank.

Average spacing between the centers of the lacing holes is about 4.8 cm.

Spacing on three of the four planks with preserved lacing holes (UM1, UM3, and UM6) is remarkably consistent at 5.5 cm, while the holes in UM5 are spaced more closely at 3.8 cm. The last plank has the smallest tetrahedral notches as well. Plank UM5 is the slightest of the four, being both thinner and narrower (see table 2.1), which may imply a relationship between the size of the lacing holes and plank size. The collective data from the wrecks seems to support this (refer to table 4.3). The Bon Porté, Marseilles, and Ma'agan Mikhael wrecks are the smaller vessels of the group, having lengths from 10–14 m, and the base sides of their notches average about 1.7 cm wide. The remaining

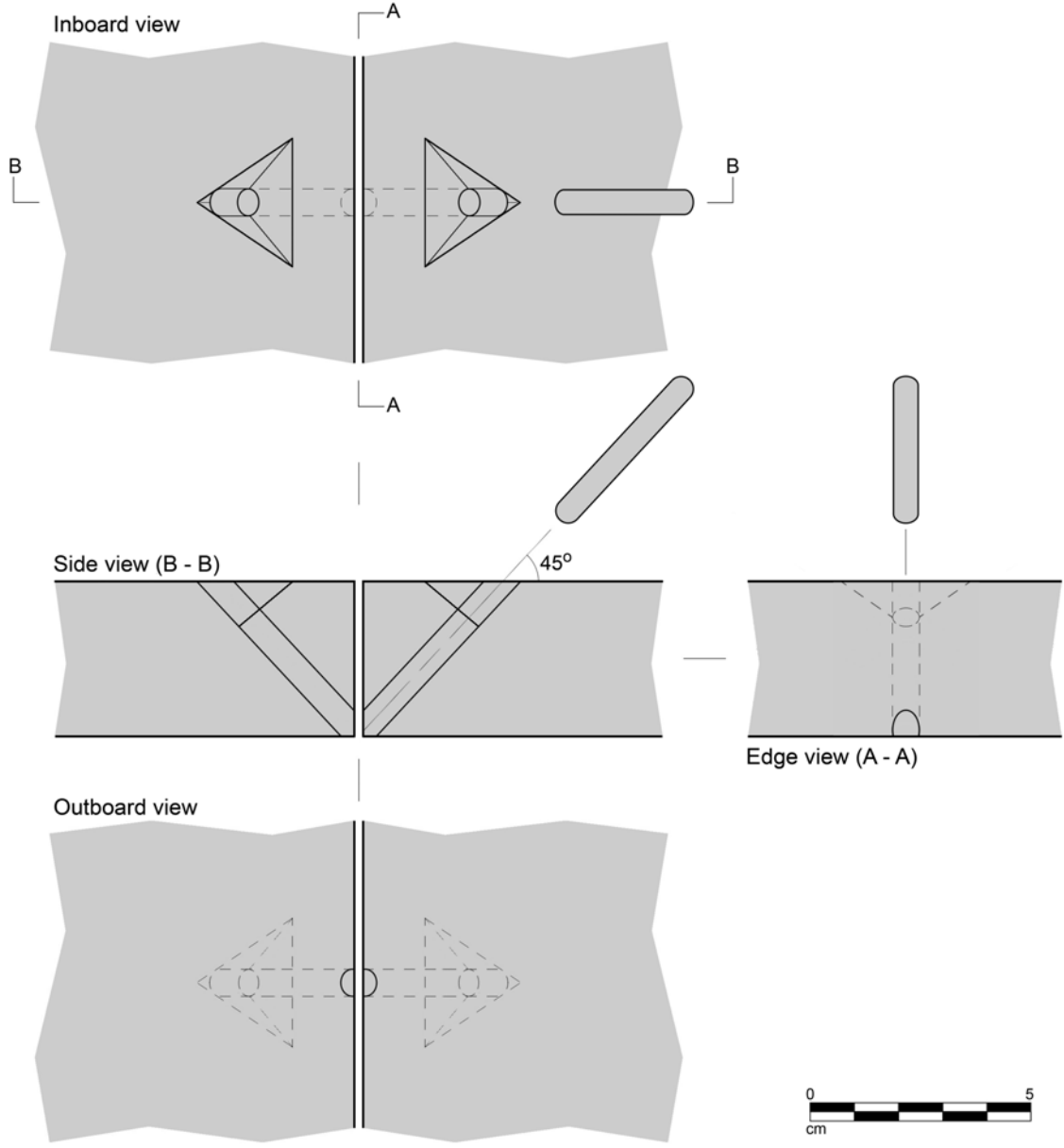


Fig. 4.9. Schematic of the Pabuç Burnu lacing notches and holes.



Fig. 4.10. Edge view of plank fragment UM 6 and the outer openings of two lacing holes.

vessels range in length from 17 to 25 m and have notches with an average base width of 2.0 cm. However, there is insufficient data to be able to make a quantitative correlation, and probably the differences in the notch sizes are too small to be significant. The diameter of the ligature holes is between 0.6 and 0.7 cm on all the wrecks. The desired hole angle seems to be around 45 degrees, which means that the distance that the holes (and notches) are set back from the edge will be determined by the thickness of the plank, in order that the holes exit at the outer edge corner of the plank.

The tetrahedral notches serve a number of functions in this lacing system. First, they provide a guide for drilling the lacing holes at the proper angle so that the holes exit at the outboard corner of the plank edge and match up correctly with their partner holes

in the adjoining plank.<sup>83</sup> The builders of the Place Jules-Verne 9 ship were so precise in their work that the lacing holes in each plank formed a semi-circle at the outer corner of the edge, and when butted up against the adjacent plank, the mated exit holes formed a complete circle.<sup>84</sup> The shipwrights ensured this accuracy by first carefully scribing the proper locations of the holes on the planks.<sup>85</sup> Secondly, by introducing an additional surface facet and corner, the notches reduce the severity of the angles around which the lacing bends, which in turn reduces stress and wear on the ligatures. The notches also orient the diagonal lacing and helps keep it in its proper position.<sup>86</sup> The size, placement, and spacing of the notches align the diagonal lacing turns at 45 degrees to the seam (fig. 4.11), which distributes the resistance strength of the diagonal lacings evenly to the

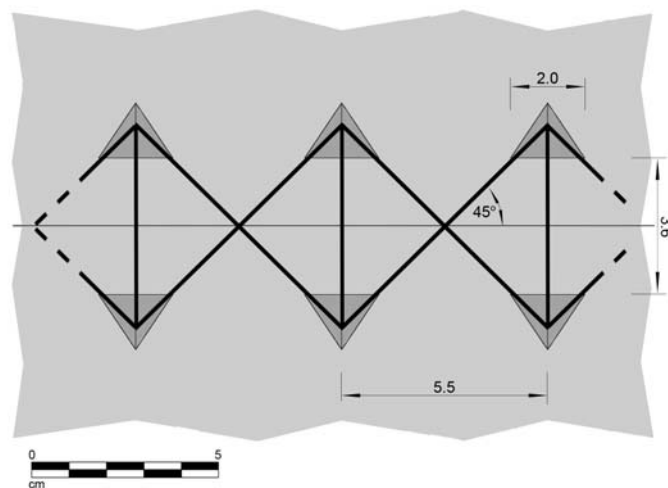


Fig. 4.11 The role of tetrahedral notches in orienting the ligatures of the Pabuç Burnu lacing.

<sup>83</sup> Pomey 1999, 150.

<sup>84</sup> Kahanov and Linder 2004, 54.

<sup>85</sup> Pomey 1995, 471.

<sup>86</sup> Pomey 1995, 474.



lateral and longitudinal loadings on the joint. Finally, the notches recess the convergence of ligatures and pegs below the level of the plank surface, which helps protect them from damage.

### Seam Wadding

Having prepared the plank for lacing, the shipwright fitted it back onto the coaks and to the strake below, making sure the edges butted closely together. He next laid a strip of wadding—a cloth batten, if you will—along the inboard seam between the two lines of lacing holes and began lacing a length of ligature through the holes, pulling it tight over the wadding and thus securing it to the seam. Wadding was recovered from the Jules-Verne 9 wreck and tentatively identified as flax (*Linum usitatissimum*).<sup>87</sup> Vestiges of cloth wadding were preserved as well in the Cala Sant Vicenç wreck, and “fabric” was found placed over the seams of the Gela 1 hull planking.<sup>88</sup> No wadding material was found on the Pabuç Burnu hull fragments, but evidence of its original presence exists. The pine tar that coats the interior surface of the planks never extends towards the edge beyond the base of the lacing notches, indicating that some type of wadding was placed there and laced over before the coating was applied.<sup>89</sup> This is especially evident on plank UM 5 (fig. 4.12).

Seam wadding is often referred to as “caulking” that is applied over the seams to make them watertight.<sup>90</sup> However, the ability of such wadding to stopper the seams is

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<sup>87</sup> Pomey 1999, 149, 150 n. 3.

<sup>88</sup> Nieto and Santos 2009, 54–5, fig. 47; Panvini 2001, 23.

<sup>89</sup> For the practice of coating the hull with pine tar, see pp. 149–151.

<sup>90</sup> See, e.g., Pomey 1997, 195. The small diameter of the wadding material (1.5 cm) found along the seams of the Gela 1 planking led investigators to surmise that it was meant to make the seams watertight and not to protect the lacing (Kahanov and Linder 2004, 57).



Fig. 4.12. Pine tar on the inner face of plank UM5.

questionable.<sup>91</sup> Rather, the wadding played an important role in the laced joinery itself, and the provision of any increased level of watertightness was a secondary benefit. Planking seams of ancient ships were made watertight by the swelling of their plank wood once they were placed in water.<sup>92</sup> The lacing (or whatever seam joinery was employed) kept the adjacent planks from separating and forced the expanding wood to press together tightly and close the seams. It was essential, therefore, that the lacing was made sufficiently taut when applied so that it was able to counter the expansion force of the wood.<sup>93</sup> The wadding helped to achieve this by providing a softer and more rounded surface under the ligatures that enabled them to be cinched down more tightly, acting, as

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<sup>91</sup> Foerster Lares 1989, 266-7. While the interpretation of the passage from Herodotus (2.96.1-2) on which Foerster is commenting may be questionable (see Haldane 1990), his insights on caulking and lacing with laths are nonetheless valid.

<sup>92</sup> Steffy 1994, 52.

<sup>93</sup> Coates 1985, 16; Foerster Lares 1989, 267.

it were, like a spring washer over which a nut is tightened. The wadding also made it easier to maintain uniform tension on the ligatures when lacing multiple turns through a hole, something that is difficult to achieve if the ligatures are bent over the sharp, bare corners of the planks.<sup>94</sup> Lastly, the wadding provided greater friction against the ligatures than if they were laced directly over smooth plank wood, and reduced the tendency of the lacing to move.<sup>95</sup> This allowed the lacing to be loaded to greater tensions, as noted above, and therefore to better resist shearing forces between the planks. The Khufu boat can perhaps serve again to provide a good illustration of the effectiveness of seam wadding, or in this case seam battens, in closing laced or lashed joints tightly. When Cheops Project director Hag Ahmed Youssef Moustafa attempted during the vessel's reconstruction to join the hull planking with linen lashings, but without seam battens, he found that he was unable to make a firm connection between the boards, and also that the lashings did not lie flat over the seams. Once he worked in wooden battens under the lashings, the seams tightened immediately and the structure as a whole became much stronger.<sup>96</sup>

#### Ligatures and Lacing Pattern

None of the original ligatures from the Pabuç Burnu ship survived, nor any indication of the original lacing pattern. The Giglio wreck yielded small bits of ligature

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<sup>94</sup> Foerster Lares 1989, 267.

<sup>95</sup> Kahanov and Linder 2004, 54) claim that wadding reduces the friction between the ligatures and planks is incorrect. Such an effect would in fact be counter-productive to the laced joinery. However, the wadding would reduce the strain on the ligatures at the corners of the notches, which in turn would protect both the lacing and notch edges from wear.

<sup>96</sup> Lipke 1985, 25.

made from a monocotyledonous plant of undetermined species.<sup>97</sup> Researchers found two small fragments of ligatures no more than 0.4 cm long inside at least two lacing holes, and they recovered bits of at least three ligatures from another hole. In addition, they observed wear marks at the corners of some tetrahedral notches, as well as at the middle of their base sides. From this evidence, they concluded that multiple ligatures had originally been laced in symmetrical and crisscrossing zigzag patterns that combined to form a double helical pattern (⊗⊗⊗), wherein each hole was joined by multiple turns to the three opposing holes across the seam in the adjacent plank. Furthermore, they estimated that there were originally at least three diagonal turns to both sides and double that number of transverse turns across the seam, for a total of 12 lacing turns connecting each hole.<sup>98</sup>

More substantial vestiges of lacing preserved in the Jules-Verne 9 wreck confirm this general pattern, but here there were four transverse turns for every pair of diagonal ones (⊗⊗⊗⊗).<sup>99</sup> The lacing passes three times across the seam to each diagonally adjacent hole and 12 times to the hole directly opposite, for a total of 18 turns emanating from each hole. At least a dozen complete lacing turns are preserved in the hull remains of the Cala Sant Vicenç ship.<sup>100</sup> The ligatures are made from esparto grass (*Stipa tenacissima*), which grows in southern Spain and northwestern Africa, and measure 0.3 cm in diameter.<sup>101</sup> Pairs of ligature strands were apparently laced simultaneously, once transversely and once diagonally in each direction, producing a double helical pattern



<sup>97</sup> Bound 1991a, 49; Bound 1991b, 34 fig. 77; Kahanov and Pomey 2004, 52.

<sup>98</sup> Kahanov and Linder 2004, 52.

<sup>99</sup> Pomey 1999, 151 fig. 5; Kahanov and Linder 2004, 54.

<sup>100</sup> Nieto and Santos 2009, 27, fig. 22.6.

<sup>101</sup> Nieto and Santos 2009, 55.

with four visible transverse turns and two diagonal turns to each side emanating from each hole .<sup>102</sup> Some of the extant bottom strakes of the Gela 1 hull were found still bound together by “plant-fibre cords,” and an area of pitch coating on the interior surface of the planking preserves an impression of the double helical lacing pattern .<sup>103</sup> Lastly, the Ma‘agan Mikhael shipwreck yielded ligatures 0.75 cm in diameter made from a monocotyledonous plant, most likely *Ruscus hypophyllum* or *Ruscus hypoglossum*. Both species are perennial evergreen shrubs of the western Mediterranean, with the latter found also in Turkey.<sup>104</sup>

Double helical lacing is accomplished by drawing a length of ligature in one direction along a section of seam and then turning and lacing back to the original starting point (fig. 4.13). The ligature crosses the seam at each turn so that regardless of which direction along the seam the ligature is pulled, it will always pass through the lacing holes in the same direction. This is important, because otherwise the lacing would work against itself in the V-shaped channels between planks and make it impossible to tighten properly. The pattern requires at least one turn between each hole and the three opposing holes in the adjacent plank. Since the lacing can pass diagonally across the seam from one hole to the next only on the inside of the hull, the corresponding returns must pass through the lacing holes within the planks, and so are not visible on the

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<sup>102</sup> Nieto and Santos 2009, 55–7, figs. 49 and 51.

<sup>103</sup> Panvini 2001, 20, 23 fig. 16.

<sup>104</sup> Kahanov and Linder 2004, 29. The ligatures were measured after they were removed from the wood and when they were waterlogged and slack; the diameter, therefore, may be overstated. See Shimony and Werker (2003) for the plant identification (note that the genus *Ruscus* is now typically classified in the family Rusaceae, but Shimony and Werker use its former classification in the family Liliaceae).

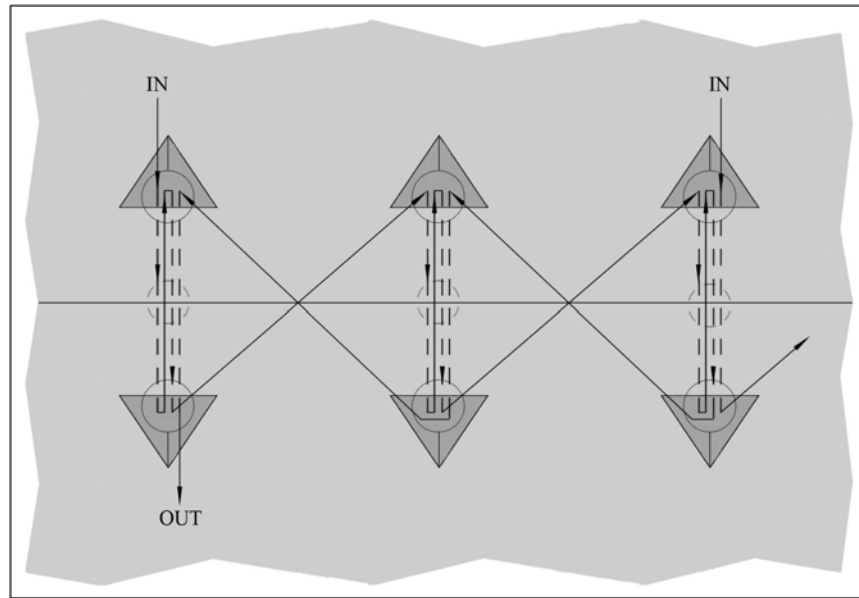



Fig. 4.13. Lacing pattern showing the minimum number of passes the ligature makes through each hole to achieve connection with the opposing three holes in the adjacent strake. The solid lines represent the portions of the lacing that are visible on the inside of the hull.

surface. In this way, the completed run of lacing forms the familiar crossing pattern along the seams on the inside of the hull. Furthermore, for each visible turn emanating from a hole, there is a corresponding hidden one passing through it, so that a total of four turns pass perpendicularly across the seams for every two diagonal turns, exactly as found in the Jules-Verne 9 lacing.

Of course, the pattern can be modified by increasing the number of transverse turns between holes, or by lacing multiple ligature strands at a time. The Cala Sant Vicenç builder did both, lacing a pair of ligatures and making a second transverse pass across the seam on the return run. Thus, each lacing hole in that pattern has twelve turns

(four visible and eight hidden) passing through it and two diagonal turn extending to either side.

From this evidence, we can draw two conclusions. First, Greek shipbuilders strung their lacing in symmetrical, double helical patterns that, in essence, formed thousands of little “joints” along each seam, in which each hole of a strake is connected directly to three holes in the adjoining strake.<sup>105</sup> The ligatures pass across the seam (both perpendicularly and diagonally) and through each hole multiple times. Turns oriented perpendicularly to the seam serve only to join the strakes and keep the seams from opening. The diagonal turns, on the other hand, work both to connect the strakes (i.e., as joints) and to prevent them from moving longitudinally against one another (i.e., as stiffeners). The ligature load resistance ( $F$ ) of each diagonal turn is distributed in the two directions according to the angle at which it crosses the seam. Since the angle here is 45 degrees, each cross ligature contributes an equal resistance of  $0.71F$  in each direction ( $\sin 45 \times F = \cos 45 \times F = 0.71F$ ). Therefore, the equivalent joining strength ( $F_j$ ) of the lacing at each hole for a single-pass double helical pattern () is:

$$F_j = (4 \times F) + (2 \times 0.71F) = 5.4F$$

and the stiffening strength ( $F_s$ ) at each hole is:

$$F_s = 2 \times 0.71F = 1.4F$$

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<sup>105</sup> Nieto and Santos (2009, 56) estimate, for example, that there may have been as many as 10,000 transverse joints and 20,000 diagonal joints in the ship’s laced joinery.

Accordingly, the lacing at each hole location provides almost four times the resistance perpendicularly across the seam as it does longitudinally along the seam. This not only highlights that lacing is much better suited for joining strakes together than it is for resisting their longitudinal movement, but it also demonstrates clearly the important function that coaks serve as stiffeners in this type of joinery.

### Ligature Pegs

Once a strake was laced to the one below it and the seam considered sufficiently tight, tapered pegs were driven into the lacing holes until they would go no further, and then trimmed flush with the inner surface of the plank. The diameter of the pegs is virtually the same as the diameter of the holes in which they are fitted (0.6–0.7 cm). Seven extant pegs in Pabuç Burnu plank UM1, seated in holes originally under a frame, were whittled from alder (*Alnus* sp.) (fig. 4.14). Another peg survived about 24 cm (or four holes) away, but this one was made from an internodal section of a monocotyledon reed (fig. 4.15). The peg was not trimmed even with the plank face, which suggests that it may have been inserted during maintenance, when some of the lacing was replaced or retightened, perhaps even while at sea. Such reeds are readily available throughout the Aegean and Mediterranean regions. The wooden pegs, on the other hand, are probably original elements. Wooden pegs were used in the Giglio, Cala Sant Vicenç, and Jules-Verne 9 hulls, while reed pegs (*Phragmites communis*) similar to the Pabuç Burnu example were employed in the lacing on the Ma‘agan Mikhael ship.<sup>106</sup>

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<sup>106</sup> Bound 1985, 55, for Giglio; Joncheray 1976, 28, 29 fig. 3, for Bon Porté; Nieto and Santos 2009, 54 fig. 45, 55, for Cala Sant Vicenç; Pomey 1999, 149, for Jules-Verne 9; and Kahanov and Linder 2004, 32–3, 157, for Ma‘agan Mikhael.





Fig. 4.14. A tapered wooden ligature peg extracted from a lacing hole in plank UM1.



Fig. 4.15. The reed ligature peg in situ in plank UM1 (left), and after being extracted (right).

Researchers often ascribe to these pegs the role of plugging lacing holes to make them watertight.<sup>107</sup> While undoubtedly they did accomplish this task, their primary function was to strengthen the laced joinery itself. The pegs locked the ligatures in their holes and allowed the stretched parts of the lacing to be loaded to their breaking point.<sup>108</sup> The two factors affecting the achievable loading tension of the ligatures are friction and the combined angle around which the ligatures are bent.<sup>109</sup> The greater the friction working against the lacing, the higher the loading that can be tolerated before the lacing slips. Maximum friction is generated by driving pegs into holes of the same diameter so that the tremendous pressures created crush the ligatures between the pegs and the surrounding plank wood. Coates estimates conservatively that the locking pegs increase the allowable loading on the lacing 7–12 times.<sup>110</sup> Furthermore, the pegs effectively isolate the ligature sections of each turn, creating in essence three independent “joints” between each pegged hole. This prevents the loosening of any ligatures that are unloaded (due to flexing of the hull, wear, or breakage) from spreading to the loaded parts of the lacing and causing the lacing as a whole to slacken.<sup>111</sup> In this way, the pegs enable symmetrical helical lacing to resist shearing forces between planks, which otherwise it could not.<sup>112</sup>

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<sup>107</sup> See, e.g., Pomey 1997, 195.

<sup>108</sup> Coates 1985, 17.

<sup>109</sup> Coates (1985, 14) gives the formula for loading as  $T_1/T_2 = e^{\mu\theta}$ , where  $T_1$  is the loaded tension and  $T_2$  the normal (unloaded) tension of the ligature,  $\mu$  is the coefficient of friction, and  $\theta$  is the combined angle of bending of the ligature (in radians).

<sup>110</sup> Coates 1985, 16–7.

<sup>111</sup> Coates 1985, 17.

<sup>112</sup> Coates 1985, 17.

### *Framing*

Once the shipwright had completed the planking of his hull, or had at least the bottom portion of it, he fashioned and installed frames, centered over the keel and extending up the sides, to strengthen the planking shell.<sup>113</sup> Evidence for framing was preserved in the Pabuç Burnu remains and in each of the other wrecks, but in some cases little has been reported concerning its details. The available information is presented in tables 4.7A and B, and demonstrates a remarkable consistency in the make, form, and application of the internal structure of these ships. The frames were pre-assembled and inserted on the hull as a single element, and so are best referred to as ‘made-frames’. They were fashioned by attaching a futtock to each end of a floor timber by means of a diagonal or a hook scarf.<sup>114</sup> The latter is simply a diagonal scarf with a short joggle (vertical edge), or hook, in the middle of the scarf table. The hook provided more surface for joinery and helped to lock the two pieces together, which made for a much sturdier frame.<sup>115</sup> It also added lateral rigidity to a frame, making it more capable of resisting the tendency of the sides of the hull to flex inward towards the keel.<sup>116</sup> The

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<sup>113</sup> Frames of the Jules-Verne 7 ship were installed after the first eight strakes went up, and before the first wale (strake 9) was added, as evidenced by carpenter marks on strake 8 that indicate the positions of the frame ends (Pomey 1999, 152). Likewise, Steffy (1994, 49) believes that the Kyrenia floor timbers would have been installed at least once the bottom planking was completed, to avoid having to lift them over the high completed sides of the hull, and in order to support the hull when the heavy wales were added.

<sup>114</sup> On the Bon Porté wreck, two of three preserved frame scarfs are diagonal, while the third is hooked (Joncheray 1976, 27); scarfs of all other wrecks are hooked.

<sup>115</sup> Steffy 1985, 94.

<sup>116</sup> When describing the Bon Porté frames, Joncheray (1976, 26) remarks on the precision and strength of the locked joints, and the meticulous care that the boat’s builders took in fashioning them.

scarfs were secured typically with two wooden treenails driven through each scarf table, on either side of the hook, at opposing angles.<sup>117</sup>

Table 4.7A. Framing Characteristics of Ancient Greek Ships

Shipwreck	Type	Wood Species	Sectional Shape and Features	Floor-Futtock Join	Fastening to Hull
Giglio	made-frames	—	trapezoidal with rounded top	—	—
Pabuç Burnu	made-frames	—	trapezoidal with rounded top	—	ligatures
	top-timbers	—	rectangular	—	ligatures and treenails
Bon Porté	made-frames	conifer	trapezoidal with rounded top	diagonal and hook scarf fixed with 2 treenails	pegged ligatures
Jules-Verne 9	made-frames	<i>Pinus halepensis</i>	trapezoidal with rounded top; base notched over seams	hook scarf fixed with treenails	pegged ligatures
	top-timbers	—	—	—	—
Jules-Verne 7	made-frames	<i>Alnus glutinosa</i> , <i>Pinus halepensis</i>	trapezoidal with rounded top; base notched over seams	hook scarf fixed with treenails	double-clenched iron nails
	top-timbers	—	rectangular	—	ligatures and treenails
Cala Sant Vicenç	made-frames	<i>Pinus pinea</i> / <i>pinaster</i>	trapezoidal with rounded top; base notched over seams	hook scarf fixed with 2 treenails	pegged ligatures
César 1	made-frames	—	trapezoidal with rounded top; base notched over seams	hook scarf fixed with square treenails	iron nails
Grand Ribaud F	made-frames	—	trapezoidal with rounded top; base notched over seams	hook scarf fixed with treenails	double-clenched iron nails
Gela 1	made-frames	<i>Pinus pinea</i>	trapezoidal with rounded top; base notched over seams	hook scarf fixed with 3 treenails	double-clenched copper or iron nails
Gela 2	made-frames	<i>Pinus pinea</i>	trapezoidal with rounded top; limber holes (8–10/frame)	hook scarf fixed with treenail	double-clenched bronze nails
Ma'agan Mikhael	made-frames futtocks/top-timbers	<i>Pinus brutia</i>	trapezoidal with rounded top; limber holes (2–6/frame)	hook scarf fixed with 3–5 square treenails	double-clenched copper nails
Kyrenia	floors/futtocks half-frames	<i>Pinus halepensis</i>	square; limber holes (2–6/frame)	detached	double-clenched copper nails through treenails

<sup>117</sup> Thus, a diagonal scarf would take two treenails, but a hook scarf would take four; two on either side of the hook (see, e.g., Joncheray 1976, 27).

Table 4.7B. Framing Dimensions of Ancient Greek Ships

Shipwreck	Type	Frame Space (cm)	Room & Space (cm)	Sided (cm)		Ratio (Top/Btm)	Molded (cm)
				Top	Btm		
Giglio	frames	—	—	18	—	—	12.3
Pabuç Burnu	frames	68.7	84	15	7.0	2.2	—
	top-timbers	68.7	84	15.3	15.3	1.0	—
Bon Porté	frames	81–83	93	10–12	2–3	4–5	11–14
Jules-Verne 9	frames	87	96	9.5	3	5.2	11.2
Jules-Verne 7	frames	—	98	—	—	—	—
	top-timbers	—	98	4–5	4–5	1.0	8
Cala Sant Vicenç	floor timbers	—	(95)	16–22	1.5–3.5	8–11	24–31
	futtock	—	(95)	25.5	—	5	—
Grand Ribaud F	frames	82	101–102	19–20	5	4	26
Gela 1	frames	84	93	(8–9)	(3.5–4)	2.6	10–14
Gela 2	frames	60–70	90	(20)	(9)	(2.2)	(30–35)
Ma'agan Mikhael	frames	61	75	14.2	6.2	2.3	23.0
	futtocks/top-timbers	61	75	12.6	5.8	2.2	10.8
Kyrenia	floors	16	25	9	9	1.0	9

Note: Values in parentheses are estimated from drawings.

The assembled frame was inserted on the hull and lashed to the underlying planking with ligatures run through sets of paired holes drilled through the planks along either side of the frame's base. Just as with lacing in the stakes, frame lashings were secured with wooden pegs driven into each of the holes.<sup>118</sup> The frame's distinct morphology, purpose suited for laced construction, facilitated this lashing. It had a wide, rounded top, inward slanted for-and-aft faces, and a narrow base.<sup>119</sup> This form presented

<sup>118</sup> In the Cala Sant Vicenç hull, these pegs were made from alder (Nieto and Santos 2009, 36), as were the ligature pegs of Pabuç Burnu (see p. 136 above).

<sup>119</sup> The sectional shape of these frames is typically described as trapezoidal, but perhaps would be better depicted as hexagonal, with elongated lower sides and the three upper sides rounded to form a semi-circle.

an ideal smooth surface without corners that could damage the lashing, and around which the builder could cinch the ligatures down tightly when securing the frame to the hull. Furthermore, the bottom of the frame was notched everywhere it passed over a planking seam (including between the keel and garboards) so that they would not sit directly on the seam joints and damage the lacing, wadding, or pegs.<sup>120</sup>

No frames from the Pabuç Burnu hull survive, but rows of lashing holes running transversely across planks UM1 (fig. 4.16.2) and UM5 (see fig. 4.12 above) mark the location of five frames. There are two sets of holes on plank UM5 separated by about 2 cm, with the holes of each pair spaced about 4 cm apart between centers. Ideally, the holes would have been drilled at converging angles of approximately 55 degrees and would have intersected at the outer surface of the plank. Instead, their angles vary from 53 to 79 degrees and so do not meet up precisely. Where this occurs, a small groove or channel was cut out between the exit holes to allow the ligatures to pass from one hole to the other without protruding beyond the plank surface, where they would be vulnerable to damage and breakage (fig. 4.17). The minimum space between the inner edges of the holes of each row represents a maximum sided dimension of 7.0 cm for the base of the frame at this station. Since the fragments of UM5 did not preserve a second frame location, frame spacing cannot be measured directly. However, based on the preserved

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Where a mast step or keelson sat over a frame, it retained its hexagonal shape (i.e., it was not rounded off at the top) in order to fit matching notches on the underside of the longitudinal timber (see, e.g., Joncheray 1976, 27).

<sup>120</sup> Contrary to Nieto and Santos (2009, 30), the notched bottom was not to facilitate repair of the seam lacing without having to remove the frames, but to keep the frames from damaging the lacing. The wooden ligature pegs preserved under a frame on Pabuç Burnu plank UM1, probably from the ship's original construction, in contrast to an unobstructed reed peg preserved nearby and likely inserted during some later repair or maintenance work, may suggest that, in at least some cases, the lacing underneath the frames was in fact not removed and replaced.



Fig. 4.16. Frame station on plank UM1, inboard face. (1) Tetrahedral notches and ligature holes with in situ wooden pegs. (2) Paired oblique frame lashing holes. (3) Treenail holes. (4) Preserved original surface and adze marks. (5) Remains of pine tar surface coating.



Fig. 4.17. Frame lashing holes on the outboard face of plank UM5. The lower holes of the two bottom sets are missing, but the grooves connecting them to their partner holes are mostly intact.

lengths of the fragments and the void distance between them, it must be either between 38 and 85 cm, or greater than 154 cm.

Plank UM1 preserves parts of three frame stations along its length. The sets of lashing holes are separated laterally almost 3 cm, and the holes of each pair are spaced 4 cm between centers. As indicated by the minimum distances between the lines of lashing holes of the two preserved pairs, the frames were sided 15.3 cm at their base.



Room-and-space between frames measures approximately 86 and 82 cm, for an average frame spacing of 84 cm. As on UM5, paired lashing holes are drilled at widely varying angles ranging from 17 to 46 degrees and, consequently, do not exit together on the outboard face of the plank. None of the lashing holes on either plank were made with tetrahedral notches, pointedly demonstrating by the imprecision of the drillings the role of the notches in orienting ligature holes. As far as is determinable, only lashing holes on the Cala Sant Vicenç wreck, and some of the top-timber lashing holes on the Jules-Verne 7 wreck, were drilled through tetrahedral notches.<sup>121</sup>

In addition to ligatures, each frame that crossed plank UM1 was fastened to it with two treenails. The treenail holes are roughly centered between the rows of lashing holes, one towards each edge of the plank, and measure 1.2 cm in diameter (see fig. 4.16.3).

Comparison of the frame dimensions evidenced in these two planks with those from the other laced vessels, as well as the means of attaching them to the hull, reveals their most likely interpretation. The frame base dimension from UM5 is comparable to the those from the other ships (2–9 cm), and is the largest of any fully laced vessel. On the other hand, the frame base dimension from UM1 is much too large to be the width of a typical lashed frame with trapezoidal section.<sup>122</sup> It is, however, comparable to the top dimensions of the frames from the other ships, which are sided 9–22 cm. Furthermore, all made-frames from fully laced vessels were attached to the hull with ligatures only.

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<sup>121</sup> Nieto and Santos 2009, 27 fig. 22; Kahanov and Linder 2004, 55.

<sup>122</sup> Applying the ratios of top to bottom frame widths for trapezoidal frames from the other laced wrecks to this dimension yields possible top sided dimensions for the Pabuç Burnu frames of 40–153 cm—obviously impossible.

This may reflect the need to disassemble the hull, at least partially, on some regular basis for maintaining and retightening the lacing joints, but perhaps also to allow for some flexibility of the hull.<sup>123</sup> Lashed frames would be able to give slightly to accommodate some flexing in a hull, especially around the turn of the bilge, and help reduce deformation of the planking joints.<sup>124</sup> The only instance of both ligature and treenail fastenings being used to secure frames is found in the Jules-Verne 7 hull, where top-timbers with rectangular sections were lashed to the sides of the hull at their lower ends, but treenailed along the rest of their length.<sup>125</sup> This suggests that the UM1 frames were, in fact, top-timbers with rectangular sections. Ligatures are not particularly well suited for holding timbers to the vertical sides of a hull, and would have to be kept extremely tight in order to create the required amount of friction between ligatures, timber, and strakes to prevent the top-timbers from sliding down towards the keel. Treenails were used to prevent this lateral movement.

Of course, it could be that these were simply trapezoidal frames whose lashing holes were not drilled up against their bottom sides, but rather some distance away located more directly beneath the outer widths of the top of the frames. This seems to be the case on the Cala Sant Vicenç hull, where impressions of the narrow frame bases are preserved by pitch on the inboard surface of the planking, and are clearly visible running

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<sup>123</sup> See, e.g., Hornell 1941, 62; Hornell 1970, 236; Hourani 1995, 94; or Varadarajan 1998 for accounts of maintaining and replacing ligatures on similar types of boats.

<sup>124</sup> Coates 1985, 11.

<sup>125</sup> Pomey 1999, 152. According to Kahanov and Linder (2004, 55), special treenails with a large head were driven through the planking and top-timber from outside the hull and locked with a small, transverse pin (similar to a forelock bolt).

across the strakes between the wider set rows of lashing holes.<sup>126</sup> This would result in a considerable gap between the frame and ligatures and leave the latter rather exposed and vulnerable. Such treatment certainly does not seem to be in keeping with the care and effort taken in other areas of construction to protect ligatures from damage. However, this is an exceptional situation, since the floors of the Cala Sant Vicenç frames are reused timbers made originally for a different vessel. Since there is only one set of lashing holes for each frame, the shipwright must have re-used the original lashing holes to fasten the new floors, rather than drilling all new holes and perforating his planks even more. In any case, evidence shows that the frames of Pabuç Burnu were not lashed in this manner. The pine tar on the interior surface of these planks always stops at the inner edges of the lashing holes, indicating that the foot of the frames did indeed butt up close to the holes (see figs. 4.12 and 4.16.5 above).

Plotting frame dimensions and spacing reveals some interesting chronological trends in these construction features (fig. 4.18). Sided frame dimensions show a definite development towards more rectangular dimensions, as the widths of the upper surface of the frames decrease from 20 to 9 cm and the lower face widths increase from 2 to 9 cm. Actually, the trend can hardly be said to be linear. The dimensions from laced ships are rather scattered, and seem more dependent upon hull dimensions, as one would expect. The larger ships tend to have frames sided 15–20 cm, while the frames of smaller vessels are 10–15 cm wide. Similarly, the bottom widths of the frames range from 5–9 cm and 2–5 cm for larger and smaller vessels, respectively. A more revealing indicator is the

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<sup>126</sup> Nieto and Santos 2009, 27 fig. 22. Whereas the frames are sided less than 4 cm along their base, the distance between the rows of lashing holes for each frame range from 15 to 25 cm, typically just slightly less than the sided dimension of the top of the frames.

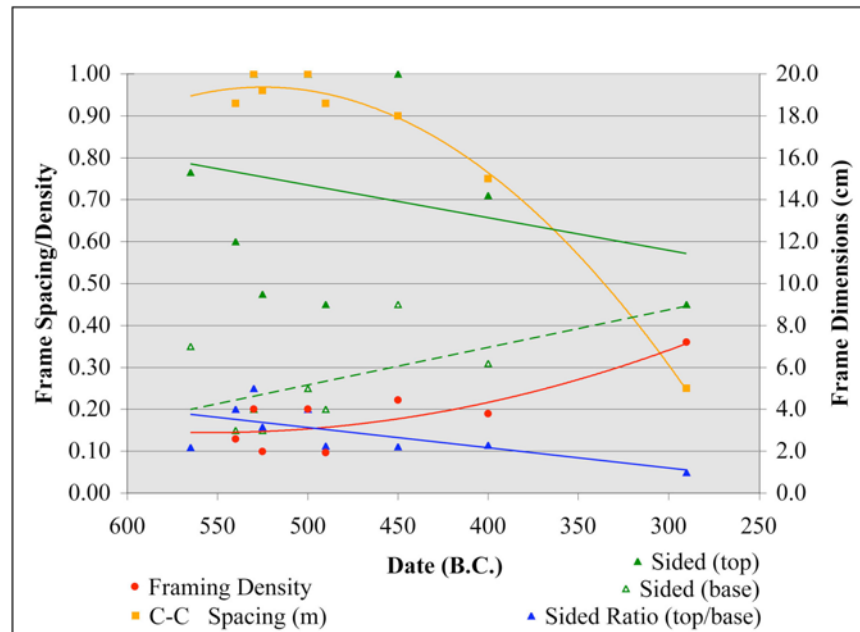


Fig. 4.18. Framing trends on ancient Greek ships.

relative proportion of the frame dimensions. A plot of the ratio of top width to base width for these frames shows much better correlation and steady decline from a factor of 9.0 (for Cala Sant Vicenç) to 1.0 (for Kyrenia). Assuming that the sided dimension of the top-timbers from Pabuç Burnu is an indication of the upper width of the made-frames, then frames from the ship would be 15 cm sided at the top and 7 cm at the bottom, for a ratio of 2.2, which is perfectly in line with the Gela and Ma‘agan Mikhael ships. This would at least seem to confirm the reasonableness of the estimation.

Another telling characteristic is framing density, which is simply the average width of the frames (room) divided by their average spacing (room-and-space). The clear trend shows the development of an increasingly robust inner support structure in these ships. Frame density for laced hulls is about 0.14, with a range of 0.10–0.20. For early

mortise-and-tenon joined vessels that retain some lacing, frame density ranges from 0.19 to 0.22 and averages 0.20. And finally, the frame density in the Kyrenia hull averages about 0.36. The robustness, if you will, of internal framing on Greek ships increases by 40% over the first 50–75 years after the introduction of pegged mortise-and-tenon joinery, but thereafter framing gains in importance more rapidly. The Kyrenia framing is 2.5 times denser than that of typical laced vessels.

### *Surface Treatment*

The last step for the shipwright to ready his hull for service was to apply a thick layer of waterproofing material over the interior of the hull. Remnants of a coating of pine tar are preserved in dark brown splotches up to 4 mm thick scattered across the inner surfaces of the Pabuç Burnu fragments.<sup>127</sup> The complete absence of tar between the frame lashing holes and along the edges of the planks confirms that the coating was applied only after hull construction was completed.

It was common practice in antiquity to waterproof ships' hulls by paying them with pine tar or mixtures of tar, wax, and resin. Pliny (*NH* 35.149) notes the effectiveness of these materials as coatings for ships, since they are imperious to sun, wind, and seawater.<sup>128</sup> Evidence shows that the interiors of the Giglio, Bon Porté, Place Jules-Verne 9, Cala Sant Vicenç, and Gela 1 hulls were all treated in this way.<sup>129</sup> A coating of tar mixed with esparto wax was applied to both inner and outer surfaces of the

<sup>127</sup> The material originates from *Pinus* sp. (see p. 27, n. 9).

<sup>128</sup> Casson 1995, 212 n. 47, see 211–2 for additional references by ancient authors to pine tar, wax, and other painted coatings for ships' hulls.

<sup>129</sup> Bound 1991b, 31; Joncheray 1975, 31; Pomey 1999, 149; Nieto and Santos 2009, 30, and identified by Glastrup (2009, 397–8) as originating from pine; Panvini 2001, 23.

Ma'agan Mikhael hull, but tar was found only on the exterior of the Kyrenia ship.<sup>130</sup>

The purpose of this practice has been assigned variously to waterproofing, sealing, and caulking.<sup>131</sup> With regards to laced ships, the main function of the tar was to protect the interior of the hull—especially the joinery (ligatures, wadding, and pegs)—from seawater, condensation, and the elements, which could cause them to rot and jeopardize the seam integrity of the hull. This is evident from the fact that only the insides of the hulls were coated, which is where the seam joinery is exposed and most vulnerable. Furthermore, the planking seams themselves were not coated, but only the wadding and ligatures tied over them. This practice was the norm in all laced boats throughout the sixth and fifth centuries B.C. The Ma'agan Mikhael wreck provides the earliest example of a hull with its outer surface payed, but its primary fastenings were pegged mortise-and-tenon joints, which are not exposed. There was still lacing on the ship—at the extremities—and the interior of the hull was still tarred. However, lacing is non-existent in the Kyrenia ship, and, perhaps consequently, the interior of the hull is no longer tarred.<sup>132</sup> It would appear that the Kyrenia shipwright was using tar more as caulking for filling small cracks or holes in the planking, or for stopping seams that opened slightly.

Coates supposes that tree or vegetable resin (i.e., pitch or tar) might have been applied to planking seams of ancient boats as a means of increasing the friction between

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<sup>130</sup> For Ma'agan Mikhael, see Kahanov 2003, 54; Glastrup and Padfield 2004. Originally, the exterior of the Kyrenia ship's hull was payed simply with pine tar, but later overhauls and maintenance included the application of additional caulking material, woven plant matter impregnated with tar, applied first at the bow under wood sheathing, and then over the entire hull under lead sheathing (Steffy 1985, 84, 87, 97–8).

<sup>131</sup> See, e.g., Pomey 1997, 195; Panvini 2001, 23; and Bound 1991b, 31, respectively.

<sup>132</sup> A dark, amber colored substance was found in certain areas on the inside of the hull, typically under some of the frames and fillers in the bow area. The material looks similar to the resinous coating applied to the exterior of the hull, but has not been identified (Swiny, personal communication).

the strakes to help keep them from sliding against one another as the hull bends. He admits immediately that there is no study to substantiate this suggestion, but that such investigation is sorely needed in light of the widespread practice of tarring laced hulls.<sup>133</sup> Not only is there no archaeological evidence that such a practice was followed in Greek laced construction, certainty that it was not is predicated on the fact that the planks were tarred only after the seams were securely fastened and covered by wadding pressed down over them by the lacing. Following Coates, Kahanov suggests that pitch was applied to lacing in the Ma‘agan Mikhael ship at least partially to increase friction on the ligatures and, thus, the effective strength of the lacing.<sup>134</sup> While it may well have accomplished this, the primary reason for its use remained to protect the wood and lacing material.

### *Other Features*

Two other features on planks UM1 and UM3 seem related to the upper works of the ship. First is the pair of rectangular holes at the left, scarfed end of UM1, and the corresponding groove (30.5 cm long x 2.4 cm wide) gouged along the inboard face of the plank.<sup>135</sup> The purpose of this feature is not clear, but the rounded surface of the groove between the two holes, whether purposefully made or resulting from wear, suggests that the holes were used to tether something to the exterior of the ship. Perhaps they were used in some way with the ship’s rigging, which would put the plank close to

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<sup>133</sup> Coates 1985, 15–6.

<sup>134</sup> Kahanov and Linder 2004, 32.

<sup>135</sup> See pp. 37–8, fig. 2.8.

the shear of the hull. It does seem a bit odd, however, that they should be located by the long planking scarf that is not edge joined, and thus is a clear weak point in the strake.

The second feature is the trapezoidal opening situated towards the right end on plank UM3 (fig. 4.19).<sup>136</sup> Again, the true nature of the hole is uncertain, but it most likely accommodated a small through-beam that supported a partial deck at the bow, or that served perhaps as a cathead to tie off the anchor or for mooring the ship.<sup>137</sup> What is unusual is that the opening is situated completely within the width of the plank, rather than along its edge. The latter application is more typically and allows for easier installation and repair. A plank can be notched to take the full molded height of the beam (in which case, the top of the beam would be flush with the plank seam), or both adjoining planks can be notched out such that the beam is centered within the seam.<sup>138</sup> Beams are usually supported on the hull by a more substantial timber than just the planking, such as a frame (top-timber) or wale, or within the hull by a stanchion.<sup>139</sup>

Part of a small stanchion survived in the Jules-Verne 9 wreck and was found still seated in the top of the only preserved frame, centered over the keel. Researchers believe it to have supported a transverse beam that served as one of several rowing

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<sup>136</sup> See p. 47.

<sup>137</sup> Through-beams are depicted at the bow of an early-sixth-century B.C. terracotta boat model from Cyprus (there are two, one sitting over the upper wale, and another fitted along the sheer); a boat depicted on a Roman tombstone from the late second or early third century A.D. (with a second one at the stern for mounting the quarter rudders), and a sprit-rigged vessel from a third-century A.D. Roman sarcophagus (which, in this case, probably served as a mast partner beam) (Casson 1995, 94, 156, 179).

<sup>138</sup> See, e.g., Mazarrón 2 (Negueruela 2004, 241, 271 fig. 19, 272 figs. 21–2); Mainz 3 (Mees and Pferdehirt 2002, 186 fig. 4, 189 fig. 17); County Hall vessel (Marsden 1974, figs. 4, 6); and Port Berteau 2 (Pomey and Rieth 2005, 115).

<sup>139</sup> The through-beam in the Mainz 3 vessel fits into a notch on the forward face of a frame (Mees and Pferdehirt 2002, 186 fig. 4), while through-beams of the Yassi Ada Byzantine ship are supported between two large wales (Bass and van Doorninck 1982, 69 figs. 4–5, 4–8, Construction Plan, facing 74).



benches centrally located in the boat.<sup>140</sup> Similar beams are reconstructed at either end of the boat to support small “cover-decks.”<sup>141</sup> The Jules-Verne 7 and Ma‘agan Mikhael remains include futtocks that are notched at their upper end to hold transverse beams.<sup>142</sup> The reconstructions of the Jules-Verne 9 and 7 vessels each include a single through-beam, located at the stern and passing over the upper wale, used to support the quarter rudders.<sup>143</sup>



Fig. 4.19. Trapezoidal opening in plank UM3.

<sup>140</sup> Pomey 2001, 426.

<sup>141</sup> Pomey 2002, 121; Pomey 2003, 63, 64 fig. 11.10.

<sup>142</sup> Pomey 1999, 150–1; Pomey 2003, 62 fig. 11.8; Kahanov 2003, 105–6; Votruba 2004, 219 fig. 7b, 220 fig. 8.

<sup>143</sup> Pomey 2003, 64 fig. 11.10, 61 fig. 11.6, respectively.

CHAPTER V  
EVOLUTION IN GREEK SHIPBUILDING: LACING TO  
MORTISE-AND-TENON JOINERY

Two shipwrecks at Marseilles (Jules-Verne 7 and César 1) and those at Grand Ribaud, Gela (wreck 2), and Ma'agan Mikhael attest to a major shift in Greek shipbuilding in which pegged mortise-and-tenon joints and metal nails replaced pegged ligatures as the principal types of joinery in the hull. Furthermore, the proveniences and dates of these wrecks established by their associated archaeological materials set them in a common social and technological context, in this case a Greek (and very likely Ionian) one of the late Archaic period. The Marseilles wrecks are particularly serendipitous in this regard. These three wrecks were all likely built at Massalia in the second half of the sixth century B.C. and abandoned sometime in the first part of the last quarter-century. They present examples of three boats built and sailed contemporaneously, but one being traditionally lace-built while the other two were constructed with mortise-and-tenon joinery. The César 1 and Jules-Verne 9 vessels were similar in size, probably small fishing boats, whereas the Jules-Verne 7 ship was a modest-sized merchant vessel capable of seagoing voyages. Thus, they provide with close proximity the date that the new joinery was adopted into Greek shipbuilding and indicate that the change was incorporated into hulls of various types, and not exclusively into only those of larger vessels.<sup>1</sup> A similar scenario is presented at Gela, where two ships of comparable size

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<sup>1</sup> Pomey 1997, 198.

and carrying similar cargoes, but in this instance separated in time by several decades, were built using the two different types of joining methods. The change seems to have been comprehensive: no Greek shipwreck earlier than the Jules-Verne 7 wreck (525–510 B.C.) has provided evidence for pegged mortise-and-tenon joinery, and none later than wreck 1 at Gela (500–480 B.C.) has yielded full laced construction, despite there being several wrecks whose dates overlap both ends of this range.

The rudimentary application of mortise-and-tenon construction in these hulls is witnessed in faulty seam joints, cracked planking, and the inability to employ the new joints in making repairs or to close the extremities of the ships. This verifies the newness of pegged mortise-and-tenon use in Greek shipbuilding and the novice proficiency of its Greek practitioners. Furthermore, the retention of made-frames and their particular laced morphology, the reversion to traditional laced-construction techniques of edge dowels, tetrahedral notches, seam wadding, and pegged ligatures in problematic areas of the hull, and the perfect similitude of their application to those features in fully laced hulls, confirms that these practitioners were working within one common tradition.

The repercussions of the change in joinery are well known and demonstrated in the Kyrenia ship. The main questions, then, with regards to ancient Greek shipbuilding, are how and why did this change occur. The following discussion will focus in particular on the archaeological evidence from shipwrecks detailed in the previous chapter, and what it reveals about how Greek shipbuilding evolved from a laced tradition

of the Archaic period (and probably much earlier) to one using mortise-and-tenon construction before the Hellenistic age.

*Tenon Usage in Ancient Mediterranean Shipbuilding*

The construction method revealed in the Jules-Verne 7, Grand Ribaud F, Gela 2, and Ma'agan Mikhael ships, which are mortise-and-tenon constructed yet retain some elements of laced joinery, is commonly referred to as “transitional” construction.<sup>2</sup> While the term is applicable in some regards, its use typically is prefaced on Greek shipbuilders transitioning from their construction method using pegged ligatures to a new one employing pegged mortise-and-tenon joints, which presumably they adopted from outside of their tradition. This assumption is based largely on the presence of much earlier use of tenons in Mediterranean shipbuilding.<sup>3</sup> Indeed, tenons were employed in Egyptian shipwrihty since at least the Old Kingdom, where they were used as coaks in the lashed construction of Khufu’s aforementioned funerary boat,<sup>4</sup> in disassembled boat timbers found in the construction ramp of Senusret I’s pyramid at Lisht (ca. 1950 B.C.),<sup>5</sup> and in six 10-m long funerary boats buried alongside the pyramid of Senusret III at Dashur (ca. 1850 B.C.).<sup>6</sup> Egyptian carpenters certainly were familiar with pegged

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<sup>2</sup> Following Pomey (1995, 478).

<sup>3</sup> Pomey 1995, 479.

<sup>4</sup> Lipke 1984, 74–5 fig. 48, 105–6 fig. 65. See Mark (2009, 134–7) for new insights on the design of the mortises and tenons in this boat.

<sup>5</sup> Haldane 1988, 143–5.

<sup>6</sup> Haldane 1996, 239–40.

mortise-and-tenon joinery, as evidenced in Third-Dynasty woodwork (ca. 2700–2600 B.C.), but it is not attested in Egyptian boatbuilding until around 500 B.C.<sup>7</sup>

The earliest archaeological evidence for pegged mortise-and-tenon joinery in Mediterranean shipbuilding comes from the sparse hull remains of a Syro-Canaanite ship from the Late Bronze Age (ca. 1320±50 B.C.) excavated at Uluburun, Turkey.<sup>8</sup> This vessel was originally about 15 m long and had an inward projecting rudimentary keel that was wider (sided 28 cm) than it was high (molded 22 cm). There was no evidence for framing, nor was there any indication for the use of ligatures in this vessel.<sup>9</sup> Rather, the hull was made from thick cedar planks (6 cm) that were edged joined with large oak tenons (30 cm long, 6.2 cm wide, 1.6 cm thick) locked in their mortises with proportionally large oak pegs (2.2 cm diameter).<sup>10</sup> Deep mortises extended almost the entire width of the planks, and were cut immediately adjacent to the two mortises extending from the opposite sides of the adjacent planks. In this way they formed continuous lateral runs of alternating paired tenons within the hull planking. The size and positioning of the joints suggest that they were intentionally designed to act as internal framing and compensate at least partially for a deficiency of proper frames.<sup>11</sup> Additional early evidence comes from another Syro-Canaanite or Cypriot ship that wrecked at Cape Gelidonya, Turkey, sometime around 1200 B.C.<sup>12</sup>

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<sup>7</sup> Lucas and Harris 1962, 451; Haldane 1996, 242.

<sup>8</sup> Pulak 1999, 2002; Manning et al. (forthcoming), for the date of the wreck.

<sup>9</sup> Preservation of this hull was extremely poor, and nothing of its extremities was found.

<sup>10</sup> Pulak 1999, 219; tenon dimensions from 232 table 1.

<sup>11</sup> Pulak 1999, 219–20.

<sup>12</sup> Bass 1967, 50–1; Pulak 1999, 214.

The only other shipwrecks with pegged mortise-and-tenon joinery that date earlier than the sixth century are two small vessels abandoned or wrecked near Mazarrón, Spain in the late seventh century B.C.<sup>13</sup> The first wreck preserves a 5.5 x 1.3-m section of hull. It has a cedar keel that is reminiscent of the keel of the Uluburun ship, in that it is larger sided (17 cm) than molded (10 cm).<sup>14</sup> The larger and better preserved second wreck is 8.5 m long with a beam of 2.2 m and sheer height of only 90 cm.<sup>15</sup> The hull strakes of both vessels are edge joined with pegged mortise-and-tenon joints.<sup>16</sup> Curiously, though, the inner edges of the strakes of Mazarrón 1 are reportedly beveled to receive caulking, which is held in place by a ligature laced around it along the planking seams in a simple diagonal (\\) pattern.<sup>17</sup> Furthermore, they have tiny “frames” with circular sections only 4 cm in diameter widely spaced along the bottom of the hull and held in place with ligatures lashing them to the planking.<sup>18</sup> The lashing points are located always over a planking seam, such that the ligature crosses back and forth over the top of the frames in an X pattern, and across the seam through mated holes in the adjoining strakes on either side of the frame. The wrecks were discovered in a western Phoenician context, but as yet their provenience and hull construction details have not been well established. Furthermore, the size and low freeboard of these hulls would seem to preclude them from being seagoing vessels.

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<sup>13</sup> Negueruela et al. 1995, 195–6.

<sup>14</sup> Negueruela 2004, 237; Azipurua and Méndez 1996, 219; Gómez-Gil and Sierra 1996, 219.

<sup>15</sup> Negueruela 2004, 235.

<sup>16</sup> Negueruela 2004, 247.

<sup>17</sup> Negueruela et al. 2000, 1673. This method of caulking the seams resembles Mark's (2009, 151) new interpretation of possible edge beveling and seam caulking on the Khufu boat.

<sup>18</sup> Negueruela et al. 2004, 467 fig. 13, 478.

### *Technology Transfer*

Based on this evidence, however, many scholars assume that Greek shipbuilders acquired their new joinery from the Phoenicians; that is to say, pegged mortise-and-tenon technology was transferred from Phoenician shipbuilding into the Greek tradition.<sup>19</sup> Indeed, Roman writers later attributed the joint to Phoenician origins by calling it *coagmenta punicana*.<sup>20</sup> It would seem quite remarkable though for Greek shipwrights to so abruptly abandon their laced technique and simply adopt an entirely new type of joinery, given the conservative nature of these craftsmen.<sup>21</sup> Some type of Phoenician influence does seem unavoidable though, given their long use of the joinery in building ships and the long history of Greek-Phoenician contact.

Phoenicians were conducting regular commercial exchange in the Aegean, at least on a small scale, in the early Iron Age. Evidence for this is scant and comes from grave goods datable to the late 10th century and mostly middle ninth century B.C. These include a Cypriot Bichrome II flask, the oldest Iron Age vessel from Cyprus in the Aegean; gold finger rings, mostly of Cypriot type, and a likely Phoenician-made pendant from Palaia Perivolia; a Syro-Phoenician bronze bowl from Kerameikos; a necklace with a Phoenician bead of variegated glass and more than a thousand faience discs from Areopagus; and disc beads, necklace of faience figurines, and three Levantine seals from

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<sup>19</sup> Bass 2006, 14; Kahanov and Pomey 2004, 24–5; Mark 2005, 35, 67–8; Pomey 1997, 201; Wachsmann 1998, 241. Others (e.g., Bound 1985, 62) have gone so far as to connect in direct lineage the Syro-Palestinian shipbuilding tradition of the Uluburun ship to the Greek method used to build the Kyrenia ship, based solely on the common usage of locked mortise-and-tenon joints in their hulls.

<sup>20</sup> Sleeswyk 1980.

<sup>21</sup> White (1984, 21, 27) lists cultural and social acceptability as one of the key factors for successful technological innovation, and remarks on the potency of conservative forces often opposed to such change; see Mark (2005, 16, 60–2) for a good discussion of the conservatism of seamen and shipwrights.

Lefkandi.<sup>22</sup> The flask coincides with the revival of the Aegean bronze industry, suggesting (along with mold fragments with an impressed design similar to widely-exported Cypriot rod tripods) that the Greeks imported technological know-how as well as copper raw material from Cyprus.<sup>23</sup>

But it is not until after the Greeks established trading posts of their own on the Levantine coast that Greece begins to accept Eastern products and influences on a significant scale.<sup>24</sup> Al Mina, in North Syria (present-day Turkey), was the first and most important Greek trading post in the Eastern Mediterranean. It was established in the eighth century B.C. and, from the following century on, East Greeks (Rhodians, Samians, Miletians, and Chians) played a leading role in its affairs.<sup>25</sup> Greek finds testify to the penetration of Greek trade southward along the Syrian and Phoenician coasts, and Ezekiel (27, 13) boasts of “Ionians” (*Jawan*) trading in Tyre.<sup>26</sup> The earliest Greek colony in the west was Pithecoussai, on the island of Ischia off the Calabrian coast, founded by Euboeans in 760 B.C.<sup>27</sup> Archaeological finds dated to the late eighth century B.C. indicate the possible presence of Semitic craftsmen or traders in the colony,<sup>28</sup> and demonstrate direct contacts between Pithecoussai and Phoenician settlements in the central Mediterranean, in the form of trans-shipped Greek imports as well as production

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<sup>22</sup> See Coldstream (1982, 264–5) for a good summary of the evidence and for additional bibliography.

<sup>23</sup> Coldstream 1982, 265.

<sup>24</sup> Boardman 1999, 38; Coldstream 1982, 264.

<sup>25</sup> Boardman 1999, 49.

<sup>26</sup> Boardman 1999, 50–2. See Aubet (1993, 120–6) for literary inconsistencies in the text and possible ramifications concerning the date of these events.

<sup>27</sup> Its founding is contemporaneous with the earliest archaeological evidence from Phoenician colonies in the central and western Mediterranean (Aubet 1993, 243).

<sup>28</sup> Ridgway 2004, 39–40; Cabrera 1994, 25; Docter and Niemeyer 1994.



from the colony's own workshops, and with Phoenician Spain as well.<sup>29</sup> Aubet and Ridgway see in this evidence a natural extension westward of the cooperative trading activities established earlier between Phoenicians and Greeks in the east, based on “common interests and enterprises,” at least from 760–700 B.C.<sup>30</sup>

Greeks were greatly stimulated by cultures with which they came in contact and traded, and orientalizing influences can be found in all facets of East Greek life at this time.<sup>31</sup> Coinciding with their settling in North Syria, the Greeks learned the Phoenician alphabet and adapted it to fit their own tongue and particular needs.<sup>32</sup> Similarly, the Greeks were quick to adopt the use of money, a Lydian invention in the second half of the seventh century B.C., and by the sixth century, many Greek cities were striking their own coins.<sup>33</sup> But the transfer of shipbuilding technologies would require “more intimate cultural contacts and exchanges” than mere trading relations.<sup>34</sup> These would need to occur at the level of skilled craftsmen. Technological advances can be found in a number of manufacturing crafts, likely as a result of an influx of immigrant craftsmen, such as with metalworking in Crete in the late ninth century B.C., ivory working in the

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<sup>29</sup> Aubet 1993, 244; Phoenicians frequented the sanctuary of Hera at Samos (de Polignac 1992, 122–3), and ivory comb offerings there may suggest links with Phoenician Iberia from at least 640–630 B.C. (Neville 2007, 160–1; Freyer-Schauenburg 1966).

<sup>30</sup> Aubet 1993, 314–5; Ridgway 2004, 35–6. Olmos (1989, 507) also sees a systematic process of trade and contact between Greeks and Phoenicians, and credits it with Phocaeen activity in the west. Not all scholars share this view, however; c.f. Burkert (1992, 21), who finds Phoenician and Greek expansions in the Mediterranean as competitive ventures.

<sup>31</sup> Akurgal 1962, 374.

<sup>32</sup> Akurgal 1962, 371; Huxley 1966, 41; Jeffery and Johnston 1990, 19–21; Powell 1996; Boardman 1999, 83–4. See Johnston 1983; Powell 1996; Ridgway 2004, 41–3 for various opinions on where this exchange took place. Young (1963, 362–4) suggests a possible Phrygian role in transmitting the alphabet to the Greeks and in creating vowels.

<sup>33</sup> *Hdt.* 1, 94; Cook 1962, 94.

<sup>34</sup> Burkert 1992, 21.

third quarter of the eighth century, and pot-making in the first half of the seventh century.<sup>35</sup>

Of course, foreign influence did not mean simply adoption and imitation, but more often it stimulated original innovation. The previously mentioned Greek ivory workers may have benefited from Semitic tutoring and adopted eastern techniques, but they produced pieces with artistic innovations all their own.<sup>36</sup> Another good example is the development of large-scale stone sculpture and architecture in East Greece during this period. While undoubtedly prompted by the monumental works of Egypt, Ionian accomplishments—whether iconic Archaic Greek statuary or Ionic order architecture—were completely original.<sup>37</sup> Cook suggests that early Ionic architects were more concerned with finding satisfactory solutions to particular problems that confronted them at any point in time than with establishing fixed conventions.<sup>38</sup> This surely must be equally attributable to East Greek shipwrights, who by necessity were conservative and practical-minded. Thus, they were not intent on creating a new shipbuilding tradition by incorporating tenons into their construction, but were attempting to address a problem or need with which they were confronted. They were probably not even aware that the changes they were making would, in fact, lead to an entirely new way of building ships. Steps taken to solve one problem would have, more often than not, unforeseen consequences that presented both challenges as well as opportunities for development. Over time, and with the passing of one generation of shipwrights to the next, the Greek

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<sup>35</sup> Ridgway 2004, 35; Boardman 1999, 56, 60, 62–3.

<sup>36</sup> Boardman 1999, 62–3.

<sup>37</sup> Cook 1962, 79–80; Akurgal 1962, 376–7; Boardman 1999, 143.

<sup>38</sup> Cook 1962, 82.

shipbuilding tradition morphed from one of dowel coaks and pegged ligatures to another of pegged tenons and metal nails—entirely new, yet traceably linked through virtually all its features to the former.

However, it is difficult to trace a specific Phoenician role in the development of Greek shipbuilding, and to quantify, if any, the nature of Phoenician-Greek interactions in the shipyard or on the seas.<sup>39</sup> In this regard it is interesting to note that while the Greeks provide clear credit for their written alphabet by calling their letters “Phoenician” and designating scribes in late Archaic Crete as *p(h)oinikastas*,<sup>40</sup> unlike the Romans, they recognize no such external source for the mortise-and-tenon joinery in their ships. The real issue is to what extent did Phoenician practices influence Greek shipbuilding and how was that influence manifested: as a direct transfer of new technology or as a stimulus for independent development and innovation? Examples of both mechanisms can be found in other areas of Greek society, but the latter is perhaps more typical. Close examination of the construction features of laced Greek ships and of those mortise-and-tenon constructed reveals a gradual and natural development of the latter from the former that belies any indication of a wholesale exchange of construction methodology.

### Hull Planking

All the vessels are of shell-based construction with relatively thin pine planking of thicknesses ranging from 2.5–4.5 cm and likely determined by proportionality to hull

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<sup>39</sup> Boardman (1999, 37–53) and Markoe (2000, 172–4) find this true in general for early and broader Phoenician-Greek interactions. Sennacherib employed ‘Ionian’ and Phoenician sailors at Nineveh in the early seventh century B.C. (Boardman 1999, 46; Luckenbill 1924, 73).

<sup>40</sup> *Hdt.* 5, 88.

size. Hull strakes consisted of two or three planks typically joined by diagonal or three-planed scarfs, although curved scarfs were used as well in the Pabuç Burnu, Cala Sant Vicenç, and Ma'agan Mikhael wrecks. Straight scarf tables would seem more compatible with mortise-and-tenon joinery, being easier to cut, mortise, and mate up. Perhaps curved scarfs were a product of ligature construction that persisted in use long after ligatures had disappeared from the method.<sup>41</sup> Even if less prevalent than diagonal and three-planed joints, all three types would remain in the Mediterranean shipbuilding repertoire throughout antiquity.<sup>42</sup>

Planking on all the ships was edge joined without the use of seam caulking, and was protected with a thick coating of pine tar. The application was primarily to waterproof and protect the exposed laced joinery, and so originally was applied to the interior of the hull. This practice continued in the so-called transitional vessels of the fifth century since, despite then being relegated to the extremities and various repaired sections, laced joinery still served an important role in maintaining the overall hull integrity of these ships. However, shipwrights and sailors were clearly beginning to think differently about their hulls and better understand the behavior of their new joinery. The only exposed elements of pegged mortise-and-tenon joinery were the transverse faces of the locking pegs on the exterior of the hull. These cut faces exposed the cross-sections of porous wood vessels to seawater, through which it could infiltrate

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<sup>41</sup> Against this, perhaps, is the use of tenon inserts along some curved scarfs in the Khufu boat (Lipke 1984, 67 fig. 42). However, this is still a ligature-joined vessel and its use of curved scarfs may reflect this and its more distant origins.

<sup>42</sup> E.g., in the third-century B.C. Punic wreck at Marsala (Frost 1974, facing 36, fig. 1; Frost 1981, facing 32, fig. 9, 245–6; Johnstone 1981, 196, fig. 113, facing 224, fig. 138) and the second Nemi vessel from the first century A.D. (Ucelli 1950, pl. 8). The builders of the second-century B.C. Chrétienne C ship apparently employed S-scarfs exclusively in its hull (Joncheray 1975, 60, fig. 21).

the hull.<sup>43</sup> By the end of the fifth century, we find in the Ma'agan Mikhael ship pine tar covering both surfaces of the hull.<sup>44</sup> A century later, after ligatures had vanished completely from Greek shipbuilding, the interior coating was abandoned and that on the exterior was employed as a type of caulking to protect the hull planking from water infiltration and to close small cracks or seam openings.<sup>45</sup>

### Edge Joinery

Edge joinery in hull planking is, of course, the most telling characteristic of ancient Greek shipbuilding. When lacing was used, it was consistent in all its attributes, the most diagnostic of which are tetrahedral notches. Any differences concerned the extent to which lacing was used, and the types of coaks that were employed with the ligatures. The Giglio, Bon Porté, and Place Jules-Verne 9 wrecks establish the features and system of standard Greek lacing—dowel coaks and ligatures strung obliquely through tetrahedral notches over seam wadding and secured with small, wooden pegs. The use of tenon coaks in the Pabuç Burnu, Cala Sant Vicenç, and Gela 1 hulls would appear to represent a new development within this standard method, and not merely a variation of the technique. Cutting and fitting tenons and mortises is more difficult and time consuming than drilling holes and shaping dowels.<sup>46</sup> This is well illustrated in the case of one particular coak hole in plank UM5, where evidently the shipwright forgot to cut one of the mortises along the upper side of the plank after installing it on the hull.

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<sup>43</sup> Ligature pegs would also be vulnerable to water infiltration, but these pegs were much smaller than those used for tenons, and their ends are not completely exposed to the outer hull. Furthermore, the peg ends would be somewhat shielded by the crushed ligatures running through the holes and closing their outer opening once the pegs are driven in.

<sup>44</sup> Kahanov 2003, 54.

<sup>45</sup> Steffy 1994, 52.

<sup>46</sup> See Steffy (1985, 90) for description of cutting mortises.

He must have realized the omission only when he began inserting tenons in preparation for fitting the next strake. Instead of taking the time to cut a mortise and shape a tenon, he chose instead simply to drill a hole and insert a dowel. It is further evident in the fact that the Cala Sant Vicenç and Pabuç Burnu shipbuilders used dowels rather than tenons for making repairs to their hulls.

Limited evidence suggests that tenons in the Pabuç Burnu hull were fitted fairly tightly. With only one half-tenon preserved, it is difficult to say for certain, but the preserved dowel coak in UM6 is certainly well-fitted. The tenons were fashioned out of oak, which, along with their fit, indicates that the shipwrights who installed them had more in mind than simple plank aligners. These fittings bear all the hallmarks of hull stiffeners, and almost certainly were used intentionally to deliver that benefit. As shown above, tenons provide greater resistance than dowels to normal stresses exerted against the seam joints and they impart greater longitudinal stiffness to the hull, which helps prevent relative movement between planks.<sup>47</sup> Recognition of this advantage must have prompted Greek shipwrights to integrate tenons into their hulls for improved strength.

This might have been the point where a Phoenician influence interjected by providing the impetus for experimentation with tenons in ship construction. Knowledge that their Phoenician counterparts were using tenons in planks may have pushed Greek builders to do the same. However, contact between Phoenician and Greek merchants, sailors, or shipbuilders does not necessarily infer shared knowledge or application of their respective technologies. Indeed, not even within a common society does technical

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<sup>47</sup> Coates 1985, 18.

knowledge in one particular sector or craft suppose its use in another, as was seen with Egyptian boatbuilding. Whatever the case may be, the Greeks did not convert to the Phoenician pegged tenon joint, rather they incorporated tenons into their hulls in the only manner they knew how: as coaks. At least initially, they were not thinking fundamentally differently about hull design or construction, they were not yet using the tenons as connectors, and they were not intentionally developing a new method of hull construction. However, this change to tenon coaks was the critical step required for eventual progression to pegged mortise-and-tenon joinery. Due to their shape, cylindrical dowels could not easily be pegged and therefore would never likely have evolved to take the place of lacing in edge joinery. The wider, flat tenon, on the other hand, was perfectly suited for pegging. It is not difficult to imagine, then, a scenario wherein shipwrights familiar with cutting mortises and inserting tenons into the edges of their strakes, lacing the seams closed, and pegging the ligatures, would finally realized that they could simply peg the tenons instead and eliminate the lacing altogether.<sup>48</sup> This eliminated the need for wadding and ligatures, and thus for regular maintenance and replacement of the lacing, but required no new elements, materials, tools, or techniques, nor any revision to their conception of the ship or its construction.

The pegs used in Greek shipbuilding to lock ligatures in their holes or tenons in their mortises were tapered. This shape was essential for pegging lacing, since pegs had to be driven into holes equal in diameter to their larger end, but also stuffed full of ligatures. As shown earlier, a ligature (or ligatures, as the case may be) passed a

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<sup>48</sup> Wachsmann 1998, 241.

minimum of four times through each hole in order to achieve the double helical lacing pattern evidenced in several laced shipwrecks. Assuming a ligature diameter of 0.3 cm, the ligature volume had to be compacted by 33% just to lace the seams, and before the pegs were hammered in. On the other hand, straight, cylindrical pegs could have been used to lock tenons, even if a slight taper would have made insertion easier.

Furthermore, in laced hulls, the pegs had to be driven into the holes from inside the hull, the only position from where the holes were accessible. Again, this was not necessary for mortise-and-tenon built hulls, which could have been pegged from either side, although it is admittedly much more convenient to do so from within the hull. Thus, the common practice in Greek mortise-and-tenon construction of locking tenons with tapered pegs driven from inside the hull may well be another example of its laced heritage.<sup>49</sup> Using tapered pegs and orienting their smaller-diameter end to the outside of the hull would have minimized the total transverse area of peg wood exposed to the sea. However, whether this was ever realized by Greek builders or was the reason they continued the custom is not known, but it still would not deny the source of this practice in laced construction.

Some argue that similarities between pegged lacing and pegged tenon joinery are superficial, and that it would require more than merely learning how to fashion a new type of joint for shipwrights to start building hulls with the latter.<sup>50</sup> Broadly speaking, this may be true, but it denies the possibility for experimentation and innovation. Furthermore, Greek shipwrights did not simply start building vessels with new joinery

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<sup>49</sup> Wachsmann 1998, 241.

<sup>50</sup> Mark 2005, 62.



overnight; the evidence demonstrates that the process evolved more gradually. Nor was it necessary even for them to learn how to make a new joint. They were already cutting mortises, fashioning tenons, and pegging ligatures, so all they had to change was the particular element of their joinery that they pegged. By combining two separate elements—tenon coaks and pegged ligatures—into one integrated joint—the pegged tenon—shipbuilders increased the sturdiness of their joinery and the structural integrity of their hulls while, at the same time, reducing the number of holes they had to drill and eliminating the cutting of tetrahedral notches and the making and stringing of ligatures and wadding, and the regular maintenance and replacement that all these elements required.

### Framing

Builders of laced boats used long made-frames in order to reinforce the hull laterally and resist inward hull pressure. Excessive flexing in the sides of the hull could cause serious problems as it worked the seam lacings loose, or worse. To accommodate the regular maintenance required by laced hulls, the frames were lashed to the planking strakes but never attached to the keel. The unique shape of these frames was well suited for the method by which the frames were attached and for the hulls that the frames reinforced. Their wide, rounded tops presented an ideal surface for the ligatures that lashed them to the hull, and the notches along their base kept them from damaging the seam joinery. Initially, little changed in framing as builders began using pegged tenons to join planking strakes. They no longer needed to routinely disassemble their hulls, and so they fastened the frames to the hull in a sturdier manner by nailing them. Curiously

though, and as a pointed reminder of the strong conservative forces in shipbuilding (indeed, in all things maritime), builders continued to fashion frames with laced morphology—rounded upper surface and narrow base with notches for the seams—despite the fact that it was no longer warranted. Modification occurred slowly and many vestigial traits of laced construction were retained, only to diminish over time and/or take on new purpose. Frames of early transitional hulls were notched over all seams, but by the middle of the fifth century, the frames of the Gela 2 ship were notched in only four or five spots along either side of the hull. By the end of that century, the reduction was completed in the Ma‘agan Mikhael hull, whose frames were notched only over the keel and in one or two other places up each side, typically before the upward curvature of the turn of the bilge (strakes 4/5 seam) and in the futtocks opposite the lower wale (strakes 9/10 seam).<sup>51</sup> This high placement of the second watercourse was not particularly practical, and may represent the last remaining vestige of lacing notches. A century later, the Kyrenia ship’s frames exhibited a similar number of holes, but they were positioned more functionally near the keel over the seam of strakes 2 and 3, and before the turn of the bilge between strakes 5 and 6.<sup>52</sup> Notches that were originally meant to accommodate laced seams now served as limber holes and watercourses, but true to their laced heritage, even though some three centuries removed, the notches were still always centered over planking seams.<sup>53</sup>

Additionally, builders gradually increased the number of frames reinforcing their hulls, so that by the end of the fifth century frame density had increased by more than

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<sup>51</sup> Kahanov 2003, 95–6, 97 table 21.

<sup>52</sup> Steffy 1985, 86 table 4.

<sup>53</sup> The limber holes in frame 8 of Ma‘agan Mikhael being the sole exception.

40%, and by the end of the following century it was more than 150% greater. They reduced the taper of their frame widths so that frame sections gradually became rectangular, and in the second half of the fifth century, they started nailing their frames through treenails inserted into pre-drilled holes. All the while, the planking shells of their hulls became more rigid as tenon joints became larger and denser.<sup>54</sup> By the fourth century, the shell was rigid enough that frames no longer needed to be joined to their futtocks with carefully crafted and treenailed scarfs. Shipbuilders instead placed more frames in the hull by spacing them closer, moved the heels of the top-timbers down almost to the keel, and extended them and the floors up the sides of the hull with detached futtocks. In this way, made-frames morphed into floors and futtocks, top-timbers into half-frames and futtocks, and the whole into the alternating framing pattern typical of Greco-Roman hulls.<sup>55</sup>

One aspect of framing that did not change was that the frames were never attached to the keel, and in most cases never even touched it. This characteristic of ancient hulls is the most obvious indication of shell-based construction, and led Steffy to remark that the Kyrenia shipbuilder “seems to have lacked the concept of tying main structural members together—frames and futtocks did not connect to each other or to the keel, beams did not brace tops of frames, etc.”<sup>56</sup> Could this be a legacy of laced construction that, like other features, stayed with Greek shipbuilders long after they had abandoned ligatures and removable made-frames? Perhaps since, as Steffy continues, “each of these members was so fastened or so arranged that it offered enough to the

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<sup>54</sup> Steffy 1975, 86.

<sup>55</sup> Steffy 1990, 317.

<sup>56</sup> Steffy 1975, 90.

strength of the whole to effect a seaworthy hull,” there was little impetus for them to modify their hulls further. In the minds of these builders, the planking shell—whether laced or tenon-joined—was the main structural element of the hull.<sup>57</sup> Converting to pegged mortise-and-tenon joints, increasing joint size and density, nailing frames to the planking, placing frames closer together and enlarging top-timbers to half-frames were all modifications intended to strengthen and support the walls of planking. Not until the first century B.C. were any frames bolted to the keel,<sup>58</sup> and even in the fourth century A.D., only a few of the frames sat on the keel and were bolted to it.<sup>59</sup>

### Hull Shape

Before the middle of the fifth century, shipbuilders had begun taking advantage of their new, more rigid joinery to modify the bottom shape of their hulls in order to strengthen them longitudinally. Here again the mind of these builders and how they conceived of their ships is apparent. Instead of connecting frames to keels in order to create a stronger spine, they chose to modify the planking instead. By beveling the lower edge of the garboards, they attached them to the keel at increasingly sharper angles to create a V-shape with the garboards and keel. From there they added planking strakes in a concave curve along the bottom of the hull before reversing and forming them into a convex sweep through the turn of the bilge and up the side of the hull. In this way they gave their hulls a graceful wine glass shape. They were only able to do so because of the sturdier mortise-and-tenon joints connecting these members. Through the

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<sup>57</sup> Steffy 1990, 317.

<sup>58</sup> As seen in the Madrague de Giens ship (Pomey 1978, fig. 10, pl. 36).

<sup>59</sup> Out of 48 preserved frames (of an estimated original total of 68) from the fourth century A.D. shipwreck at Yassada, three were bolted to the sternpost and four to the keel (van Doorninck 1976, 118 fig. 4, 124).

fifth century, only the stem and sternpost, and a short section of each end of the keel, were rabbeted to receive the ends of the garboards and strakes, while the garboards butted flush against the sides of the keel. In the fourth century, though, builders finally cut a rabbet into the full length of the keel to make the connections with the garboards more structurally sound. As a consequence, the curves became more severe and the V-shape formed by the keel and garboards became deeper. Under the frames they placed chocks to fill in the space between the keel and floor timbers. These they set up and aligned to their floor timbers with unpegged tenon inserts and then nailed them to the garboard and second strakes.<sup>60</sup> This assembly of keel-garboards and garboards-second strakes-chocks-floors served as a base support for the planking shell and acted as “a sort of arched box girder” to provide considerable longitudinal strength to the hull.<sup>61</sup>

All these features of laced and mortise-and-tenon construction are summarized graphically in figure 5.1. When viewed chronologically, they show a clear evolution from laced traits to those of mortise-and-tenon based construction, with all the intermediate—what some would call transitional—stages of progression. The transformation in each of these constructional elements was predicated on the conversion from pegged ligatures to pegged mortise-and-tenon joints. Evidence from the Pabuç Burnu, Cala Sant Vicenç, and Gela 1 wrecks point to the mechanism for that change and strongly suggests that the conversion was one of gradual development within the Greek laced tradition, and was not due necessarily to the interjection of foreign technology.

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<sup>60</sup> Steffy 1985, 84–5. One tenon was pegged in the floor, but not the chock, and two chocks were aligned with 1-cm treenails.

<sup>61</sup> Steffy 1975, 89.

600 B.C.	500	400	300
Hull Planking	pine planks; typical thickness consistent relative to vessel size (2.5–4.5 cm)		
	planks joined with diagonal, three-planed (Z), and curved (S) scarfs		
	pegged lacing with dowel coaks	pegged mortise-and-tenon joinery	
Hull Planking	joints locked with tapered pegs hammered in from inside the hull		
	increasing coak/joint density (+150%)		
	interior of hull coated with pine tar	interior & exterior coated	exterior coated
Framing	alt. made-frames & top-timbers; futtocks joined by treenailed hook scarfs; wide, rounded top, tapering sides, narrow base		
	bottom notched to protect seam lacing & wadding	bottom notched for limber holes & water courses	alt. floors & half-frames w/ detached futtocks; sq. section
	notched over all planking seams	4–5 notches/side	1–3 notches/side
	ratio of width of top of frame to width of bottom of frame diminishes from 9:1 to 1:1		
	frames lashed to hull; top-timbers lashed & treenailed to hull	frames nailed to hull with double-clenched metal nails	
		driven through wooden treenails in pre-drilled holes	
	increasing frame density (+150%)		
	no frames attached to keel		
Hull	rabbets only in ends of keel and endposts		entire keel rabbeted
	(proto-wine glass shaped ?)	wine glass shaped hull	
Shipwrecks	round symmetrical hull with sharp extremities		
	increasingly complex curvature		
600 B.C.	500	400	300
	Giglio	Pabuç Burnu	Kyrenia
	Bon Porté		
	Jules-Verne 9 & 7		
	César 1		
	Grand Ribaud F		
	Gela 1		
	Gela 2	Tektas Burnu	
		Ma`agan Mikhael	
		Porticello	

Fig. 5.1. Evolution of hull and construction features in ancient Greek shipbuilding.

## CHAPTER VI

### CONCLUSIONS

The vessel that sank at Pabuç Burnu during the first half of the sixth century was of moderate size, probably around 18 m in length and 6–7 m in beam, based on the distribution of material across the site. The ship was laden with a cargo of agricultural goods carried in approximately 260 amphoras and perhaps other less durable bulk containers. The ship's wares suggest an East Greek crew from the environs of Halikarnassos and Knidos to Rhodes. The regional styles of the cargo amphoras and other ceramics on board reflect a local trade limited to the southeastern Aegean. The wreck is dated by the pottery to 570–560 B.C.

The wreckage included only six fragmentary planks from the ship's hull, but these pieces and their features have provided solid evidence not only to place the vessel within the Greek shipbuilding tradition of the time, but to help refine our understanding of the profound changes taking place in that tradition during the dynamic last century of the Archaic period.

The Pabuç Burnu ship was assembled shell-first using traditional Greek laced construction techniques. Its hull strakes consisted of planks joined end-to-end with curved and diagonal scarfs, typical of such craft. The strakes were joined together to form the shell of the hull by fitting them with tenon coaks and lacing the edges with plant ligatures secured by wooden pegs. The Pabuç Burnu hull is virtually identical in its construction details to the hull of the Cala Sant Vicenç vessel dated a half-century

later, and potentially similar as well to the Gela 1 ship. The details of these vessels' construction are consistent with those of other laced boats from the era, save for one difference: the shipwrights who built these hulls used tenons, rather than traditional dowels, for coaks between the hull planking strakes. This application in the Pabuç Burnu ship is the earliest archaeologically attested use of tenons in Greek shipbuilding. Evidence from more than a dozen Greek shipwrecks dating between the sixth and fourth centuries B.C. clearly demonstrates that Greek shipwrights replaced pegged lacing with pegged mortise-and-tenon joinery in their hulls sometime towards the end of the sixth century, and that within a few decades, the new method had completely supplanted lacing as the principal joinery in ships' hulls. The Pabuç Burnu, Cala Sant Vicenç, and Gela 1 wrecks provide key evidence that points to the early process of this conversion, and that suggests that the evolution of Greek shipbuilding was a gradual one that occurred to and within the laced tradition. Traces of that tradition can be found in virtually all aspects of early Greco-Roman mortise-and-tenon construction, as typified by the features so well documented in the Kyrenia ship's hull.

All of the tools, techniques, and constructional elements were present in Greek laced shipbuilding for the development of pegged mortise-and-tenon joinery once its practitioners started using tenons as coaks. The Pabuç Burnu remains establish at least an early sixth-century date for when that change occurred. After that, all that was needed was for an experienced and innovative shipwright to peg the tenon coaks of his joinery rather than the ligatures. The implications of this seemingly simple innovation were far reaching. But the adoption of any new technology always comes with a period



of learning, experimentation, adaptation, and implementation. This is demonstrated, perhaps, in the different specific application of tenon coaks in the Pabuç Burnu and Cala Sant Vicenç hulls, where tenons were used exclusively in the original construction, and dowels were used in repairs, compared to that in the Gela 1 ship, where perhaps dowels and coaks were used together in its original construction, one alternated with the other along the plank seams in at least some areas of the hull; and, subsequently, in the differences between the early mortise-and-tenon built vessels, although any differences are surprisingly small. All of the intricacies that shipwrights building laced vessels had mastered over generations had to be relearned with this new method as they gained experience building and sailing their new hulls. Such challenges were encountered immediately in planking the bow and stern areas of the hull and in retrofitting damaged joints or planks.

The progression from dowel to tenon coaks in laced boats, to the pegged tenons of so-called transitional hulls, to the mortise-and-tenon joinery in the Kyrenia ship shows a steady evolution within Greek shipbuilding, not only in the joints specifically, but in the mindset of the shipwrights who employed them. They transformed their tenon inserts from mere seam connectors to an increasingly important structural element of their hulls. They steadily enlarged the size of the tenons and reduced their spacing, so as to create a denser and more robust network of internal joints that added considerable stiffness to their hulls. Working within a shell-based system, a strong planking shell was paramount to these builders. Hull modifications seen in the transitional ships should be understood as adaptations learned from experience to augment the attributes of the new

joinery. Keels became somewhat larger and deeper, framing was nailed to the hull, made-frames became heavier and more numerous, and top-timbers longer and positioned lower in the hull. Once the planking joinery was sturdy enough, futtocks were detached from their floors altogether. Thus, the transition from coak to joint was one of plank aligners that reinforced seam joinery longitudinally, to plank aligners that added more longitudinal resistance as well as lateral stiffness; then to seam connectors (i.e., true joints) that improved on all of these benefits; and finally to a system of edge joinery wherein pegged tenons served as “little internal frames” and contributed a considerable amount of stiffness to the hull and improved its structural integrity.<sup>1</sup>

As to who or what provided the original impetus that prompted Greek shipwrights use tenons in their laced joinery, the question remains unresolved. Phoenician shipwrights are the obvious and tempting choice, but little is known about how they were building their own ships at this time. If the Mazarrón boats prove to be typical of Phoenician construction, then they would suggest a tradition still closely linked to that of the Uluburun ship (with a more rudimentary keel and little internal framework) and significantly different than the Greek method. The gradual transition from dowel to tenon to joint, and the accompanying supporting modifications to other hull construction features, strongly suggests a natural development within a consistent and evolving building tradition rather than a direct transfer and adoption of foreign technology. More definite conclusions must await better evidence of Phoenician construction in the seventh and sixth centuries. Steffy remarks that “the Kyrenia ship

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<sup>1</sup> Steffy 1985, 90.

must have been a descendant of centuries of similarly constructed vessels, and so the form and methodology were already fixed in the mind of the trained ship carpenter.”<sup>2</sup>

The humble hull remains from Pabuç Burnu, along with those from other Greek ships of the late Archaic and Classical periods, provide a clearer picture now of that heritage, but one vastly different than what Steffy originally supposed. The Kyrenia ship stems from laced construction and is the product of some three centuries of development, demonstrating that not only were the form and methodology employed not “fixed”, they were steadily, if not dynamically, evolving.

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<sup>2</sup> Steffy 1994, 77.

## WORKS CITED

- Akurgal, E. 1962. "The Early Period and the Golden Age of Ionia." *AJA* 66:369–79.
- Alexandrescu, P. 1978. *La céramique d'époque archaïque et classique (VIIe–IVe s.)*. *Histria* 4. Bucharest: Editura Academiei Republicii Socialiste Romania.
- Artzy, M., and J. Lyon. 2003. "The Ceramics." In *The Ma'agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman: Final Report*, Vol. 1, edited by E. Linder and Y. Kahanov, 183–202. Jerusalem, Haifa: Israel Exploration Society, University of Haifa.
- Azipurua, C., and J. Méndez. 1996. "Extracción y tratamientos del barco Fenicio (barco 1) de La Playa de La Isla (Puerto de Mazarrón, Mazarrón)." *Cuadernos de Arqueología Marítima* 4:217–25.
- Aubet, M.E. 1993. *The Phoenicians and the West: Politics, Colonies, and Trade*. Translated by M. Turton. Cambridge: Cambridge University Press.
- Barra-Bagnasco, M. 1992. "Le anfore." In *Locri Epizefiri IV: Lo scavo di Marasà Sud, il sacello tardo arcaico e la "casa dei leoni"*, edited by M. Barra-Bagnasco, 205–40. Florence: Casa Editrice le Lettre.
- Basch, L. 1976. "Le navire cousu de Bon-Porté." *CahArchSubaq* 5:37–42.
- . 1978. "L'assemblage du navire de Bon-Porté." *Les Dossiers de l'archéologie* 29:71–3.
- . 1981. "The Sewn Ship of Bon Porté." *Mariner's Mirror* 67:244.
- Bass, G.F. 1967. *Cape Gelidonya: A Bronze Age Shipwreck*. *TAPS* 57. Philadelphia: American Philosophical Society.
- . 1974. "Turkey: Survey for Shipwrecks, 1973." *IJNA* 3:335–8.
- . 1975. "Underwater Survey – 1973." *TürkArkDerg* 22(2):33–8.
- . 2001. "INA Increases its Fleet." *INA Quarterly* 28(2):11–3.
- . 2002. "Log of the Submersible Survey 2001." *INA Quarterly* 29(2):3–9.
- . 2006. "New Techniques of Archaeology and Greek Shipwrecks of the Sixth and Fifth Centuries BC." *PAPS* 150:1–14.

- Bass, G.F., and F.H. van Doorninck, eds. 1982. *Yassi Ada: A Seventh-Century Byzantine Shipwreck*, Vol. 1. College Station: Texas A&M University Press.
- Bats, M. 1996. "I Greci in Gallia e in Corsica." In *I Greci in Occidente*, edited by G.P. Carratelli, 577–84. Milan: Bompiani.
- Benini, A. 2001. "The Second Wreck at Gela: Notes on Naval Architecture." In *The Archaic Greek Ship at Gela (and Preliminary Exploration of a Second Greek Shipwreck)*, edited by R. Panvini, 97–106. Palermo: Salvatore Sciascia Editore.
- Boardman, J. 1999. *The Greeks Overseas: Their Early Colonies and Trade*. 4th ed. London: Thames and Hudson.
- Bound, M. 1985. "Early Observations on the Construction of the Pre-Classical Wreck at Campese Bay, Island of Giglio: Clues to the Vessel's Nationality." In *Sewn Plank Boats: Archaeological and Ethnographic Papers Based on those Presented to a Conference at Greenwich in November, 1984*, edited by S. McGrail and E. Kentley, 49–66. Greenwich, Oxford: National Maritime Museum, B.A.R.
- . 1991a. "A Wreck of Likely Etruscan Origin off the Mediterranean Island of Giglio (c. 600 B.C.)." In *Recent Advances in Marine Archaeology: Proceedings of the Second Indian Conference on Marine Archaeology of Indian Ocean Countries, January, 1990*, edited by S.R. Rao, 43–50. Goa: Society for Marine Archaeology, National Institute of Oceanography.
- . 1991b. *The Giglio Wreck: A Wreck of the Archaic Period (c. 600 BC) off the Tuscan Island of Giglio. An Account of its Discovery and Excavation: A Review of the Main Finds. Enalia Supplements 1*. Athens: Hellenic Institute of Marine Archaeology.
- Bound, M., and R. Vallintine. 1983. "A Wreck of Possible Etruscan Origin off Giglio Island." *IJNA* 12:113–22.
- Brashinsky, J.B. 1976. "Amfori Mendi (Amphoras from Mende)." *Akademiia Nauk SSSR*:67–74.
- Burkert, W. 1992. *The Orientalizing Revolution: Near Eastern Influence on Greek Culture in the Early Archaic Age*. Translated by W. Burkert and M.E. Pinder. Cambridge, Mass.: Harvard University Press.
- Cabrera, P. 1994. "Comercio internacional mediterráneo en el siglo VIII a.C." *AEA* 67:15–30.

- Casson, L. 1995. Reprint with addenda and corrigenda. *Ships and Seamanship in the Ancient World*. Baltimore: Johns Hopkins University Press. Original edition, Princeton: Princeton University Press, 1971.
- Carlson, D.N. 1999. "The 1999 Excavation Season at Tektaş Burnu, Turkey." *INA Quarterly* 26(4):3–11.
- . 2001. "The 2000 Excavation Season at Tektaş Burnu, Turkey." *INA Quarterly* 28(2):3–8.
- . 2002. "The 2001 Excavation Season at Tektaş Burnu, Turkey." *INA Quarterly* 29(2):12–4.
- . 2003. "The Classical Greek Shipwreck at Tektaş Burnu, Turkey." *AJA* 107:581–600.
- Catling, H.W. 1983. "Archaeology in Greece, 1982–3." *Archaeological Reports for 1982–3*:3–62.
- Catling, R.W.V., and D.G.J. Shipley. 1989. "Messapian Zeus: An Early Sixth-Century Inscribed Cup from Lakonia." *BSA* 84:187–200.
- Coates, J.F. 1985. "Some Structural Models for Sewn Boats." In *Sewn Plank Boats: Archaeological and Ethnographic Papers Based on those Presented to a Conference at Greenwich in November, 1984*, edited by S. McGrail and E. Kentley, 9–18. Greenwich, Oxford: National Maritime Museum, B.A.R.
- Coldstream, J.N. 1982. "Greeks and Phoenicians in the Aegean." In *Phonizier im Westen: Die Beiträge des Internationalen Symposiums über 'Die Phonizische Expansion im Westlichen Mittelmeerraum' in Köln vom 24. bis 27. April, 1979*, 261–75. Mainz am Rhein: Zabern.
- Cook, J.M. 1962. *The Greeks in Ionia and the East*. New York: Frederick A. Praeger.
- Cristofani, M. 1996. "Un naukleros greco-orientale nel Tirreno." In *Etruschi e altre genti nell'Italia preromana*, 21–48. Rome: Bretschneider Giorgio.
- Davis, P.H. 1965. *Flora of Turkey and the East Aegean Islands*. Vol. 1. Edinburgh: University Press.
- de Polignac, F. 1992. "Influence extérieure ou évolution interne? L'innovation culturelle en Grèce géométrique et archaïque." In *Greece Between East and West, 10th-8th Centuries BC: Papers of the Meeting at the Institute of Fine Arts, New York University, March 15-16th, 1990*, edited by G. Kopcke and I. Tokumaru, 114–27. Mainz, Rhine: Verlag Philipp von Zabern.

- Docter, R.F., and H.G. Niemeyer. 1994. "Pithekoussai: The Carthaginian Connection. On the Archaeological Evidence for Euboeo-Phoenician Partnership in the Eighth and Seventh Centuries B.C." In *Apoikia: I più antichi insediamenti Greci in Occidente: Funzioni e modi dell'organizzazione politica e sociale: Scritti in onore di Giorgio Buchner*, edited by B. D'Agostino and D. Ridgway, 101–15. Naples: Istituto universitario orientale.
- Dupont, P. 1998. "Archaic East Greek Trade Amphoras." In *East Greek Pottery*, edited by R.M. Cook and P. Dupont, 142–91. London: Routledge.
- . 1999a. "La circulation amphorique en Mer Noire à l'époque archaïque." In *Production et commerce des amphores anciennes en Mer Noire: Colloque international organisé à Istanbul, 25–28 mai 1994*, edited by Y. Garlan, 143–61. Aix-en-Provence: Publications de l'Université de Provence.
- . 1999b. "Marques signalétiques avant-cuisson sur les amphores ioniennes archaïques: Cercles et croix." *Pontica* 32:9–18.
- . 2001. "Amphores 'samiennes' archaïques: Sources de confusion et questionnements." In *Ceràmiques jònies d'època arcaica: Centres de producció i comercialització al mediterrani occidental*, edited by P. Cabrera Bonet and M. Santos Retolaza, 57–62. Barcelona: Generalitat de Catalunya.
- . 2005. "Les amphoras commerciales grecques archaïques: Trouvailles du temple d'Aphrodite (Fouilles 1972–1981)." In *La zone sacrée d'époque grecque (fouilles 1915–1989)*, edited by P. Alexandrescu, A. Sion, A. Avram and M.A. Vianu, 218–55. Bucharest: Editura Academiei Române.
- Eiseman, C.J., and B.S. Ridgway. 1987. *The Porticello Shipwreck: A Mediterranean Merchant Vessel of 415–385 B.C.* College Station: Texas A&M University Press.
- Faccenna, F. 1997. "Indagini preliminari sul secondo relitto di Gela (Gela II)." In *Atti del Convegno Nazionale di Archeologia Subacquea (Anzio, 30–31 maggio, 1 giugno 1996)*, 143–6. Bari: Edipuglia.
- Fitzgerald, M.A. 1994. "The Ship." In *The Harbours of Caesarea Maritima: Results of the Caesarea Ancient Harbour Excavation Project 1980-85. Vol. 2, The Finds and the Ship*, edited by J.P. Oleson, 163–223. Oxford: Tempus Reparatum.
- . 1995. "A Roman Wreck at Caesarea Maritima, Israel: A Comparative Study of its Hull and Equipment." Ph.D. diss., Texas A&M University.
- Foerster Laures, F. 1989. "Caulking in Sewn Boats?" *IJNA* 18:266–7.

- Freyer–Schauenburg, B. 1966. “Kolaios und die west-phönizischen Elfenbeine.” *Madriider Mitteilungen* 7:89–108.
- Frost, H. 1974. “The Punic Wreck in Sicily: Second Season of Excavation.” *IJNA* 3:35–54.
- . 1981. *Lilybaeum*. Atti della Accademia Nazionale dei Lincei 373. Rome: Accademia Nazionale dei Lincei.
- Gjerstad, E. 1977. “Pottery from Various Parts of Cyprus.” In *Greek Geometric and Archaic Pottery Found in Cyprus*, edited by E. Gjerstad and Y. Calvet, 23–59. Stockholm: Svenska Institutet i Athen.
- Glastrup, J. 2009. “Annex 6. Analysis of Archaeological Samples of Resin and Other Remains.” In *El vaixell grec arcaic de Cala Sant Vicenç*, edited by X. Nieto and M. Santos, 397–401. Barcelona: Museu d’Arqueologia de Catalunya.
- Glastrup, J., and T. Padfield. 2004. “Analysis of Paint.” In *The Ma‘agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman: Final Report, Volume 2*, edited by Y. Kahanov and E. Linder, 138–42. Jerusalem, Haifa: Israel Exploration Society, University of Haifa.
- Gómez–Gil, C., and J.L. Sierra. 1996. “Extracción y tratamientos del barco fenicio (barco I) de la Playa de la Isla (Puerto de Mazarrón, Mazarrón).” *Cuadernos de Arqueología Marítima* 4:271–5.
- Green, J., S. Matthews, and T. Turanli. 2002. “Underwater Archaeological Surveying Using PhotoModeler, VirtualMapper: Different Applications for Different Problems.” *IJNA* 31:283–92.
- Greene, E. 2003. “Endless Summer: The 2002 Excavation Season at Pabuç Burnu, Turkey.” *INA Quarterly* 30(1):3–11.
- Greene, E.S., and G.F. Bass. Forthcoming. “Discovery and Excavation: The 2001 Submersible Survey and the 2002 Excavation at Pabuç Burnu, Turkey.” In *Tropis VIII. Proceedings of the 8th International Symposium on Ship Construction in Antiquity, August 2002*, edited by H.E. Tzalas. Athens: Hellenic Institute for the Preservation of Nautical Tradition.
- Greene, E.S., M.L. Lawall, and M.E. Polzer. 2008. “Inconspicuous Consumption: The Sixth-Century B.C.E. Shipwreck at Pabuç Burnu, Turkey.” *AJA* 112:685–711.
- Greene, E.S., and M.E. Polzer. 2004. “Evidence for a 6th-Century BCE Lifeboat and its Anchor?” *INA Quarterly* 31(3):12–8.



- Hadjidaki, E. 1996. "Underwater Excavations of a Late Fifth Century Merchant Ship at Alonnesos, Greece: The 1991-1993 Seasons." *BCH* 120:561-93.
- Haldane, C.W. 1988. "Boat Timbers from El-Lisht: A New Method of Ancient Egyptian Hull Construction. Preliminary Report." *Mariner's Mirror* 74:141-52.
- . 1990. "Egyptian Hulls and the Evidence for Caulking." *IJNA* 19:135-7.
- . 1996. "Ancient Egyptian Hull Construction." In *Tropis IV. Proceedings of the 4th International Symposium on Ship Construction in Antiquity, Center for the Acropolis Studies, Athens, 28-31 August 1991*, edited by H.E. Tzalas, 235-44. Athens: Hellenic Institute for the Preservation of Nautical Tradition.
- Hayes, J. 1966. "The Pottery." In *Excavations at Tocra, 1963-1965: The Archaic Deposits I*, edited by J. Boardman and J. Hayes, 19-148 London: Thames and Hudson.
- Hoadley, R.B. 1990. *Identifying Wood: Accurate Results with Simple Tools, A Fine Woodworking Book*. Newtown, CT: Taunton Press.
- Hornell, J. 1941. "The Sea-Going *Mtepe* and *Dáu* of the Lamu Archipelago." *Mariner's Mirror* 27:54-68.
- . 1970. Reprint. *Water Transport: Origins and Early Evolution*. Newton Abbot: David & Charles. Original edition, Cambridge: Cambridge University Press, 1946.
- Hourani, G.F. 1995. *Arab Seafaring in the Indian Ocean in Ancient and Early Medieval Times*. Rev. and expanded ed. Princeton: Princeton University Press. Original edition, 1951.
- Huxley, G.L. 1966. *The Early Ionians*. New York: Humanities Press.
- Isserlin, B.S.J. 1964. *Motya: A Phoenician-Punic Site Near Marsala, Sicily: A Preliminary Report of the Leeds-London-Farleigh Dickinson Expedition, 1961-63. Annual of Leeds University Oriental Society* 4. Leiden: E. J. Brill.
- Italy Magazine. 28 July 2008. *2,500-Year-Old Greek Ship Salvaged off Sicily*. <http://www.italymag.co.uk/> (30 July).
- Jeffery, L.H., and A.W. Johnston. 1990. *The Local Scripts of Archaic Greece: A Study of the Origin of the Greek Alphabet and its Development from the Eighth to the Fifth Centuries B.C.* Rev. ed. with suppl. by A.W. Johnston. Oxford, New York: Oxford University Press, Clarendon Press. Original edition, 1961.

- Jestin, O., and F. Carrazé. 1980. "Mediterranean Hull types Compared 4: An Unusual Type of Construction: The Hull of Wreck 1 at Bon Porté." *IJNA* 9:70–2.
- Johnstone, W. 1981. "Signs." In *Lilybaeum*, edited by H. Frost, 191–239. Rome: Accademia nazionale dei Lincei.
- Johnston, A.W. 1983. "The Extent and Use of Literacy: The Archaeological Evidence." In *The Greek Renaissance of the Eighth Century B.C.: Tradition and Innovation. Proceedings of the Second International Symposium at the Swedish Institute in Athens, 1–5 June, 1981*, edited by R. Hägg, 63–8. Stockholm: Svenska Institutet i Athen.
- Joncheray, J.-P. 1975. *L'épave "C" de la Chrétienne*. Vol. 1, *Supplément aux CahArchSubaq*. Gap, France: Publications Scientifiques et Littéraires.
- . 1976. "L'épave grecque, ou étrusque, de Bon Porté." *CahArchSubaq* 5:5–36.
- Kahanov, Y. 1996. "Conflicting Evidence for Defining the Origin of the Ma'agan Mikhael Shipwreck." In *Tropis IV. Proceedings of the 4th International Symposium on Ship Construction in Antiquity, Athens 1991*, edited by H.E. Tzalas, 245–8. Athens: Hellenic Institute for the Preservation of Nautical Tradition.
- . 2003. "The Hull." In *The Ma'agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman: Final Report*, Vol. 1, edited by E. Linder and Y. Kahanov, 53–129. Jerusalem, Haifa: Israel Exploration Society, University of Haifa.
- . 2004. "The Sewing of the Ship." In *The Ma'agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman: Final Report*, Vol. 2, edited by Y. Kahanov and E. Linder, 3–79. Jerusalem, Haifa: Israel Exploration Society, University of Haifa.
- Kahanov, Y., and E. Linder. 2004. *The Ma'agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman: Final Report*, Vol. 2. Jerusalem, Haifa: Israel Exploration Society, University of Haifa.
- Kahanov, Y., and P. Pomey. 2004. "The Greek Sewn Shipbuilding Tradition and the Ma'agan Mikhael Ship: A Comparison with Mediterranean Parallels from the Sixth to the Fourth Centuries BC." *Mariner's Mirror* 90:6–28.
- Katzev, M.L. 1970. "Kyrenia 1969: A Greek Ship is Raised." *Expedition* 12(4):6–14.
- . 1974. "Cyprus Underwater Archaeological Search, 1967." In *National Geographic Society Research Reports: Abstracts and Reviews of Research and Exploration Authorized Under Grants from the National Geographic Society*

- During the Year 1967*, edited by P.H. Oehser, 177–84. Washington, D. C.: National Geographic Society.
- . 1976. “Cyprus Underwater Archaeological Search, 1968.” In *National Geographic Society Research Reports: Abstracts and Reviews of Research and Exploration Authorized Under Grants from the National Geographic Society During the Year 1968*, edited by P.H. Oehser, 177–88. Washington, D. C.: National Geographic Society.
- . 1978. “Cyprus Underwater Archaeological Search, 1969.” In *National Geographic Society Research Reports: Abstracts and Reviews of Research and Exploration Authorized Under Grants from the National Geographic Society During the Year 1969*, edited by P.H. Oehser and J.S. Lea, 289–305. Washington, D. C.: National Geographic Society.
- Katzev, S.W. 2005. “Resurrecting an Ancient Greek Ship: Kyrenia, Cyprus.” In *Beneath the Seven Seas: Adventures with the Institute of Nautical Archaeology*, edited by G.F. Bass, 72–9. London: Thames & Hudson.
- Kerschner, M., and H. Mommsen. 2005. “Transportamphoren milesischen Typs in Ephesos: Archäometrische und archäologische Untersuchungen zum Handel im archaischen Ionien.” In *Synergia: Festschrift für Friedrich Krinzingler*, edited by F. Krinzingler, B. Brandt, V. Gassner and S. Ladstätter, 119–30. Vienna: Phoibos.
- Lawall, M.L. 1995. “Transport Amphoras and Trademarks: Imports to Athens and Economic Diversity in the 5th c. B.C.” Ph.D. diss., University of Michigan.
- . 1998. “Bolsals, Mendian Amphoras, and the Date of the Porticello Shipwreck.” *IJNA* 27:16–23.
- Linder, E., and Y. Kahanov. 2003. *The Ma‘agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman: Final Report*, Vol. 1. Jerusalem, Haifa: Israel Exploration Society, University of Haifa.
- Liou, B. 1974. “Note provisoire sur deux gisements gréco-étrusques (Bon-Porté A et Pointe du Dattier).” *CahArchSubaq* 3:7–19.
- . 1975. “Direction des recherches archéologiques sous-marines.” *Gallia* 33:571–605.
- Lipshchitz, N. 2004. “Dendroarchaeological Investigations.” In *The Ma‘agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman: Final Report*, Vol. 2, edited by Y. Kahanov and E. Linder, 156–63. Jerusalem, Haifa: Israel Exploration Society, University of Haifa.

- Lipke, P. 1984. *The Royal Ship of Cheops: A Retrospective Account of the Discovery, Restoration and Reconstruction. Based on Interviews with Hag Ahmed Youssef Moustafa*. BAR-IS 225. Greenwich, Oxford: National Maritime Museum, B.A.R.
- . 1985. “Retrospective on the Royal Ship of Cheops.” In *Sewn Plank Boats: Archaeological and Ethnographic Papers Based on those Presented to a Conference at Greenwich in November, 1984*. BAR-IS 276, edited by S. McGrail and E. Kentley, 19–34. Greenwich, Oxford: National Maritime Museum, B.A.R.
- Long, L., P. Drap, L.-F. Gantès, and M. Rival. 2001. “L’épave Grand Ribaud F: Rapport scientifique intermédiaire année 2001.” Marseille: DRASSM.
- Long, L., L.-F. Gantès, and P. Drap. 2002. “Premiers résultats archéologiques sur l’épave Grand Ribaud F (Giens, Var). Quelques éléments nouveaux sur le commerce étrusque en Gaule vers 500 avant J.-C.” *CahArchSubaq* 14:5–40.
- Lucas, A., and J.R. Harris. 1962. *Ancient Egyptian Materials and Industries*. 4th rev. and enl. ed. London: E. Arnold.
- Manning, S., C. Pulak, B. Kromer, S. Tolamo, C. Bronk Ramsey, and M. Dee. Forthcoming. “Absolute Age of the Uluburun Shipwreck: A Key Late Bronze Age Time-Capsule for the Eastern Mediterranean.” In *Tree-Rings, Kings, and Old World Archaeology and Environment: Proceedings of the Cornell Dendrochronology-Archaeology Conference in Honor of Peter Ian Kuniholm, 3-5 November 2006, Ithaca, New York*, edited by S.W. Manning. Ithaca: Cornell University Press.
- Mark, S. 2005. *Homeric Seafaring*. College Station: Texas A&M University Press.
- . 2009. “The Construction of the Khufu I Vessel (c.2566 BC): A Re-Evaluation.” *IJNA* 38:133–52.
- Markoe, G.E. 2000. *Phoenicians, Peoples of the Past*. Berkeley: University of California Press.
- Marsden, P. 1974. “The County Hall Ship, London.” *IJNA* 3:55–65.
- McCarthy, M. 2005. *Ships’ Fastenings: From Sewn Boat to Steamship*. College Station: Texas A&M University Press.
- McGrail, S., and E. Kentley. 1985a. Editors’ Introduction to *Sewn Plank Boats: Archaeological and Ethnographic Papers Based on Those Presented to a Conference at Greenwich in November, 1984*. BAR-IS 276, edited by S. McGrail and E. Kentley. Greenwich, Oxford: National Maritime Museum, B.A.R.

- , eds. 1985b. *Sewn Plank Boats: Archaeological and Ethnographic Papers Based on Those Presented to a Conference at Greenwich in November, 1984, BAR-IS 276*. Greenwich, Oxford: National Maritime Museum, B.A.R.
- Mees, A.W., and B. Pferdehirt. 2002. *Römerzeitliche Schiffsfunde in der Datenbank "Navis I", Kataloge vor- und frühgeschichtlicher Altertümer*. Mainz, Bonn: Verlag des Römisch-Germanischen Zentralmuseums, In Kommission bei Rudolf Habelt.
- Meyza, H. 2004. "Kouriaka Again: Amphora Stamps from the Kourion Acropolis Excavations." In *Transport Amphorae and Trade in the Eastern Mediterranean: Acts of the International Colloquium at the Danish Institute at Athens, September 26–29, 2002*, edited by J. Eiring and J. Lund, 273–84. Aarhus: Aarhus University Press.
- Monakhov, S.I. 2003. *Grecheski amfory v Prichernomor'e: Tipologiya amfor vedushchikh tsentrov-eksporterov tovarov v keramicheskoi tare. Katalog-opredelitel*. Moscow: Kimmerida.
- Naveh, J. 1962. "The Excavations at Mesad Hashavyahu: Preliminary Report." *IEJ* 12:89–113.
- Negueruela, I. 2004. "Hacia la comprensión de la construcción naval fenicia según el barco "Mazarrón-2" de siglo VII a.C." In *La Navegación fenicia: Tecnología naval y derroteros: Encuentros entre marinos, arqueólogos e historiadores*, edited by V. Peña, C.G. Wagner and A. Mederos, 227–78. Madrid: Centro de Estudios Fenicios y Punicos.
- Negueruela, I., R.G. Gallero, M.S. Claudio, A.M. Sanmartín, M. Presa, and C. Marín. 2004. "Mazarrón-2: el barco fenicio del siglo VII a.C. Campaña de noviembre 1999/marzo 2000." In *El mundo púnico: Religión, antropología y cultura material: Actas II Congreso Internacional del Mundo Púnico, Cartagena, 6-9 de abril de 2000*, edited by A.G. Blanco, G.M. Séiquer and A.E. Vivancos, 453–84. Murcia: Universidad de Murcia, Instituto del Próximo Oriente Antiguo, Área de Historia Antigua.
- Negueruela, I., J. Pinedo, M. Gómez, A. Miñano, I. Arellano, and J.S. Barba. 1995. "Seventh-Century BC Phoenician Vessel Discovered at Playa de la Isla, Mazarron, Spain." *IJNA* 24:189–97.
- . 2000. "Descubrimiento de dos barcos fenicios en Mazarrón (Murcia)." In *Actas del IV Congreso Internacional de Estudios Fenicios y Púnicos: Cádiz, 2 al 6 de octubre de 1995*, edited by M.E. Aubet and M. Barthélemy, 1671–9. Cádiz: Servicio de Publicaciones, Universidad de Cádiz.

- Neville, A. 2007. *Mountains of Silver & Rivers of Gold: The Phoenicians in Iberia, University of British Columbia Studies in the Ancient World*. Oxford: Oxbow Books.
- Nieto, X., and M. Santos. 2009. *El vaixell grec arcaic de Cala Sant Vicenç. Monografies del CASC 7*. Barcelona: Museu d'Arqueologia de Catalunya.
- Nieto, X., M. Santos, and F. Tarongí. 2004. "Un barco griego del siglo VI a.C. en Cala Sant Vicenç (Pollença, Mallorca)." In *La Navegación fenicia: Tecnología naval y derroteros: Encuentros entre marinos, arqueólogos e historiadores*, edited by V. Peña, C.G. Wagner and A. Mederos, 197–225. Madrid: Centro de Estudios Fenicios y Punicos.
- . 2005. "El barco griego de Cala Sant Vicenç (Pollença, Mallorca)." In *Aequora, jam, mare ... Mare, uomini e merci nel Mediterraneo antica. Atti del Convegno Internazionale, Genova, 9–10 dicembre 2004*, edited by B.M. Giannattasio, C. Canepa, L. Grasso and E. Piccardi, 42–55. Madrid: All'Insegna del Giglio.
- Nieto, X., F. Terongí, and M. Santos. 2002. "El pecio de Cala Sant Vicenç: El barco griego más Antiguo de Baleares." *Revista de Arqueología* 258:18–25.
- . 2003. "Il relitto greco-arcaico di *Cala Sant Vicenç*, Maiorca." *L'Archeologo Subacqueo* 9(2):11–4.
- Nowak, T.J. 2001. "A Preliminary Report on *Ophthalmoi* from the Tektaş Burnu Shipwreck." *IJNA* 30:86–94.
- Olmos, R. 1989. "Los griegos en Tartessos: Una nueva contrastación entre las fuentes arqueológicas y las literarias." In *Tartessos: Arqueología protohistórica del bajo Guadalquivir*, edited by M.E. Aubet, 495–521. Barcelona: Editorial AUSA.
- Panvini, R. 1993. "La nave greca di Gela. Dentro lo scafo." *Archeologia Viva* 37:58–67.
- . 2001a. *The Archaic Greek Ship at Gela (and Preliminary Exploration of a Second Greek Shipwreck)*. Translated by B.E. McConnell. Palermo: Salvatore Sciascia Editore.
- . 2001b. "The Second Greek Wreck at Gela: Preliminary Observations." In *The Archaic Greek Ship at Gela (and Preliminary Exploration of a Second Greek Shipwreck)*, edited by R. Panvini, 79–95. Palermo: Salvatore Sciascia Editore.
- Parker, A.J. 1992. *Ancient Shipwrecks of the Mediterranean and the Roman Provinces. BAR-IS 580*. Oxford: Tempus Reparatum.

- Piqué-Huerta, R. 2009. "Annex 1. Determinació de les fustes." In *El vaixell grec arcaic de Cala Sant Vicenç*, edited by X. Nieto and M. Santos, 331–40. Barcelona: Museu d'Arqueologia de Catalunya.
- Pomey, P. 1978. "La coque." In *L'épave romaine de la Madrague de Giens (Var) (Campagnes 1972-1975). Gallia Supplement 34*, edited by A. Tchernia and P. Pomey. Paris: CNRS Editions.
- . 1981. "L'épave de Bon Porté et les bateaux cousus de Méditerranée." *Mariner's Mirror* 67:225–43.
- . 1995. "Les épaves grecques et romaines de la place Jules-Verne à Marseille." *CRAI*:459–84.
- . 1997. "Un exemple d'évolution des techniques de construction navale antique: De l'assemblage par ligatures à l'assemblage par tenons et mortaises." In *Techniques et économie antiques et médiévales: Le temps de l'innovation. Colloque international (C.N.R.S.)*, edited by D. Meeks and D. Garcia, 195–203. Aix-en-Provence: Editions Errance.
- . 1999. "Les épaves grecques du VI<sup>e</sup> siècle av. J.-C. de la place Jules-Verne à Marseille." In *Construction navale maritime et fluviale: Approches archéologique, historique et ethnologique: Actes du Septième Colloque international d'archéologie navale, Île Tatihou, 1994. Archaeonautica 14*, edited by P. Pomey and É. Rieth, 147–54. Paris: CNRS Éditions.
- . 2001. "Les épaves grecques archaïques du VI<sup>e</sup> siècle av. J.-C. de Marseille: Épaves Jules-Verne 7 et 9 et César I." In *Tropis VI. Proceedings of the 6th International Symposium on Ship Construction in Antiquity, Lamia, 1996*, edited by H.E. Tzalas, 425–37. Athens: Hellenic Institute for the Preservation of Nautical Tradition.
- . 2002a. "Épave de Bon Porté 1." In *Les Étrusques en mer: Épaves d'Antibes à Marseille*, edited by L. Long, P. Pomey and J.-C. Sourisseau, 113–6. Aix-en-Provence: Musées de Marseille, Édisud.
- . 2002b. "Épaves Jules-Verne 9 et Jules-Verne 7." In *Les Étrusques en mer: Épaves d'Antibes à Marseille*, edited by L. Long, P. Pomey and J.-C. Sourisseau, 121–3. Aix-en-Provence: Musées de Marseille, Édisud.
- . 2003. "Reconstruction of Marseilles 6th Century BC Greek Ships." In *Boats, Ships and Shipyards: Proceedings of the Ninth International Symposium on Boat and Ship Archaeology, Venice 2000*, edited by C. Beltrame, 57–65. Oxford: Oxbow Books.

- Pomey, P., and L. Long. 1992. "Le premiers échanges maritimes du midi de la Gaule du VI<sup>e</sup> au III<sup>e</sup> s. av. J.-C. à travers les épaves." In *Marseille grecque et la Gaule: Actes du Colloque international d'histoire et d'archéologie et du Ve Congrès archéologique de Gaule méridionale (Marseille, 18-23 novembre 1990)*. Études Massaliètes 3, Travaux du Centre Camille Jullian 11, edited by M. Bats, G. Bertucchi, G. Conges and H. Tréziny, 189–98. Aix-en-Provence: Université de Provence.
- Pomey, P., and E. Rieth. 2005. *L'archéologie navale*. Paris: Editions Errance.
- Pomey, P., and M. Rival. 2002. "Épave Grand Ribaud F." In *Les Étrusques en mer. Épaves d'Antibes à Marseille*, edited by L. Long, P. Pomey and J.-C. Sourisseau, 117–9. Aix-en-Provence: Musées de Marseille, Édisud.
- Polzer, M.E. 2004. "An Archaic Laced Hull in the Aegean: The 2003 Excavation and Study of the Pabuç Burnu Ship Remains." *INA Quarterly* 31(3):3–11.
- Powell, B.B. 1996. *Homer and the Origin of the Greek Alphabet*. Cambridge: Cambridge University Press.
- Prins, A.H.J. 1986. *A Handbook of Sewn Boats: The Ethnography and Archaeology of Archaic Plank-built Craft. Maritime Monographs and Reports* 59. Greenwich: Trustees of the National Maritime Museum.
- Pulak, C. 1999. "The Late Bronze Age Shipwreck at Uluburun: Aspects of Hull Construction." In *The Point Iria Wreck: Interconnections in the Mediterranean ca. 1200 BC. Proceedings of the International Conference, Island of Spetses, 19 September 1998*, edited by W. Phelps, Y. Lolos and Y. Vichos, 209–38. Athens: Hellenic Institute of Marine Archaeology.
- . 2002. "The Uluburun Hull Remains." In *Tropis VII: Proceedings of the 7th International Symposium on Ship Construction in Antiquity. Pylos, 26-29 August 1999*, edited by H.E. Tzalas, 615–36. Athens: Hellenic Institute for the Preservation of Nautical Tradition.
- Py, F., and M. Py. 1974. "Les amphores étrusques de Vaunage et de Villevieille (Gard)." *MÉFRA* 86:141–254.
- Ridgway, D. 2004. "Phoenicians and Greeks in the West: A View from Pithekoussai." In *The Archaeology of Greek Colonisation: Essays Dedicated to Sir John Boardman*, edited by G.R. Tsetschkladze and F.D. Angelis, 35–46. Oxford: Oxford University School of Archaeology. Original edition, 1994.
- Rosloff, J.P. 1981. "INA's 1980 Turkish Underwater Survey." *IJNA* 10:277–86.



- Schlotzhauer, U. 2000. "Die südionischen Knickrandschalen: Formen und Entwicklung der sog. Ionischen Schalen in archaischer Zeit." In *Akten des Symposiums Die Ägäis und das Westliche Mittelmeer: Beziehungen und Wechselwirkungen 8. bis 5. Jh. v. Chr.; Wien, 24. bis 27. März 1999*, edited by F. Krinzinger, 407–16. Vienna: Verlag der Österreichischen Akademie der Wissenschaften.
- Schlotzhauer, U., and A. Villing. 2006. "East Greek Pottery from Naukratis: The Current State of Research." In *Naukratis: Greek Diversity in Egypt: Studies on East Greek Pottery and Exchange in the Eastern Mediterranean*, edited by A. Villing and U. Schlotzhauer, 53–68. London: British Museum Press.
- Shimron, A.E., and D. Avigad. 2003. "The Rock Assemblage." In *The Ma'agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman: Final Report*, Vol. 1, edited by E. Linder and Y. Kahanov, 153–82. Jerusalem, Haifa: Israel Exploration Society, University of Haifa.
- Shimony, C., and E. Werker. 2003. "The Plant Lashings." In *The Ma'agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman: Final Report*, Vol. 1, edited by E. Linder and Y. Kahanov, 230–4. Jerusalem, Haifa: Israel Exploration Society, University of Haifa.
- Sleeswyk, A.W. 1980. "Phoenician Joints, *coagmenta punicana*." *IJNA* 9:243–4.
- Steffy, J.R. 1975. "Nautical Archaeology: Construction Techniques of Ancient Ships." *Naval Engineers Journal* 87:85–91.
- . 1985. "The Kyrenia Ship: An Interim Report on its Hull Construction." *AJA* 89:71–101.
- . 1990. "Problems and Progress in Dating Ancient Vessels by their Construction Features." In *Tropis II. Proceedings of the 2nd International Symposium on Ship Construction in Antiquity, Delphi, 27-29 August 1987*, edited by H.E. Tzalas, 315–20. Delphi: Hellenic Institute for the Preservation of Nautical Tradition.
- . 1994. *Wooden Ship Building and the Interpretation of Shipwrecks*. College Station: Texas A&M University Press.
- . 1999. "Seldom Discussed Features of Ancient and Medieval Ship Construction." In *Construction navale maritime et fluviale: Approches archéologique, historique et ethnologique: Actes du Septième Colloque international d'archéologie navale, Ile Tatihou, Saint-Vaast-la-Hougue, 1994*, edited by P. Pomey and E. Rieth, 165–9. Paris: CNRS Éditions.
- Stern, E. 1982. *Material Culture of the Land of the Bible in the Persian Period, 538–332 B.C.* Warminster: Aris & Phillips.

- Ucelli, G. 1950. *Le navi di Nemi*. 2nd ed. Rome: Libreria dello Stato.
- Udell, M. 2003. "The Woodworking Tools." In *The Ma'agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman: Final Report*, Vol. 1, edited by E. Linder and Y. Kahanov, 203–18. Jerusalem, Haifa: Israel Exploration Society, University of Haifa.
- Van Doorninck, F.H. 1976. "The 4th Century Wreck at Yassi Ada: An Interim Report on the Hull." *IJNA* 5:115–31, 142.
- Van Duivenvoorde, W. Forthcoming. "The Fifth-Century B.C. Shipwreck at Tektaş Burnu, Turkey: Evidence for the Ship's Hull from Nail Concretions." In *Tropis IX. Proceedings of the 9th International Symposium on Ship Construction in Antiquity. Agia Napa, Cyprus, 25-30 August 2005*, edited by H.E. Tzalas. Athens: Hellenic Institute for the Preservation of Nautical Tradition.
- Varadarajan, L. 1998. *Sewn Boats of Lakshadweep*. Dona Paula: National Institute of Oceanography. Original edition, New Delhi, 1994.
- Votruba, G.F. 2004. "Reassembly of the Hull." In *The Ma'agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman: Final Report*, Vol. 2, edited by Y. Kahanov and E. Linder, 211–20. Jerusalem, Haifa: Israel Exploration Society, University of Haifa.
- Wachsmann, S. 1998. *Seagoing Ships and Seamanship in the Bronze Age Levant*. College Station: Texas A&M University Press.
- Waldbaum, J.C., and J. Magness. 1997. "The Chronology of Early Greek Pottery: New Evidence from Seventh-Century B.C. Destruction Levels in Israel." *AJA* 101:23–40.
- Watson, L. and M.J. Dallwitz. 2007, June. *The Families of Flowering Plants: Descriptions, Illustrations, Identification, and Information Retrieval*. Biodiversity and Biological Collections Web Server. <http://delta-intkey.com/angio/www/ident.htm> (10 December 2008).
- White, K.D. 1984. *Greek and Roman Technology*. Aspects of Greek and Roman Life. Ithaca: Cornell University Press.
- Winters, H., and Y. Kahanov. 2004. "Hull-Lines, Seaworthiness, and Burden." In *The Ma'agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman: Final Report*, Vol. 2, edited by Y. Kahanov and E. Linder, 130–3. Jerusalem, Haifa: Israel Exploration Society, University of Haifa.
- Young, R.S. 1963. "Gordion on the Royal Road." *PAPS* 107:348–64.

Yovel, I. 2004. "Tenons." In *The Ma'agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman: Final Report*, Vol. 2, edited by Y. Kahanov and E. Linder, 105–11. Jerusalem, Haifa: Israel Exploration Society, University of Haifa.

APPENDIX A  
CITED TABLES

Table 3.1 Shipwreck Provenience, Date, and Estimated Original Dimensions

Shipwreck	Location	Provenience	Date (B.C.)	Length (m)	Capacity (tons)	Type of Joinery*
Giglio	Italy	Corinth/East Greece <sup>1</sup>	600–580 <sup>2</sup>	25 <sup>3</sup>	—	lig., dc
Pabuç Burnu	Turkey	East Dorian <sup>4</sup>	570–560 <sup>5</sup>	17–18 <sup>6</sup>	—	lig., tc
Bon Porté	France	Massalia <sup>7</sup>	540–510 <sup>8</sup>	10 <sup>9</sup>	2–4	lig., dc
Cala Sant Vicenç	Majorca	Massalia/Emporion <sup>10</sup>	520–500 <sup>11</sup>	20–22 <sup>12</sup>	30	lig., tc
Jules-Verne 9	France	Massalia <sup>13</sup>	525–510 <sup>14</sup>	9.50 <sup>15</sup>	3.0	lig., dc
Jules-Verne 7	France	Massalia <sup>16</sup>	525–510 <sup>17</sup>	15.65 <sup>18</sup>	15.2	(m&t), nails
César 1	France	Massalia <sup>19</sup>	510–500 <sup>20</sup>	10 <sup>21</sup>	—	(m&t), nails
Grand Ribaud F	France	Greece/Massalia <sup>22</sup>	510–490 <sup>23</sup>	25 <sup>24</sup>	30–38	m&t, nail
Gela 1	Sicily	Magna Graecia <sup>25</sup>	500–480 <sup>26</sup>	20 <sup>27</sup>	—	lig., dc, tc
Gela 2	Sicily	Magna Graecia/Greece <sup>28</sup>	450–425 <sup>29</sup>	18 <sup>30</sup>	—	(m&t), nails
Tektaş Burnu	Turkey	Ionia (Erythrae?) <sup>31</sup>	440–425 <sup>32</sup>	14 <sup>33</sup>	6–7	(m&t), nails
Alonnesos	Greece	Greece (Athens?) <sup>34</sup>	420–400 <sup>35</sup>	>25 <sup>36</sup>	>126	—
Ma`agan Mikhael	Israel	Aegean or Cyprus <sup>37</sup>	410–390 <sup>38</sup>	13.8 <sup>39</sup>	23	(m&t), nails
Porticello	Italy	Greece <sup>40</sup>	400–385 <sup>41</sup>	16.6 <sup>42</sup>	—	m&t, nails
Kyrenia	Cyprus	Rhodes <sup>43</sup>	295–285 <sup>44</sup>	14 <sup>45</sup>	30+	m&t, nails

\*Principal types of joinery evident in the hull remains: “lig.” = ligatures laced through tetrahedral notches; “dc” = dowel coaks; “tc” = tenon coaks; “(m&t)” = pegged mortise-and-tenon joinery with ligatures in the extremities or repairs, or any other vestige of laced construction; “m&t” = pegged mortise-and-tenon joinery; “nails” = metal nails to attach the frames.

<sup>1</sup> Cristofani 1996; Bats 1996, 577; Mark 2005, 40–2.

<sup>2</sup> Bound 1985, 50–1; Bound 1991, 14–6.

<sup>3</sup> Winters and Kahanov 2004, 49.

<sup>4</sup> Greene et al. 2008, 703–4.

<sup>5</sup> Greene et al. 2008, 700.

<sup>6</sup> Greene et al. 2008, 703.

<sup>7</sup> Liou 1975b, 597; Pomey and Long 1992, 192; Kahanov and Pomey 2004, 14.

<sup>8</sup> Liou 1974, 1975a; Pomey 2002, 113.

<sup>9</sup> Joncheray 1976, 23; Pomey 2002, 116.

<sup>10</sup> Nieto et al. 2004, 208.

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- <sup>11</sup> Nieto and Santos (2009, 318) give a *terminus post quem* of 520 B.C. and a *terminus ante quem* of between 510 and 500 B.C., bringing the date of the shipwreck forward slightly from earlier reports (Nieto et al. 2004, 209).
- <sup>12</sup> Nieto and Santos 2009, 60–4.
- <sup>13</sup> Pomey 1995, 470–1.
- <sup>14</sup> Pomey 1995, 470–1.
- <sup>15</sup> Pomey 2003, 64.
- <sup>16</sup> Pomey 1995, 470–1.
- <sup>17</sup> Pomey 1995, 470–1.
- <sup>18</sup> Pomey 2003, 63.
- <sup>19</sup> Pomey 1999; Pomey 2001, 430.
- <sup>20</sup> Pomey 2001, 425, 432 n. 9.
- <sup>21</sup> Pomey 2001, 429.
- <sup>22</sup> Long et al. 2001, 43.
- <sup>23</sup> Long et al. 2002, 34.
- <sup>24</sup> Long et al. 2001, 31, 42; Pomey and Rival 2002, 119.
- <sup>25</sup> Panvini 2001a, 33.
- <sup>26</sup> Panvini 2001a, 17.
- <sup>27</sup> Long et al. 2001, 42.
- <sup>28</sup> Panvini 2001b.
- <sup>29</sup> Panvini 2001b, 81–3.
- <sup>30</sup> Benini (2001, 104) estimates the original length to be comparable to that of the Gela 1 ship, which he reports erroneously as 17 m.
- <sup>31</sup> Carlson 2003, 596.
- <sup>32</sup> Carlson 2003, 581, 590.
- <sup>33</sup> Van Duivenvoorde (forthcoming), superceding Carlson's (2003, 596) original estimate of 10–12 m; see Carlson (2003, 596 n. 66) for tonnage estimate of the cargo.
- <sup>34</sup> Hadjidaki 1996.
- <sup>35</sup> Hadjidaki 1996, 590.
- <sup>36</sup> Hadjidaki 1996, 564, 588.
- <sup>37</sup> Based on types of wood used in the hull (Liphschitz 2004, 159) and on the ceramic assemblages (Artzy and Lyon 2003, 197–8), respectively.
- <sup>38</sup> Artzy and Lyon 2003, 197.
- <sup>39</sup> Winters and Kahanov 2004, 131 table 2.
- <sup>40</sup> Eiseman and Ridgway 1987, 112–3.
- <sup>41</sup> Lawall (1998), refining the originally published date of 415–385 B.C. (Eiseman and Ridgway 1987).
- <sup>42</sup> Eiseman and Ridgway 1987, 13. The vessel's size and capacity are based on the reconstructed dimensions of the Kyrenia ship, proportioned accordingly by the number and distribution of fasteners (nails) on each wreck.
- <sup>43</sup> Katzev 2005, 75.
- <sup>44</sup> Katzev 2005, 76.
- <sup>45</sup> Steffy 1985, 100; Katzev 2005, 75–6.

Table 4.1. Keel Design on Ancient Greek Ships

Shipwreck	Wood	Shape Sectional, Longitudinal	Rabbet	Pres. Length (m)	Sided (cm)	Molded (cm)	False Keel	Keel-Stem Scarf	Keel-Sternpost Scarf
Giglio <sup>1</sup>	—	rectangular rockered	at ends	2.76	15 <sup>2</sup>	22	no	—	chamfered and tongued
Bon Porté <sup>3</sup>	<i>Pinus</i> sp.	slightly trapezoidal	no	—	6/6.4	9.6	no	—	—
Cala Sant Vicenç <sup>4</sup>	<i>Quercus ilex</i>	rectangular	no	5.50	13	17	yes <sup>5</sup>	—	—
Jules-Verne 9 <sup>6</sup>	<i>Quercus</i> sp.	rectangular	no	—	6.8	7	—	keyed box scarf	endposts rabbeted
Jules-Verne 7 <sup>7</sup>	<i>Quercus ilex</i>	rectangular	at ends	10.7	10.0	11.0	—	keyed box scarf and treenail	endposts rabbeted at lower length
Grand Ribaud F <sup>8</sup>	<i>Quercus</i> sp.	—	—	—	—	—	—	—	—
Gela 1 <sup>9</sup>	<i>Pinus pinea</i>	rectangular	at ends	—	25	37	—	rabbeted	rabbeted
Gela 2 <sup>10</sup>	—	rectangular	—	—	—	—	no	—	—
Ma`agan Mikhael <sup>11</sup>	<i>Pinus brutia</i>	rectangular slightly rockered	at ends	8.62	11.0	16.0	yes <sup>12</sup>	box scarf with vertical pegged tenon	rabbeted
Kyrenia <sup>13</sup>	<i>Pinus brutia</i>	rectangular slightly trapezoidal	entire length	9.33	12.8	20.3	yes <sup>14</sup>	hook scarf (wedged) inner/outer post assembly nailed/m&t	keel/stern-post knee

<sup>1</sup> Bound 1985, 53; Bound 1991, 31, 33 fig. 76; Kahanov and Linder 2004, 50, which gives maximum dimensions of 21.3 cm sided and 22.1 cm molded.

<sup>2</sup> The keel is sided about 15 cm and molded 22 cm along most of its length (Bound 1985, 53), but towards the stern it has dimensions of 19.6 and 20.6 cm, respectively. From there, the molded dimension diminishes to 11.9 cm at the aft end (Bound 1991, 31).

<sup>3</sup> Joncheray 1976, 26, 32–4.

<sup>4</sup> Nieto and Santos 2009, 40–1.

<sup>5</sup> The false keel has a square section with 13 cm sides, and is also made of Holm oak (*Quercus ilex*) (Nieto and Santos 2009, 41).

<sup>6</sup> Pomey 1999, 148.

<sup>7</sup> Pomey 1999, 150–1; Kahanov and Linder 2004, 55.

<sup>8</sup> Long et al. 2001, 40–1.

<sup>9</sup> Panvini 2001, 20 fig. 10, 24–5; Terranova and Campo 2001, 111 for the wood species.

<sup>10</sup> Benini 2001, 100–1.

<sup>11</sup> Kahanov 2003, 54–64; Liphschitz 2004, 156–7 for the keel wood species.

<sup>12</sup> The false keel measures 10.18 m long; it is sided 11 cm and molded 7.5 cm along most of its length, but reduces to 6.0 cm at the bow and 7.2 cm at the stern (Kahanov 2003, 59–61). It is made of oak (*Quercus petraea*/*Q. pubescens*) (Liphschitz 2004, 157).

<sup>13</sup> Steffy 1985, 72–6; Steffy 1994, 43, 45 fig. 3–24. The keel was sided 12.2 cm at the rabbet and 10 cm at the false keel, giving it a trapezoidal cross section (Steffy 1985, 87).

<sup>14</sup> The false keel is less than 3 cm thick (Steffy 1985, 75 ill. 3) and made of Turkey oak (*Quercus cerris*) (Steffy 1985, 87).

Table 4.3. Hull Planking from Ancient Greek Shipwrecks

Shipwreck	Hull Length (m)	Primary Joinery	Width <sup>1</sup> (cm)	Thickness <sup>1</sup> (cm)	Wood Type
Giglio <sup>2</sup>	25	lacing	26	2.5–4.2	<i>Pinus sylvestris</i>
Pabuç Burnu	17–18	lacing	20.2–30.5	2.5–4.5 (3.7)	<i>Pinus nigra</i>
Bon Porté <sup>3</sup>	10	lacing	12	2.4–2.6 (2.5)	—
Jules-Verne 9 <sup>4</sup>	9.50	lacing	15–20	2.7–3.0	<i>Pinus halepensis</i> , <i>Pinus pinea</i>
Jules-Verne 7 <sup>5</sup>	15.65	mortise-and-tenon	14–28	2.5–3.0	<i>Pinus halepensis</i>
Cala Sant Viçenc <sup>6</sup>	20–22	lacing	30–45 (39)	4.5	<i>Pinus sylvestris</i>
César 1 <sup>7</sup>	10	mortise-and-tenon	—	—	—
Grand Ribaud F <sup>8</sup>	25	mortise-and-tenon	—	3.5	<i>Abies alba</i>
Gela 1 <sup>9</sup>	20	lacing	—	—	<i>Pinus pinea</i>
Gela 2 <sup>10</sup>	18	mortise-and-tenon	25–30	4.5	<i>Pinus nigra</i>
Ma'agan Mikhael <sup>11</sup>	13.8	mortise-and-tenon	11.3–32.0	3.5–5.0 (4.3)	<i>Pinus brutia</i>
Kyrenia <sup>12</sup>	14	mortise-and-tenon	18.5–31.5	3.2–4.1 (3.7)	<i>Pinus brutia</i>

<sup>1</sup> Value in parentheses is the average value for the range.

<sup>2</sup> Bound (1991a, 49) gives the width of a garboard as 26 cm; see Kahanov and Linder (2004, 50) for the planking thicknesses; Bound 1991a, 43; Bound 1991b, 31 for the wood species. Kahanov and Linder (2004, 50) gives the plank wood as pine and fir.

<sup>3</sup> Joncheray 1976, 28; Pomey 2002, 113. The plan of the hull remains shows planking fragments from six strakes with widths of 18–28 cm (21 cm on average) (Joncheray 1976, 24); three sectional drawings show similarly wider planks (Joncheray 1976, 27).

<sup>4</sup> Pomey 1999, 148, 150 n. 3.

<sup>5</sup> Pomey 1999, 150, 151 n. 6.

<sup>6</sup> Nieto and Santos 2009, 46.

<sup>7</sup> No specific dimensions are provided, but they are reported to be similar to those of Jules-Verne 9 (Pomey 2001 429).

<sup>8</sup> Long et al. 2001, 39.

<sup>9</sup> Terranova and Campo 2001, 111.

<sup>10</sup> Benini 2001, 104 for dimensions; Terranova and Campo 2001, 113 for wood identification.

<sup>11</sup> Linder and Kahanov 2003, 71–8, 80 table 13 for dimensions; Hillman and Liphschitz 2004, 145 for wood identification.

<sup>12</sup> Steffy 1985, 79 for dimensions, 87 for wood identification.

Table 4.4. Planking Scarfs in Ancient Greek Hulls

Shipwreck	Type	Location on Hull	Bow-ward Angle	
			Forward	Aft
Giglio <sup>1</sup>	diagonal, three-plane (Z)	lower	—	—
Pabuç Burnu	diagonal	lower	—	—
	butt	upper (above waterline)	—	—
	curved (S) with hook	upper (above waterline)	—	—
Jules-Verne 9 <sup>2</sup>	diagonal	garboard, strake 3	down	—
Jules-Verne 7 <sup>3</sup>	diagonal	strakes 1–6	down	up
	three-planed (Z)	strakes 7–13	down	up
Cala Sant Vicenç <sup>4</sup>	diagonal	garboards	—	—
	curved (S)	strake 3E, 5E, 3W?	—	—
Gela 1 <sup>5</sup>	diagonal	strake 4	—	up
Gela 2 <sup>6</sup>	diagonal	strake 2	—	—
		strake 10?	down?	—
Ma‘agan Mikhael <sup>7</sup>	curved (S)	strakes 2–5	down	up
	three-planed (Z)	strake 4	down	up
	diagonal	strake 6–11	down	up
Kyrenia	diagonal	all planking	down	up
	three-planed (Z)	wales	down	up

<sup>1</sup> Kahanov and Linder 2004, 50.

<sup>2</sup> Pomey 1995, 472 fig. 7.

<sup>3</sup> Pomey 1999, 149 fig. 3, 150.

<sup>4</sup> Nieto et al. 2004, 222 fig. 3.

<sup>5</sup> Panvini 2001, 18 fig. 3.

<sup>6</sup> Benini 2001, 104 fig. 60, 152 pl. 36.

<sup>7</sup> Kahanov 2003; Linder and Kahanov 2003, 78–81.



Table 4.5. Edge Inserts (Coaks and Joints) Employed in Ancient Greek Hulls

Shipwreck	Type	Function	Construction	Dimensions (cm)				Sp. (c-c) <sup>1</sup>
				Diam.	Width	Thk.	Length	
Giglio <sup>2</sup>	dowel	coak	original	1.5	—	—	—	33
Pabuç Burnu	tenon	coak	original	—	3.2	0.9	11.1	29.8
	dowel	coak	repair	1.0–1.4	—	—	17.4	26.5
Bon Porté <sup>3</sup>	dowel	coak	original	1.0	—	—	12	15–16
Jules-Verne 9 <sup>4</sup>	dowel	coak	original	1.0	—	—	11	20.5
Jules-Verne 7 <sup>5</sup>	tenon	joint	original	—	3.0–3.5	0.5	14–15	23
	dowel	coak	original and repair	—	—	—	—	—
Cala Sant Vicenç <sup>6</sup>	tenon	coak	original (strakes)	—	2.8–3.0	0.9	13.5	18–35 (28)
	dowel	coak	repair (keel)	1.7	—	—	20–25	20–45 (32)
César 1 <sup>7</sup>	tenon	joint	original	—	—	—	—	—
	dowel	coak	original and repair	—	—	—	—	—
Grand Ribaud F <sup>8</sup>	tenon	joint	original	—	4.5	—	12	20
Gela 1 <sup>9</sup>	dowel	coak	original	1.0–1.2	—	—	—	18
	tenon	coak	original	—	—	—	—	—
Gela 2 <sup>10</sup>	tenon	joint	original	—	—	—	12	24.5
	dowel	coak	original and repair	—	—	—	—	—
Ma`agan Mikhael <sup>11</sup>	tenon	joint	original	—	3.9	0.7	15.4	13.0
Kyrenia <sup>12</sup>	tenon	joint	original	—	4–5	0.55	15–16	11.7
Kyrenia ceiling <sup>13</sup>	dowel	coak	reused	1.5	—	—	—	14

<sup>1</sup> Value in parentheses is the average of the range.

<sup>2</sup> Bound 1985, 55; Kahanov and Linder 2004, 50–1. Spacing is provided only for dowel coaks between the keel and garboards, which were applied in pairs (one on either side of the keel) spaced 3.8 cm apart (Kahanov and Linder 2004, 51).

<sup>3</sup> Joncheray 1976, 28. Coak spacing along the keel-garboard seams is 13 cm, and the coaks in one side of the keel are staggered from those in the opposite side (Joncheray 1976, 25–6).

<sup>4</sup> Pomey 1995, 471; Kahanov and Linder 2004, 54 for the length of the dowels.

<sup>5</sup> Pomey (1997, 198) gives the space between tenons as 19–20 cm.

<sup>6</sup> Nieto and Santos 2009, 27 fig. 22, 42 for the dowels, 51 for the tenons.

<sup>7</sup> Pomey 2001, 429–30.

<sup>8</sup> Long et al. 2001, 39.

<sup>9</sup> Panvini (2001, 21–2, 26 fig. 22) reports a space of 20 cm between tenons.

<sup>10</sup> Benini 2001, 101 fig. 59 for tenon length (estimated from the distance between locking pegs), 104 for spacing.

<sup>11</sup> Yovel 2004, 106 table 1. Average mortise dimensions are slightly larger: 4.1 cm wide, 0.8 cm thick, and 8.2 cm deep (Kahanov and Linder 2004, 126 table 1).

<sup>12</sup> Steffy 1985, 81, 82 table 3. Average mortise depth is 8 cm, and while some tenons are the same length as the combined depths of their mortises, most are 0.5–1.0 cm shorter.

<sup>13</sup> Steffy 1985, 95, with dimensions estimated from ill. 17 (starboard ceiling B at F28).

Table 4.6. Average Dimensions of Lacing Holes and Notches from Ancient Greek Shipwrecks

Shipwreck	Ligature Holes (cm)		Tetrahedral Notches (cm)					
	Diam.	Angle	Base	Side 1	Side 2	Offset from Edge*	Space between corners	Space (c-c)
Giglio <sup>1</sup>	0.7	45–62°	2.1	1.6	1.5	1.5	3.4	5.6
Pabuç Burnu	0.7	45°	2.0	1.8	1.8	1.8	2.8	4.8
Bon Porté <sup>2</sup>	0.6	45°	1.3–1.7 (1.5)			0.6	2.5	4.1
Jules-Verne 9 <sup>3</sup>	0.6	—	1.5–1.7 (1.7)			0.8	3.4	4.8–5.0
Jules-Verne 7 <sup>4</sup>	—	—	slightly larger than those of Jules-Verne 9 (1.7 cm)			—	—	—
Cala Sant Viçenc <sup>5</sup>	—	—	2.0	—	—	1.5	2.5–3.0	5.0
César 1 <sup>6</sup>	—	—	similar to those of Jules-Verne 9 (1.7 cm)			—	—	—
Gela 1 <sup>7</sup>	—	—	1.5			1.5	3.0	4.5
Gela 2 <sup>8</sup>	—	—	1.5–2.0	1.0–1.5		—	—	—
Ma`agan Mikhael <sup>9</sup>	0.6	42°	1.7	1.6	1.5	1.1	2.9	4.5

\*Distance from the base of the tetrahedral notch to the seam edge of the plank.

<sup>1</sup> Bound 1985, 55; Kahanov and Linder 2004, 51–2, tables 5–7.

<sup>2</sup> Joncheray 1976, 26, 28–9; Pomey 1981, 225; Kahanov and Linder 2004, 53.

<sup>3</sup> Kahanov and Linder 2004, 54; Pomey (1999, 149) gives a spacing (assumed to be between corners) of 2.5 cm.

<sup>4</sup> Kahanov and Linder 2004, 55.

<sup>5</sup> Nieto et al. 2004, 202–3.

<sup>6</sup> Pomey 2001, 429.

<sup>7</sup> Panvini 2001, 21; Kahanov and Linder 2004, 57.

<sup>8</sup> Estimated from Benini 2001, 101 fig. 59.

<sup>9</sup> Average of the values given in Kahanov and Linder 2004, 297 appendix A.

Table 4.7A. Framing Characteristics of Ancient Greek Ships

Shipwreck	Type	Wood Species	Sectional Shape and Features	Floor-Futtock Join	Fastening to Hull
Giglio <sup>1</sup>	made-frames	—	trapezoidal with rounded top	—	—
Pabuç Burnu	made-frames	—	trapezoidal with rounded top	—	ligatures
	top-timbers	—	rectangular	—	ligatures and treenails
Bon Porté <sup>2</sup>	made-frames	conifer	trapezoidal with rounded top	diagonal and hook scarf fixed with 2 treenails	pegged ligatures
Jules-Verne 9 <sup>3</sup>	made-frames	<i>Pinus halepensis</i>	trapezoidal with rounded top; base notched over seams	hook scarf fixed with treenails	pegged ligatures
	top-timbers	—	—	—	—
Jules-Verne 7 <sup>4</sup>	made-frames	<i>Alnus glutinosa</i> , <i>Pinus halepensis</i>	trapezoidal with rounded top; base notched over seams	hook scarf fixed with treenails	double-clenched iron nails
	top-timbers	—	rectangular	—	ligatures and treenails
Cala Sant Vicenç <sup>5</sup>	made-frames	<i>Pinus pinea</i> / <i>pinaster</i>	trapezoidal with rounded top; base notched over seams	hook scarf fixed with 2 treenails	pegged ligatures
César 1 <sup>6</sup>	made-frames	—	trapezoidal with rounded top; base notched over seams	hook scarf fixed with square treenails	iron nails
Grand Ribaud F <sup>7</sup>	made-frames	—	trapezoidal with rounded top; base notched over seams	hook scarf fixed with treenails	double-clenched iron nails
Gela 1 <sup>8</sup>	made-frames	<i>Pinus pinea</i>	trapezoidal with rounded top; base notched over seams	hook scarf fixed with 3 treenails	double-clenched copper or iron nails
Gela 2 <sup>9</sup>	made-frames	<i>Pinus pinea</i>	trapezoidal with rounded top; limber holes (8–10/frame)	hook scarf fixed with treenail	double-clenched bronze nails
Ma'agan Mikhael <sup>10</sup>	made-frames futtocks/top-timbers	<i>Pinus brutia</i>	trapezoidal with rounded top; limber holes (2–6/frame)	hook scarf fixed with 3–5 square treenails	double-clenched copper nails
Kyrenia <sup>11</sup>	floors/futtocks half-frames	<i>Pinus halepensis</i>	square; limber holes (2–6/frame)	detached	double-clenched copper nails through treenails

<sup>1</sup> Kahanov and Linder 2004, 50.

<sup>2</sup> Joncheray 1976, 26–7, with frame spacing estimated from hull plan (p. 24); spacing is reported elsewhere as 92–100 cm (Pomey 1981, 225) and 90 cm (Pomey 2002, 113).

<sup>3</sup> Kahanov and Linder 2004, 54; Kahanov and Pomey 2004, 15) gives a spacing between centers of 96 cm; Pomey (1995, 426–7) reports frame dimensions of 8.5 cm sided at the top, 3 cm sided at the base, and a spacing of 90 cm.

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<sup>4</sup> Kahanov and Linder 2004, 55; Pomey (1995, 426) and Pomey (1999, 151–2) report a spacing of 90 cm; see Pomey 1999, 151 n. 6 for wood species identification.

<sup>5</sup> Nieto and Santos 2009, 30; Piqué-Huerta 2009, 338; Nieto et al. 2004, 206; Nieto et al. 2005, 44.

<sup>6</sup> Pomey 2001, 430; Kahanov and Pomey 2004, 17; Kahanov and Linder 2004, 56.

<sup>7</sup> Long et al. 2001, 39–40.

<sup>8</sup> Panvini 2001, 20–1, with floor sided dimensions estimated from fig. 10. Frame spacing is from Benini 2001, 101 n. 11. Kahanov and Linder (2004, 57) report a center-to-center spacing of 84 cm. Reconciling these data, it would seem that frame spacing between centers (room-and-space) is 93 cm, and between edges (space) is 84 cm.

<sup>9</sup> Benini (2001, 101, 153 pls. 36–7) reports a spacing of 60–70 cm, but does not specify the type of spacing. Judging from pl. 36, it is probably space between the frames. Kahanov and Linder (2004, 58) would seem to confirm this when reporting spacing between frames as 70 cm. Assuming frame dimensions estimated from Benini (2001, 153 pls. 36–7), room-and-space would be approximately 90 cm.

<sup>10</sup> Kahanov 2003, 88–95.

<sup>11</sup> Steffy 1985, 84–6; Steffy 1994, 48–9.

Table 4.7B. Framing Dimensions of Ancient Greek Ships

Shipwreck	Type	Frame Space (cm)	Room & Space (cm)	Sided (cm)		Ratio (Top/Btm)	Molded (cm)
				Top	Btm		
Giglio <sup>1</sup>	frames	—	—	18	—	—	12.3
Pabuç Burnu	frames	68.7	84	15	7.0	2.2	—
	top-timbers	68.7	84	15.3	15.3	1.0	—
Bon Porté <sup>2</sup>	frames	81–83	93	10–12	2–3	4–5	11–14
Jules-Verne 9 <sup>3</sup>	frames	87	96	9.5	3	5.2	11.2
Jules-Verne 7 <sup>4</sup>	frames	—	98	—	—	—	—
	top-timbers	—	98	4–5	4–5	1.0	8
Cala Sant Vicenç <sup>5</sup>	floor timbers	—	(95)	16–22	1.5–3.5	8–11	24–31
	futtock	—		25.5	—	5	—
Grand Ribaud F <sup>6</sup>	frames	82	101–102	19–20	5	4	26
Gela 1 <sup>7</sup>	frames	84	93	(8–9)	(3.5–4)	2.6	10–14
Gela 2 <sup>8</sup>	frames	60–70	90	(20)	(9)	(2.2)	(30–35)
Ma‘agan Mikhael <sup>9</sup>	frames	61	75	14.2	6.2	2.3	23.0
	futtocks/top-timbers	61	75	12.6	5.8	2.2	10.8
Kyrenia <sup>10</sup>	floors	16	25	9	9	1.0	9

Note: Values in parentheses are estimated from drawings.

<sup>1</sup> Kahanov and Linder 2004, 50.

<sup>2</sup> Joncheray 1976, 26–7, with frame spacing estimated from hull plan (p. 24); spacing is reported elsewhere as 92–100 cm (Pomey 1981, 225) and 90 cm (Pomey 2002, 113).

<sup>3</sup> Kahanov and Linder 2004, 54; Kahanov and Pomey (2004, 15) gives a spacing between centers of 96 cm; Pomey (1995, 426–7) reports frame dimensions of 8.5 cm sided at the top, 3 cm sided at the base, and a spacing of 90 cm.

<sup>4</sup> Kahanov and Linder 2004, 55; Pomey (1995, 426; 1999, 151–2) reports a spacing of 90 cm; see Pomey 1999, 151 n. 6 for wood species identification.

<sup>5</sup> Nieto et al. 2004, 206; Nieto et al. 2005a, 44.

<sup>6</sup> Long et al. 2001, 39–40.

<sup>7</sup> Panvini 2001, 20–1, with floor sided dimensions estimated from 20 fig. 10; frame spacing is from Benini 2001, 101 n. 11; Kahanov and Linder (2004, 57) reports a center-to-center spacing of 84 cm. However, reconciling these data, it would seem that frame spacing between centers is 93 cm, and between edges (space) is 84 cm.

<sup>8</sup> Benini (2001, 101, 153 pls. 36–7) reports a spacing of 60–70 cm, but does not specify the type of spacing; judging from pl. 36, it is probably between the frames. Kahanov and Linder (2004, 58) would seem to confirm this in reporting spacing between frames of 70 cm. Using frame dimensions estimated from Benini 2001, 153 pls. 36–7, spacing between centers would be approximately 90 cm.

<sup>9</sup> Kahanov 2003; Linder and Kahanov 2003, 88–95.

<sup>10</sup> Steffy 1985, 84–6; Steffy 1994, 48–9.

## VITA

Mark Polzer received a Bachelor of Science degree in chemical engineering, with a minor emphasis in petroleum engineering, from Texas A&M University in 1986. He enjoyed a successful career in the petroleum refining and petrochemicals business for more than a dozen years before deciding to pursue his lifelong interest in maritime archaeology of the ancient world. He received a Masters of Arts degree in anthropology from Texas A&M University in 2009. During his time in the Nautical Archaeology Program and as a research associate of the Institute of Nautical Archaeology, he has participated in and directed numerous shipwreck excavations and surveys in the Mediterranean, Aegean, Sea of Marmara, and Black Sea. He co-directed the excavation of the Archaic shipwreck at Pabuç Burnu and is the principal investigator of its hull remains. He is currently co-directing the excavation of a Phoenician shipwreck off the southeastern coast of Spain, and is developing an underwater survey for ancient shipwrecks in Libya. His research interests include ancient ship construction, Archaic ships and seafaring, Greek and Phoenician colonization, sails and rigging in the ancient world, and ship iconography.

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