A ROMAN WRECK AT CAESAREA MARITIMA, ISRAEL:
A COMPARATIVE STUDY OF ITS HULL AND EQUIPMENT

A Dissertation

by

MICHAEL ANDREW FITZGERALD

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

DOCTOR OF PHILOSOPHY

May 1995

Major Subject: Anthropology
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Approved as to style and content by:

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(Co-Chair of Committee)

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May 1995

Major Subject: Anthropology
ABSTRACT

A Roman Merchant Ship at Caesarea Maritima, Israel:
A Comparative Study of Its Hull and Equipment. (May 1995)

Michael Andrew Fitzgeral, B.A., University of Colorado

Co-Chairs of Advisory Committee: Dr. George F. Bass
Dr. Frederick H. van Doorninck, Jr.

The hull remains and equipment of a heavy Roman merchant ship are described and illustrated, with particular attention given to construction details and features. Succeeding chapters comprise individual treatments of each construction detail of the hull and equipment, including relevant ancient literary and pictorial evidence and catalogs of all accessible comparative archaeological data. Each chapter concludes with a discussion of the feature with regard to evident technological patterns or trends and their implications for the interpretation of the Caesarea hull. The final chapters are devoted to the reconstruction, dating, and analysis of the ship in its historical, archaeological, and technological contexts. The comparative studies reveal that the ship was probably quite flat-bottomed, measured some 40–45 m in length, and is one of the most heavily built Roman merchant hulls yet documented. In this perhaps unique case, hull construction and equipment details allow the dating of the ship’s construction with a fair degree of confidence. The most important product of both the documentation of the Caesarea hull and its analysis with respect to the comparative corpus may be a new hypothesis regarding Graeco-Roman shipbuilding: that approaches to the construction of large ships differed fundamentally from approaches common to the building of small ships. Due to limitations inherent in the nature of mortise-and-tenon “shell-first” shipbuilding, wherein the shell is the primary structural hull component, frames were more important in large ships than they were in small ships. Therefore, knowledge accumulated through a long history of building big ships facilitated changes to faster and more efficient methods of shipbuilding required by the deteriorating economic conditions of the later Roman and early Byzantine periods. These and other factors were part of an evolution in ship construction that resulted in “frame-first” techniques at least by the tenth or eleventh century A.C.
DEDICATION

To my parents.
ACKNOWLEDGEMENTS

A study of the hull at Caesarea was suggested to me by Professor Avner Raban in the summer of 1984 and echoed by Professor Frederick H. van Doorninck, Jr., in the winter of the following year. Without that little push and Professor Raban’s permission to study the wreck, this project might not have been undertaken. Professor George F. Bass’ unflagging confidence and support since my entry into the doctoral program has been a constant source of inspiration. Professor van Doorninck’s agreement to serve as co-chair of the advisory committee eliminated potential problems with graduation deadlines. For the opportunity to study under the guidance of Professor J. Richard Steffy I am most privileged and grateful. Sincere thanks to all for the opportunities they have afforded me, and for their services as advisory committee members. Thanks also to Professor Craig W. Kallendorf for serving as the outside committee member.

The field work upon which this study is based was conducted only with the help of the directors, staff, and volunteers of the Caesarea Ancient Harbour Excavation Project (CAHEP). Directors were Professor Avner Raban, University of Haifa; Professor Robert L. Hohlfelder, University of Colorado; Professor John P. Oleson, University of Victoria, British Columbia; Professor Robert L. Vann, University of Maryland; and Professor Robert R. Stieglitz, Rutgers University. CAHEP staff members Steven Breitstein and Yossi Tur-Caspa of the University of Haifa provided tireless technical and logistical support, and excavation equipment that always worked, with the help of Danny Syon, Ezra Marcus, and Steve Burton. Steve Breitstein, Yossi Tur-Caspa, Ezra Marcus, and Zaraza Friedman performed emergency photographic services in 1985. Additional photographic support was provided by Professors Raban and Hohlfelder, Mark Little, Harry Wadsworth, and Zaraza Friedman. Staff architects Jill Schick, Sissela Malmström, Clark Blouir, Lauren Goldberg, and Donna McIntire, under the direction of Professor Vann, drew the ship timbers. CAHEP staff members Tom Hillard and Mark Little were always ready and willing to do anything to help.

Special gratitude is extended to Lauren Goldberg, who in 1986 was often my only dive partner and consequently spent a huge amount of time on the wreck either removing sand, filling sandbags, or re-fueling the dredge pump and starting it up again. All this was in addition to producing most of the fine drawings of the hull timbers.
Thanks also to the many CAHEP volunteers who helped suck prodigious amounts of sand off the wreck, fill sandbags, assist with air-jet probes, set up and break down dredges and inflatable boats, and do all the other things that made it happen.

In the course of researching, evaluating, and preparing the material, I have benefited from discussions with fellow students Elizabeth Garver, (now Dr.) Fred Hocker, Jack Neville, (now Dr.) Bob Neyland, Aleydis Van de Moortel, and Cemal Pulak. Elizabeth Garver, Claire Peachey, Ralph Pedersen, Paul Willoughby, and especially Maria Jacobsen read and critiqued different parts of the manuscript at various stages. Professor John Oleson performed extensive editing while preparing most of this manuscript for inclusion in the Caesarea excavation report. Professor Donny Hamilton permitted and guided my use of the Texas A&M University Conservation Research Laboratory facilities during the processing and replication of iron and copper alloy artifacts. Bruce Thompson willingly gave assistance and advice regarding the casting of some iron artifacts. Peter van Alfen, Elizabeth Greene, and Jeff Tippie rendered photographic services in College Station and saved me considerable expense. Debbie Meier drew the fastenings and replicated a lost Lauren Goldberg drawing. Claudia LeDoux was always a friend and never failed to answer questions and fix problems and help in any way she could.

Many people contributed financial and moral support in one form or another. Very special thanks to my parents, Andy and Joan Fitzgerald, and to Clifford and Mildred Haines, Duane and Linda Sharp, Charles and Carla Waters, William B. Graff, Cemal and Sema Pulak, Thomas A. Quesenbery, Ann Bass, Kevin and Ginny Crisman, and the directors of CAHEP. I am most particularly grateful to Professor Robert Hohlfelder, Professor of Ancient History at the University of Colorado. His enthusiasm for his work at Caesarea and our sustained contact over the years led to my first volunteer season at Caesarea, after which I applied to the Nautical Archaeology Program at Texas A&M University. His assistance and encouragement as a friend and CAHEP director have been fundamental to this work.

The importance of Claire Peachey’s friendship and support during the past two years cannot be overstated. Thank you.
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CHAPTER I

INTRODUCTION

Between 22 and 10 B.C.E., Herod the Great, Augustus’ client king of Judea, built the city and harbor of Caesarea Maritima. Herod intended that the city glorify his own name, demonstrate his loyalty to Caesar, and challenge Alexandria as the preeminent seaport in the eastern Mediterranean (Hohlfelder 1988: 1; Sidebotham 1986: 71–77). The harbor itself was called Σεβαστός (Sebastos), the Greek equivalent of the title Augustus, and is described in some detail by the first-century historian Flavius Josephus (Bellum Judaicum 1.408–14; Antiquitates Judaicae 15.331–41). Situated on the Levantine coast between Haifa and Tel Aviv, Israel (fig. 1), the now-submerged harbor structures have been the object of study by the Caesarea Ancient Harbour Excavation Project (CAHEP) since 1980 and by the Combined Caesarea Expedition since 1989.¹ It was in association with the CAHEP explorations between 1983 and 1988 that the hull remains of an ancient ship found in the north bay, adjacent to the major harbor complex, were partly excavated and documented.

This dissertation seeks to reconstruct the hull’s basic configuration, establish its date, and determine its significance in the history of Graeco-Roman shipbuilding, through comparison of its hull and equipment with pertinent pictorial, literary, and archaeological evidence.

Pictorial representations of ships of all sizes from the Graeco-Roman period abound (Foucher 1957; 1967; Morrison and Williams 1968; Casson 1986; Basch 1988). They convey general ideas about hull configurations, equipment and rigging, but elucidate few details of shipwrightry. A rare exception, dated to the late second or early third century A.D., is a shipbuilding scene in relief on the tombstone of one P. Longidienus. The relief depicts a shipwright, presumably the deceased, trimming with an adze the frame of a ship or boat. Behind him is a vessel with its planking already in

¹This dissertation follows the Bulletin of the American Schools of Oriental Research in style and format.
Fig. 1. Location of Caesarea Maritima on the modern Levantine coast. (Courtesy of CAHEP.)
place (Casson 1986: fig. 163). This relief is taken as evidence for the shipbuilding method of the day, that of first building up a shell of planks and installing the frames later.

The assembly of a shell of planks is set forth to some extent in a passage in Homer (Odyssey 5.244–57), but that a mortise-and-tenon-built hull is described therein has been debated recently (Casson 1986: 217–19; Mark 1991; Casson 1992). Lucian (Navigium 5) and Athenaeus (5.206d–209b), both writing in the second century A.C., give the best descriptions of ships and their construction, yet provide only general information. Many ancient authors attest to the types and distribution of Mediterranean shipbuilding timber but few recommend specific woods for particular hull elements. The most specific references to construction materials for ships or their components are found in the Historia Plantarum of Theophrastus, a Greek writer of the fourth century B.C.E., and in the Naturalis Historia written by the Roman encyclopedist Pliny the Elder in the first century A.C. Neither writer, however, engages in a particularly thorough treatment. Similarly, numerous ancient literary passages supply various details that help reveal the nature of Graeco-Roman shipbuilding and seafaring, but nowhere in the literature does there appear to be means of discerning even the most general construction guidelines and approaches observed by the shipwrights. Such guidelines and approaches, necessarily functions of the contemporary shipbuilding technology, can be revealed therefore only by archaeology.

The considerable body of knowledge pertaining to Graeco-Roman shipbuilding and seafaring is grounded primarily in the study of wrecks of ships that did not exceed about 25 m in length. Aspects of material usage, fastening techniques, and other construction details of various wrecks are known to different degrees and are often sparse. This state of affairs will therefore hinder any attempt to synthesize the information at hand, but at the same time it underscores the need to attempt a synthesis of the available information. The pioneering work of J.R. Steffy and F. H. van Doorninck, Jr. on four hulls dating from the fourth century B.C.E. to the eleventh century A.C. (Steffy 1982a; 1982b; 1985; van Doorninck 1976; 1982a; 1982b) supplemented by studies of numerous wrecks by others (Charlin, Gassend, and Lequément 1979; Clerc and Negrel 1973; Gassend 1982; Gassend, Liou, and Ximénès 1985; Jézégou 1985; Joncheray 1975; Negrel 1973), has among other things illuminated a fundamental evolution in the way Greek, Roman, and Byzantine ships were built. Through careful excavation and study of these hull remains, it has been
shown that in early Graeco-Roman ships the planking served as the primary structural component of the hull. This was a result of the way the hulls were built: planks were joined securely to the keel and to one another edge-to-edge with mortise-and-tenon joints. Only after a number of planks had been built up from the keel of the vessel were frames added to serve as secondary support components. But as economic factors changed through the Greek, Roman, and Byzantine periods, shipbuilding methods were adapted accordingly. Labor-and material-intensive methods characteristic of the Greek and Roman periods evolved into those that, in the later Roman empire, reflected the political and economic consequences of the *Pax Romana*’s dissolution. Shipbuilding approaches inherent in mortise-and-tenon joinery techniques proved incompatible with needs for more economical construction methods in the early Byzantine period, and the rudiments of more efficient skeleton-first techniques appeared at least by the tenth or eleventh century A.D.

But this might not be the whole story. The very nature of mortise-and-tenon joinery limits the practical size (still unknown) to which a seagoing vessel can be built. This is of special interest with respect to ships of appreciably greater size than those just cited. Yet knowledge of ships of some 30–50 m in length from the ancient Mediterranean is severely limited. To date, only one big seagoing ship that wrecked off the southern coast of France about 60–40 B.C.E. has been excavated extensively and published. Investigated during the 1970s near the small town of Giens, it is still under study (Pomey 1978; 1982; Tchernia 1987; Tchernia et al. 1978). Numerous wrecks of other large Roman ships are only partly known. One at Antikythera (Throckmorton 1964; 1965) was discovered early in this century and salvaged to some extent, but never really excavated; others at Albenga (Lamboglia 1953; 1961b), Mahdia (de Frondeville 1956), Punta Scaletta (Lamboglia 1964), Punta Scifo (Pensabene 1978), San Pietro (Ward-Perkins and Throckmorton 1965), Spargi (Lamboglia 1961a; 1971; Pallarés 1986), and Torre Sgarrata (Throckmorton 1969), among others, have fallen victim to shortfalls in funding or other unfortunate circumstances.

For these reasons any thorough study of the remnants of a large ship like that at Caesarea, whose original length exceeded 34 m can contribute significantly to what is known of big seagoing ships of the Roman period. Of course the assessment of any hull’s significance hinges upon a valid date for the loss of the ship or for its construction, but this is problematic for the Caesarea wreck. Carbon-14 analyses of
several wood samples taken from the hull have yielded a date with an unacceptably large margin of error (200 B.C.E. ±240 years). Moreover, the dynamic nature of the site makes the dating of artifacts found there suspect and circumstantial at best, and the wreck has been routinely scavenged for artifacts by local divers for years.

Therefore, aside from a preliminary reconstruction of the hull, which because of scant data can be only limited in scope, a central issue must be the ascertainment of the ship's date of construction. This will be attempted through comparison of the hull's construction details, fastenings, and equipment with those of other Graeco-Roman Mediterranean wrecks. While the subsequent chapters must be regarded as parts of a strictly-focused preliminary study—of both the wreck and of the comparative material—every effort has been made to include in the comparative corpus as much published material as possible. A far more comprehensive catalog of ancient shipwreck sites is found in A.J. Parker's *Ancient Shipwrecks of the Mediterranean and the Roman Provinces* (Oxford 1992), and the material in the relevant catalog entries has been incorporated below. Parker's book should be consulted for additional information on the wrecks discussed below, however, because much of its bibliography is not obtainable in the U.S. Therefore it is emphasized that the conclusions submitted here are based strictly upon data presented in the catalogs within the comparative sections, and that those catalogs and conclusions are subject to continual revision as new information becomes available.

The comparative chapters are discrete in order to isolate patterns or trends in the history of Graeco-Roman shipbuilding that can help determine the ship's date of construction. The discernment of any such patterns or trends may also provide evidence of general practices or principles characteristic of Greek and Roman shipbuilding, as well as illuminating differences between construction approaches to large as opposed to small seagoing vessels of the Graeco-Roman world. These factors as a whole will foster a more accurate assessment of the socio-economic and technological significance of the Caesarea hull remains in the history of Graeco-Roman ship construction.
Notes

1. See Raban 1989 and Oleson et al. 1994 for bibliography pertaining to the work at Caesarea. These references together, and primarily the latter, constitute a preliminary version of this dissertation.

2. As Parker (1990a: 336, fig. 1; 1992a: figs. 3–5) has shown, arguments must be tempered with the knowledge that the Graeco-Roman shipwreck “data base” is heavily concentrated in the years between ca. 200 B.C.E. and A.D. 200.
CHAPTER II

SITE HISTORY

SITE CONDITIONS

The wreck rests on sand just above a bed of dense clay about 60 m from shore in less than 3.5 m water. Usually covered by a thick layer of sand, it is exposed periodically because offshore currents have been altered by the construction between 1974 and 1978 of a large loading platform for an electrical power station a few kilometers south of the site. These prevailing south-to-north currents now tend to draw sand away from shorelines for some distance north of the platform. Although this is primarily a winter phenomenon, as are the storms that have done the most damage to the wreck, the site is always at the mercy of the dynamic sea conditions along the coast. Sand is moved in huge volumes on a daily basis, not unlike desert sand dunes. The wreck can lie uncovered one day and rest beneath a meter of sand the next. Fortunately, the site is located on the lee of a line of rocky shallows to the west. This creates a breaker line near or over the wreck that assures continual sand deposition (A. Raban, personal communication 1986), such that the site is covered with a layer of sand ca. 0.30–1 m thick most of the time. Nevertheless, storms have taken most of the remains that were excavated and probed in 1983 (see below). These losses have occurred despite care taken at the conclusion of each season’s work to pack stones around and beneath the timbers and to place sandbags on the hull and around its perimeter.

Seas are most calm on the Israeli coast in spring and fall. Storms typically occur during the winter and summer months, though they can arise at any time, and waters can start getting rough in late May. Further, the wreck’s location within the breaker zone means that access to the site is an issue every day. Even when relatively calm conditions prevail farther from shore, surf and surge at the site can make excavation and recording difficult or impossible.
DISCOVERY, SURVEY, AND EXCAVATIONS

The wreck was discovered in the summer of 1976 during a casual survey led by A. Raban with a group of Israel Underwater Exploration Society divers. The upper extremities of 25 frames spaced about 0.25 m apart center-to-center were observed protruding from the sand over a distance of about 6 m. Their position in less than 2.5 m of water measured some 60 m from the shoreline, inside the partially protected bay about 200 m northwest of the Hellenistic quay in Area J, and about 80 m north of the two round towers discovered in 1960 by the Italian mission (fig. 2). Heavy surge and poor visibility made it impossible to carry out an extensive reconnaissance at that time, and during later visits the timbers were always deeply buried in sand.

Early in 1980 a rip current exposed a few wooden planks between and beneath some scattered stone blocks several meters south of the frames discovered in 1976. The presence of large, rectangular, closely spaced mortise-and-tenon joints, along with radiocarbon analyses of wood samples, indicated the ship was of Greek or Roman date. In early April of 1980, winter storms cleared the sand away from the south end of the surviving portion of the hull. During a few days between two storms, the site was surveyed and a rough plan of the site was sketched. The remains were determined to be part of the lower portion of a large hull. The south end comprised an intact segment of 14 planking strakes up to ca. 0.30 m wide and just under 0.09 m thick; two strakes extended an additional 6.2 m southward. Forty-three frames, consisting of half-frames alternating with floor timbers and their futtocks, were counted above the sand along the eastern edge. These frames were molded (high) ca. 0.25–0.28 m,\(^1\) sided (wide) about 0.16 m, and set some 0.09 m apart. A coiled rope was found near the two planks extending farther southward, while other scattered finds included numerous large fragments of small *dolia*, one leg from a folding bronze table, a badly worn plate, a bronze rod that might be part of the beam of a balance scale, a few lead rings, and some pieces of lead sheathing. Two more table legs and numerous lead circles of unknown function (see Oleson 1988) were recovered in 1980 by Shelley Wachsmann, marine supervisor of what is now the Israel Antiquities Authority.

The first excavations on the site, then designated Area Y, were carried out in CAHEP's 1983 season. During that six-week period seas were rough and it was possible to work only 12 days on the site, usually in heavy surge and low visibility. Each day began with the removal of sand deposited the night before. A retaining bank
Fig. 2. General plan of CAHEP excavations (top), and detail with location of wreck site (bottom). (Courtesy of CAHEP.)
of sand bags around the wreck reduced the influx somewhat, but this was ineffective in moderate or heavy surge. Nevertheless, an area 14 x 5 m was cleared, starting at the southern, less deeply buried end of the wreck. Eight two-meter grid squares were surveyed and drawn (fig. 3) and the profiles of frames 27–30 were recorded. Some concreted nails were recovered, along with fragments of planking and frames broken off the hull by the surge. A series of air-jet probes along the central longitudinal axis and at right angles to it suggested that hull members extended approximately 28 m north of the southwest corner of the known portion of the hull (Raban 1985: 176, fig. 23).

In the autumn of 1984 additional excavations were carried out and the site was surveyed with a metal detector. The sea bottom west and south of the wreck was observed to be littered with building stones, broken amphoras, and scattered coins and other metal objects that appeared to have been deposited by rip currents (A. Raban, personal communication 1986).

In the winter of 1985 a routine survey after a storm yielded a lead box with a lead pipe attached to one end, along with numerous fragments of lead sheathing.

During 11 days of calm seas in 1986, which marked my first work on the site, two areas at opposite ends of the preserved hull were uncovered and partly recorded. Frames 8, 9, 10, and 13 at the north end (designated Area Y1) were drawn in plan view. Profiles of frames 8 and 13 were recorded and elevations of the outboard and inboard edges of the hull between frames 8 and 13 were also drawn. At the southern extremity of the wreck (Area Y2), a small portion of planking south of floor timber 33 was drawn in plan view. Excavations and air-jet probes revealed that a section of frames and planking 3 m long had disappeared from the south end of the wreck since 1983. Moreover, most of the hull thought to have been located north of the 1983 excavation area was found to have been shifted or destroyed during the intervening years, as probes revealed wood only between the north and south survey points, a distance of less than 10 m (fig. 4).

Few artifacts were found in 1986. A gaming die of ivory or bone was retrieved from the sand at the outboard extremity of floor timber 13. An undatable lead token with a bust and an illegible inscription on the obverse was recovered from the fill between two frames. A pinecone was discovered concreted between frames 12 and 13 and lengths of two thick ropes were recovered from near the west or inboard extremity of floor timber 13. Numerous concretions of iron nails of various sizes and
Fig. 4. 1986 excavation areas and probe grid. (After figs. 7, 8.)
configurations were raised and later used as molds for the casting of replicas. Remnants of copper or bronze nails or bolts were also raised. One such nail or bolt was found in situ in the broken inboard extremity of floor timber 15; another was noted in half-frame 12. Of special interest was the discovery nearby of a concretion of a copper or bronze washer. Some of the metal core remained within the concretion, which later served as the mold for a cast replica.

A routine survey by Raban in the winter of 1987 yielded more bits of lead sheathing, nails or their concretions, the concretion of another copper or bronze washer, the head of a nail or bolt identical to that in floor timber 15, two lead rings, and a length of lead pipe. The positions of more fastenings like the one in floor timber 15 were plotted as well.

In 1988, five days of excavations focused on exposure of the inboard edge of the wreck between frames 15 and 25 (Area Y3). Frames 22–24 were drawn in plan view and an elevation of the inboard edge of the hull from frames 14 through 17 was also drawn. The fastening in the broken inboard end of floor timber 15 was recorded further and another was discovered in situ, exposed in the broken inboard extremity of floor timber 25. More thick rope like that recovered in 1986 was observed beneath the inboard planking edge between frames 10 and 13.

EXCAVATION PROCEDURES AND EQUIPMENT

In 1983 excavations were conducted with a 5-inch induction dredge connected by a 3-inch firehose to a pump located on shore. The pump delivered 1500 liters of water per minute at a pressure of 4 atmospheres. A smaller pump was mounted on an inflatable boat moored over the wreck. This pump developed 3 atmospheres of pressure and supplied 500 liters per minute through a 2-inch firehose that terminated in a Galiazzo nozzle, which produced an easily regulated stream that was used to help clear off the heavy overburden of sand. After the orientation of the timbers was determined, a baseline was extended at right angles to the frames from the known southwest corner of the wreck; a metal grid was then placed lengthwise along the eastern side of the baseline at its southern limit. The grid consisted of four adjacent squares, measuring 2 m on a side, that could be levelled independently of one another. A grid of 0.20 m squares was superimposed on each 2 m square after the hull was
completely exposed within it to provide a base level from which vertical measurements could be taken. Sandbags were placed at strategic points to help stem the influx of sand.

In 1986 the 5-inch dredger was again employed but the pump was mounted on an inflatable boat anchored at the site. Sandbags were also used again in an attempt to control the approximately 1 m of sand covering the wreck (fig. 5). In fact a large percentage of our bottom time was devoted to dredging and to filling sandbags by hand. After determining the length of the hull remains by probing, pipes were driven into the dense clay beneath the hull at each end such that a baseline bisecting the frames could be extended between the north and south extremities of the wreck at the level of the sand surface. This baseline was used to orient air-jet probes north and south of the remains and to help determine relative frame positions. Buoys were tied to the pipes and their positions triangulated with a surveyor’s transit. The wreck’s longitudinal axis was determined to be 16° east of magnetic north. Photographs taken of the north portion of the remains were intended to be test shots for a photomosaic, but proved to be the only such photos obtained before stormy weather closed the site for the season (fig. 6).

In 1988 the location of the north pole was refined with a laser theodolite, but the southern pole had been taken by storms. Compass readings taken against several frames revealed the hull’s axis is actually oriented 20° east of magnetic north. Once again the 5-inch dredge and sandbags were used to remove and control the deep sand.

The air-jet used to probe the site consisted of a piece of stainless steel tubing 2 m long and 0.015 m in diameter connected to a scuba tank by means of a reinforced plastic hose attached to the first stage of a scuba regulator. The air supply to the probe was controlled by an in-line valve fitted to the hose. With this apparatus one diver could probe anywhere at will.
Fig. 5. Removal of sand from frames 6–10 (left to right); inboard (west) edge of hull remains in foreground. (Photo M. Little.)
Fig. 6. Photomosaic of frames 14–8 (left to right). (Photos M. Little.)
Notes

1. As viewed in cross-section, the fore-and-aft dimension (width) of a frame or keel is known as the sided dimension, while the dimension of its forward or after surface (height) is termed the molded dimension.
CHAPTER III

THE HULL REMAINS AND EQUIPMENT

WOOD SPECIES AND RADIOCARBON DATING ANALYSES

Analyses of wood samples taken from the south end of the wreck in 1983 indicate that two planks are of the white pine group, while planks A, D, K, and one other are of the red pine group. One plank sample was identified only as a pine not native to the eastern Mediterranean, as were samples from floor timber and futtock 31. Half-frame 26 is of the red pine group. Four tenon pegs and three tenons are from the live (evergreen) oak group, and two tenons are poplar. Four treenails are of the live (evergreen) oak group, while one is of an unidentified hardwood (cf. Raban et al. 1989: 192–93).¹

Carbon-14 analyses were performed at the Weizmann Institute of Science, Rehovot, Israel, on samples from Plank A, floor timber 37, an unidentified plank, and an unidentified tenon. Results yield dates of 1900 BP ±140 years and 1900 BP ±220 years, calculated at a non-corrected half-life decay rate of 5570 years. Dendrochronological correction based on the Bristlecone pine yields dates of approximately 200 B.C.E., ±240 years, or a span of from ca. 440 B.C.E. to A.D. 40 (cf. Raban et al. 1989: 197–98).

PLANKING

It should be noted that in all subsequent descriptions and analyses of the hull remains, whose longitudinal axis lies essentially north-south, the western edge of the remains is termed the inboard or keel edge, i.e., the edge of the remains closest to the original position of the keel. In turn, the eastern edge is the outboard edge of the hull remnants.

In 1983 a single layer of 16 strakes was found preserved over a width of approximately 3.5 m and a length of more than 14 m. The planks average ca. 0.22 m
wide and do not exceed 0.32 m in width; lengths are unknown (figs. 7, 8). Planks along the inboard or keel edge are 0.09 m thick between frames 8 and 25 (figs. 9, 10) and south of floor timber 33. But on the outboard edge, between floor timbers 7 and 13, the planks are 0.093–0.094 m thick (fig. 11). The planks are edge-joined with pegged mortise-and-tenon joints that are staggered across the thickness of each plank. The dimensions of only a few mortises and tenons have been recorded, because the exposed planking edges are splintered and damaged around much of the hull perimeter. Measurable mortises along the outboard edge between frames 8 and 13 average 0.09 m wide and 0.01 m thick, ranging from 0.08 m to 0.095 m wide by 0.009–0.012 m thick (figs. 11–13). Along the inboard edge beneath frames 15 and 18 the mortises range from 0.07 m to 0.083 m wide by 0.0085 m thick (fig. 10). A portion of a plank that was sawn, not adzed, is 0.27 m wide and 0.081 m thick and displays mortises ca. 0.09 m wide at each plank edge. A tenon fragment remains within one mortise 0.095 m deep. Both mortise and tenon taper from a thickness of 0.01 m at the plank edge to 0.006 m at the bottom of the mortise; the tenon fills the mortise tightly and completely. A mortise cut into the opposing plank edge is also 0.01 m thick at the plank edge but tapers to 0.008 m at its bottom at a depth of 0.109 m. Two mortises within a second planking fragment (see below) measure 0.07 m and 0.077 m wide; both are 0.012 m thick. One measured tenon peg tapers from ca. 0.018 m to 0.01 m. All pegs traverse the entire thickness of the planking; they are driven from inside to secure the joints that are closer to the inner plank faces, and from outside to secure joints that are closer to the outer plank faces. Tenon pegs are 0.13–0.14 m apart center-to-center, set 0.03–0.04 m from the planking seams. Most mortises are 0.05–0.06 m apart, with a range of 0.04–0.07 m.

A small plank fragment that may include a portion of a scarf, hooding end, or be a remnant of a stealer is preserved for a length of 0.28 m (figs. 14–18). This fragment appears to have been sawn to thickness; no tool marks suggestive of adzing are evident. Found floating in the loose sand near the south end of the wreck during the 1985 excavations, it is 0.10 m wide and 0.082 m thick at one extremity, where a treenail hole of 0.024 m diameter at the exterior plank surface is partly preserved. The hole is 0.02 m in diameter at the fragment's interior surface. At the opposite extremity, dimensions are 0.08 m in width and 0.072 m in thickness. At this end, a treenail ca. 0.017 m in diameter at the interior surface is pierced by a round copper or bronze nail. The concreted nail head measures about 0.038 m in diameter; its shaft
WEST ELEVATION
AREA Y
JUNE 1986
LAG

Fig. 9. 1986 elevation of inboard (west) planking edge and frames 7–13. (Drawing L. Goldberg.)
Fig. 10. 1988 elevation of inboard (west) planking edge and frames 14–17. (Drawing D. McIntire.)
EAST ELEVATION

AREA Y

JUNE 1986

LAG

Fig. 11. 1986 elevation of outboard (east) planking edge and frames 8–12. (Drawing L. Goldberg.)
Fig. 12. Detail of outboard (eas) planking edge beneath frame 11. Note head of copper or bronze nail at lower left (scale in centimeters). (Photo M. Lilje.)
Fig. 13. Detail of outboard (east) planking edge beneath frame 10. Four nails are driven into the plank edge around a mortise and its tenon (scale in centimeters). (Photo M. Little.)
Fig. 14. Plank fragment with mortises and plug-treenail pierced by copper or bronze nail. (Drawings L. Goldberg.)
Fig. 15. Exterior surface of plank fragment (scale in centimeters). (Photo M. Little.)
Fig. 17. Interior surface of plank fragment (scale in centimeters). (Photo M. Litde.)
Fig. 18. Inboard edge of plank fragment (scale in centimeters). (Photo M. Little.)
diameter is ca. 0.0065 m. Two mortises cut perpendicular to the surface believed to be the outboard edge extend completely through the fragment. Spaced just under 0.06 m apart and 0.012 m thick, one is 0.077 m wide, the other 0.07 m. They are only slightly staggered, as the inboard edge of one is essentially aligned with the outboard edge of the other. On the outboard edge of the fragment, one mortise displays an enlargement at one end that seems to be evidence of the tool used to cut the mortise. The edges of the enlargement are jagged, like those made by a mortising chisel, not smooth, as would be suggestive of a spooned bit. That no tenon pegs or holes for them exist in the fragment indicates the tenons passing through the mortises were pegged only in the adjacent planks. The possible significance of this detail is discussed below (pp. 134–35).

The slight taper in the fragment’s width suggests it probably is not the remnant of a diagonal scarf, for such a scarf would have been extraordinarily long. If lines are projected to follow the taper in width from the wide end toward and beyond the narrow end, the point of intersection occurs some 1.38 m beyond the narrow end. If this distance is added to the 0.28 m length of the piece, a reconstructed length of about 1.66 m results. This seems not an unreasonable length over which to join planks in a strake some 0.20 m wide, for example. However, if lines are projected from the narrow extremity to and beyond the wide end, ca. 1.90 m of length from the narrow extremity are required to attain a plank width of 0.20 m. Thus an approximate scarf length of 3.28 m, measured from the reconstructed tip to a point at which the plank would have reached 0.20 m in width, is derived. This would have been a long scarf indeed, even in a relatively narrow strake.

Professor Steffy (personal communication 1989) ventures that this piece of planking could be the remnant of either an S scarf or of a three-planed (Z) scarf. Either configuration would permit reconstruction of a more practical scarf length. Steffy also observes that the fragment might be part of a hooping end or stealer from near one end of the hull. Its taper both in width (from 0.10 m to 0.08 m) and thickness (0.082 m to 0.072 m) over 0.28 m of length is consistent with this idea. Unfortunately, the plank fragment has no provenance on the wreck, so its identification and the nature of its contribution to the knowledge of scarfs, hooping ends, and stealers on this hull are tentative.

Four nails driven into the edge of the plank at the outboard edge of the hull beneath half-frame 10 (figs. 11–13) are arranged around a mortise and its tenon. The
two nails closest to the exterior surface of the plank are farther from each other than the other pair of nails. The two intact concreted heads of the nails on the left side of the photo (fig. 13) measure 0.025–0.03 m in diameter; heads of the other two nails are missing. These nails might represent a nailed scarf tip, a common feature of Roman ships. Yet no scarf seam was detected on the inner surface of the plank, which is exposed for ca. 0.30 m north of half-frame 10 because of the absence of futtock 9. It is possible that such a seam was overlooked, despite close examination, but Steffy notes that the nails might simply indicate the repair of a split in the plank.

FRAMES

These pine timbers (figs. 5–11, 19–23) are beautifully preserved and their structural integrity is generally excellent. Only the outboard extremities bear signs of shipworm damage; other damage has been effected mostly by storms. All observed frame components are naturally grown shapes and the end grain of most half-frames indicates the timbers were fashioned from trees cut into halves or quarters at the heart. Most surfaces are well worked, with only the odd timber—somewhat smaller than the norm—left in its original, rounded shape. Surfaces appear to have been sawn, as no marks suggestive of axes or adzes are evident. The extremities of the half-frames at the keel edge are usually cut perpendicular to the grain and are as nicely finished as the other surfaces. In some instances the top edges or corners are bevelled (figs. 9 [frame 8], 11 [frame 12]).

Floor timbers with futtocks alternate regularly with half-frames in typical Graeco-Roman fashion.² Floor timbers are not scarfed to their futtocks in the excavated portions of the hull. There are gaps of 0.01–0.10 m between them. The gaps are aligned along the entire length of the hull remains exposed in 1986 and 1988, and watercourses in the half-frames are aligned with the gaps as well (see below). At the inboard edge between floor timbers 7 and 25 the broken ends of the floor timbers are roughly aligned with one another. Most of the finished inboard extremities of the half-frames also terminate near this line, though some lie as much as 0.40 m outboard (figs. 23, 24). No impressions on the frame tops suggestive of a mast step, mast step stringer, or keelson have been discovered. Average spacing of frames (center-to-center) is ca. 0.25 m, as sided dimensions average about 0.18 m, with the timbers set
Fig. 20. Profile of frame 13, from the south. Paths of treenails are conjectural. (Drawing L. Goldberg.)
Fig. 21. Schematic profile of frame 38, from the south. Representation of strake G as a wale is conjectural. (Courtesy CAHEP.)
Fig. 22. Profiles of frames 8, 13, and 38. (After figs. 19–21.)
Fig. 23. 1988 plan of frames 22, 23, and part of 24. (Drawing D. McIntire.)
Fig. 24. Plan view of hull timbers as recorded in 1986 and 1988. Gaps between floor timbers and futtocks align with watercourses in half-frames. Note inconsistent alignment of finished half-frame extremities with broken ends of floor timbers at inboard (west) edge. (After figs. 7, 8, 23.)
an average of 0.068 m apart. Half-frame 8 spans a breadth of 2.8 m; the distance spanned by floor timber 13 and its futtock is ca. 3.5 m. Frames 27, 28, and 38, as recorded in 1983, span distances of 3.8 m, 3.8 m, and 3.6 m, respectively, and are molded an average of 0.20 m.

The floor timbers are 1.95–2.35 m long. At the inboard edge they range from 0.155 m to 0.26 m in the molded dimension and 0.14–0.18 m in the sided dimension. Averages are 0.184 m molded and 0.163 sided. Half-frames range from ca. 0.14 m to 0.20 m molded and 0.165–0.22 m sided, with average dimensions of 0.172 m molded and 0.192 m sided. Therefore, at the inboard edge the average floor timber is molded ca. 0.184 m and sided some 0.163 m, while the average half-frame measures 0.172 m molded and 0.192 m sided.

Along the outboard planking edge recorded half-frames are molded 0.175–0.22 m, averaging ca. 0.195 m, and sided 0.175–0.195 m, averaging 0.183 m. Frames, especially the half-frames, increase in their molded dimensions as the turn of the bilge begins near the outboard edge of the hull remains. Half-frame 8 is molded 0.155 m at its inboard extremity but reaches its maximum of 0.23 m at the turn of the bilge. Similarly, half-frame 18 measures 0.15 m at the inboard edge and 0.29 m some 0.40 m inboard of the eastern edge of the planking. At this same point futtock 17 is molded 0.21 m; its floor timber at the inboard edge of the remains is molded 0.17 m.

In general terms, sided dimensions of floor timbers and their futtocks are usually the same, and half-frames too maintain a constant sided dimension through their length. The latter, however, exhibit sided dimensions notably greater than those of the floor timbers. The floor timbers are molded slightly more than the half-frames at the inboard edge of the preserved hull, but this relationship reverses with distance outboard, as floor timbers diminish slightly in their molded dimensions while half-frames increase appreciably. Therefore half-frames are essentially heavier frames than are floor timbers and their futtocks, particularly where the turn of the bilge commences.

Watercourses

Triangular and rectangular water-courses in the half-frames are aligned down the length of the hull remains with the gaps that separate the floor timbers from their futtocks. The gaps are 0.01–0.10 m wide. No other watercourses or limber holes have been observed along the frame lengths or along the inboard edge of the hull.
remains. Frame/plank interfaces were not often visible, however, either because of incomplete excavation or concreted materials on the frame and plank surfaces. Therefore other watercourses or limber holes could have escaped detection.

A rectangular watercourse some 0.07 m wide was cut 0.045 m into the underside of half-frame 42. Another in the shape of a triangle was cut only about 0.025 m into half-frame 8; it measures 0.034 m on a side with a base of about 0.05 m. A rope (R3, see below) 0.015 m in diameter found within this watercourse was also present within those of half-frames 10 and 12 (figs. 7, 19, 22, 24, 25). A fragment presumably of the same rope is also concreted to the finished outboard extremity of floor timber 33, from which it extended some 0.10 m toward floor timber 35 (figs. 8, 24). Clearly the function of this rope was to keep the watercourses open and free of bilge material, assuring easy passage of water to the bilge pump.

Shim (?)

Between floor timbers 33 and 35 at the south end of the wreck, in the space once occupied by half-frame 34, there remains in situ a short, thin, wedge-shaped plank (figs. 8, 24). One treenail 0.02 m in diameter still holds it in place against the hull planking, and holes of the same diameter indicate the original positions of three others. The plank is 0.63 m long, 0.185 m wide at its inboard end and 0.16 m wide at its outboard extremity; it swells from a thickness of only 0.008 m at the outboard terminus to 0.03 m at the opposite end. The plank thereby creates a significant offset from its upper surface to the planking surface at the inboard extremity. This would require a considerable hollow along the length of the missing frame if the piece is to be considered a frame shim.

Notches

A notch let into the top surface of futtock 39 near its outboard extremity was noted in 1983 (fig. 26). Cut across the full sided dimension of the timber to a depth of 0.035 m, it is ca. 0.55 m long and well finished. On the north molded surface of floor timber 35, 0.11 m from its outboard extremity, a vertical notch is let into the entire molded dimension of the frame (figs. 8, 24). It is 0.11 m wide at the upper surface of the frame, 0.06 m deep at its inboard extremity and 0.04 m deep at the outboard extremity. At the frame/plank interface the depth diminishes and the cutting is less well defined. The notch is poorly fashioned in general.
Fig. 26. Horizontal notch let into futtock 39 near its outboard (eastern) extremity (top, center left). Bottom: detail. (Photos M. Little.)
**Unexplained Treenails**

A curious feature was observed in 1988 by Professor Raban. The finished inboard extremity of half-frame 22 is located about 0.40 m short of the adjacent broken floor timber extremities (fig. 27). Preserved planking extends another 0.10 m inboard of the floor timbers and four treenails in the planking continue inboard along the line of the half-frame. They are staggered, 0.02–0.025 m in diameter and 0.10–0.14 m apart, thus characteristic of treenails used to fasten frames to the planking. No frame impressions were noticed on the planking, however. Unfortunately these treenails were noted at the end of the last day of excavation and were not fully recorded. They are mystifying because they suggest the possibility that timbers were fastened to the planking that extended inboard toward the keel. If so, the keel might have been significantly farther from the inboard edge of the remains than currently believed.

But there are more plausible explanations. The treenails could be associated with a second layer of planking in this portion of the hull (see Chapter XIII). Professor Steffy (personal communication) suggests they could be evidence of either a reused plank or of a cleat fastened to the outer planking surface during construction, the removal of which required the holes to be plugged. The holes and treenails might also be indicative of repairs. On the Kyrenia ship, floor timber 40 was cut away between the second and third plank seams at both sides of the hull to create a sump. Four frame nails thus remained in the planks; they were removed and the holes filled with tapered wooden plugs. Two other plugs were observed in the garboard, adjacent to the port arm of frame 40 (Steffy 1985b: 85, 96). In another place in the Kyrenia hull, a frame extremity had been fastened to the planking but was cut away in order to make the turn of the bilge (J.R. Steffy, personal communication 1989).

**Graffiti**

Two groups of Greek letters are carved into the upper face of the inboard extremity of futtock 21 (fig. 28). They repeat a single word that may be read ΧΙΑΙΑΙΨΙΝ and may represent “1000, 750” or “1750.” The original significance and purpose are unknown. L. Casson has suggested they might have been scratched by a stevedore involved with lading the ship (Raban et al. 1989: 188).
Fig. 27. Treenails in the planking that extends inboard (west) of finished inboard extremity of half-frame 22. (Photo H. Wadsworth.)
Fig. 28. Greek letters ΣΙΑΙΑΙΨΙΝ carved into inboard extremity of futtock 21 (top). Bottom: detail. (Photos H. Wadsworth.)
Evidence for Stringers

There is only indirect evidence for the existence of stringers. Three concretions of iron fastenings were observed on the upper surface of half-frame 10 (fig. 7). One concretion 0.80 m from the inboard extremity of the timber covers the remains of a nail shaft measuring 0.02 x 0.01 m at the frame top. This concretion and the one at the other end of the frame align with the copper or bronze fastenings found in half-frame 12 and futtock 25, respectively (see below). A remnant of an iron nail shaft was also noted on the top of futtock 23 ca. 0.26 m from its inboard extremity (fig. 23). This shaft aligns with copper or bronze fastenings in half-frames 22 and 26 (see Chapter XIII).

FASTENINGS

Frame timbers are fastened to the hull planks with treenails of evergreen oak and at least one other hardwood driven from outside and staggered along the frames to prevent splitting. They are usually 0.02–0.025 m in diameter at the outer planking surface and 0.018–0.02 m at the frame tops, though some measure only 0.015 m at the frame tops. The frequency of occurrence and usage pattern of these smaller treenails is not yet known. No wedged treenails have been observed.

Bronze or copper nails with head diameters of ca. 0.035 m and shaft diameters of 0.0065 m are driven through some treenails, but due to our inability to examine the exterior of the hull, no frequency of use for nails within plug-treenails has been ascertained. A number of copper or bronze nails and concretions of iron nails and other fastenings were recovered. All were found loose in the sand above, around, and beneath the hull remains, not in situ. Replicas of the iron nails and other fastenings were cast from their concretions when possible.

The most interesting aspect of the Caesarea hull fastenings is the presence of large copper or bronze fastenings driven up through the planks and frames. In some areas they appear to join planks and frames, and they might have fastened stringers to the planking and frames in other areas as well. Further, two copper or bronze washers were discovered along the inboard edge of the hull remains. Their cast replicas reveal hole diameters that match perfectly the diameters of the upper extremities of the recorded copper or bronze fastenings.
**Catalog of Copper or Bronze Fastenings**

**Cu1.** Plug-treenail and nail (fig. 29): nail is probably bronze; incomplete shaft, slightly bent; MPL shaft ca. 0.205 m; round shaft D 0.065 m except where corroded at extremities; MPL of concreted treenail ca. 0.11 m, with D ca. 0.02 m; D concretion 0.026 m. The species of the treenail wood has not been determined. Provenance: loose in sand.

**Cu2.** Nail (fig. 30:A): bronze; incomplete; MPL 0.235 m, with head 0.009 m Th and shaft L 0.226 m; head rounded as viewed from above, maximum D 0.033 m, hammered conical in section; rectangular shaft 0.013 x 0.0134 m at head, 0.0063 x 0.0067 m at broken extremity, slightly bent; weight 215.2 g. Provenance: loose in sand.

**Cu3.** Nail (fig. 30:B): copper or bronze; incomplete; MPL 0.118 m, with head 0.0045 m Th and shaft L 0.1135 m; head rounded and deformed as viewed from above, D 0.015, rounded in section; rectangular shaft 0.0066 x 0.0064 m at head, 0.0024 m square at broken extremity, slightly bent; weight 22.8 g. Provenance: loose in sand.

**Cu4.** Nail (fig. 30:C): copper or bronze; incomplete; MPL 0.044 m, with head 0.008 m Th and shaft L 0.036 m; head rounded as viewed from above, D 0.018 m, hammered conical in section; rectangular shaft 0.0083 x 0.0085 m at the head, 0.006 m square at broken extremity, slightly bent; weight 23.4 g. Provenance: loose in sand.

**Cu5.** Nail (fig. 30:D): copper or bronze; incomplete shaft; MPL 0.086 m; rectangular shaft 0.0055 x 0.006 m at one extremity, 0.007 m square at other extremity, slightly bent; weight 28.4 g. Provenance: loose in sand.

**Cu6.** Nail (fig. 30:E): copper or bronze; complete; L 0.173 m, with head 0.005 m Th and shaft L 0.168 m; head round as viewed from above, D 0.01 m, flattened bulb in section; round shaft D 0.0065 at head, tapering to sharp tip, bent in an open U shape; weight 17.9 g. Provenance: loose in sand.

**Cu7.** Nail (fig. 31): 94.2 percent copper, remaining components unknown; complete; L 0.15 m, with head 0.006 m Th and shaft L 0.144 m; head corroded, rounded as viewed from above, maximum D 0.018 m, hammered conical in section; shaft 0.0085 m square at head, tapering to tip, bent and corroded; weight 51.8 g. Provenance: loose in sand along inboard edge. The analysis was performed by Dennis James of the Center for Chemical Characterization and Analysis, Texas A&M University.
Fig. 29. Concreted plug-treenail pierced by nail (CuI) probably of bronze. (Photo Z. Friedman.)
Fig. 30. Copper and bronze nails and fragments Cu2–Cu6. A: Cu2; B: Cu3; C: Cu4; D: Cu5; E: Cu6. (Drawings D. Meier.)
Fig. 31. Copper nail Cu7. (Photo author; Drawing D. Meier.)
Cu8. Nail (fig. 32:A): copper or bronze; incomplete; MPL 0.058 m, with head 0.005 m Th and shaft L 0.053 m; head rounded as viewed from above, D 0.0136 m, hammered conical in section; rectangular shaft 0.0055 x 0.0053 m at head, 0.0032 x 0.0037 m at broken extremity. Provenance: loose in sand along inboard edge.

Cu9. Nail (fig. 32:B): copper or bronze; complete; L 0.153 m, with head 0.003 m Th and shaft L 0.15 m; head rounded as viewed from above, D 0.017 m, rounded but quite flat in section; shaft is round at head for a distance of 0.028 m from head, where it becomes rectangular and corroded for remainder of its length; D at head 0.006 m, and 0.0052 x 0.0054 m where it becomes rectangular. Provenance: loose in sand along inboard edge.

Cu10. Nail or bolt (fig. 33): copper or bronze; incomplete round shaft; MPL 0.105 m; D 0.013 m at 0.02 m beneath the top of the frame; upper extremity D 0.011 m; upper extremity is somewhat rounded and irregular, not pointed. Provenance: 0.93 m from finished inboard extremity of half-frame 12, where it protruded 0.085 m above the frame top; remnants of the frame top still adhere to the shaft; was bent slightly outboard, toward shore.

Cu11. Nail or bolt: corrosion product is 64.2 percent copper, remaining components unknown; incomplete round shaft; MPL 0.09 m; lower extremity D 0.013 m; upper extremity D 0.009 m; upper extremity was somewhat rounded and irregular, not pointed. Provenance: loose in sand near floor timber 35.

Cu12. Nail or bolt (figs. 34–38): copper or bronze; incomplete round shaft; MPL 0.13 m; cast replica of extremity L 0.04 m (fig. 35), as most of the concretion crumbled when opened for casting; upper extremity D 0.012 m; opposite extremity D 0.0135 m; upper extremity is somewhat rounded and irregular, not pointed, and matches the shape and appearance of the analogous extremities preserved within concretions Cu10 and Cu11. Provenance: in situ in the broken inboard extremity of floor timber 15 (figs. 36–38). The upper extremity did not reach the top of the frame, terminating ca. 0.01 m below it. The remainder of this fastening is in situ; its concreted head is some 0.05 m from the outer planking face. No wood fragments adhere to the concreted shaft and head. Reconstructed dimensions of this fastening, based on this data and the cast replica of Cu13 below, are: L 0.38 m; rounded head 0.01 m Th, D 0.04 m; shaft L ca. 0.37 m, D 0.018 at head tapering to 0.012 m at preserved extremity. It should be noted that this fastening and others like it (cf. Cu10, Cu11, Cu13) were prematurely identified as portions of bolts in Raban et al. 1989.
Fig. 32. Copper or bronze nails *Cu9* (left) and *Cu8* (right). (Drawings D. Meier.)
Fig. 33. Concretion of copper or bronze fastening shaft Cu10 found in situ in top of half-frame 12. Left: exterior of concretion with remnants of frame wood at bottom (scale in centimeters). Right: interior of concretion (Left photo M. Little; Right photo author.)
Fig. 34. Concreted shaft fragment of copper or bronze fastening Cu/2. Found in situ in the broken inboard (west) extremity of floor timber 15 (scale in centimeters). (Photo M. Little.)
Fig. 35. Cast replica of extremity of CuI2. (Photo author; Drawings H. Dewolf)
Fig. 36. Cu12 *in situ* in broken inboard extremity of floor timber 15. Plank remnant in foreground has fallen below level of plank beneath frame. (Photo M. Little.)
Fig. 37. Copper or bronze fastening *Cu12 in situ* with head exposed beneath planking. (Photo H. Wadsworth.)
Fig. 38. Detail of fig. 37. (Photo H. Wadsworth.)
(187–88, 489, fig. III.192). The fact that the shafts taper is more consistent with the form of nails, but the inability to determine how these fastenings were configured at their upper extremities precludes definitive identification.

_Cu13_. Head of nail or bolt (fig. 39): copper or bronze; incomplete; cast replica MPL 0.037 m, with head 0.009 m Th and shaft L 0.028 m; head rectangular with rounded corners as viewed from above, with maximum dimensions of 0.04 x 0.042 m, rounded in section; round shaft D 0.018 m at head and 0.015 m at extremity; wood impregnated and preserved by the concretion extends ca. 0.0115 m from the broken extremity of the concretion toward the head and stops 0.017 m from the underside of the head; wood grain is perpendicular to shaft. Provenience: loose in sand along inboard edge.

_Cu14_. Washer (fig. 40:A, B): copper or bronze; incomplete; cast replica MPL 0.043 m; MPW 0.036 m; minimum W 0.03 m; maximum Th 0.009 m, at wide end; minimum Th 0.005 m, at narrow end; hole slightly off center and worn, minimum D 0.014 m, maximum D 0.015 m; wear area confined to ca. 180 degrees of hole’s circumference; small lip rises as much as 0.001 m above the surface of the washer around the hole. Provenience: loose in sand along inboard edge.

_Cu15_. Washer (fig. 40:C, D): copper or bronze; incomplete; cast replica maximum outer D 0.04 m; maximum Th 0.0065 m; minimum Th 0.0045 m; hole slightly off center and worn, minimum D 0.0135, maximum D 0.014 m; worn areas are located approximately every 90 degrees around the circumference of the hole; two wear areas diametrically opposed to one another are more evident than the other two; a small lip rises as much as 0.002 m above the surface of the washer around the hole. Provenience: beneath inboard planking edge between frames 11 and 12.

It is notable that all examined fastening shafts within concretions _Cu10, Cu11_, and _Cu12_ have essentially the same diameter and all are slightly rounded at their extremities. There is no indication of bending, twisting, or other damage at these extremities. For this reason it cannot yet determined if any of these fastenings were originally longer and broke in antiquity or later. The consistency of appearance within all three concretions, however, suggests that they are remnants of the original extremities of the fastenings.

Remains of fastenings identical to those in concretions _Cu10, Cu11_ and _Cu12_ have been noted in frames 12 (at two points), 22 (fig. 41), 24, 25 (in two places), and
Fig. 39. Head of copper or bronze fastening Cul3. Top: copper core preserved within concretion. Middle and bottom: cast replica. (Photos author; Drawings D. Meier.)
Fig. 40. Copper or bronze washers. A: core of Cu14; B: cast replica; C: core of Cu15; D: cast replica. (Photo author; Drawings D. Meier and H. DeWolf.)
Fig. 41. Concretion of copper or bronze fastening in half-frame 22. Top: remnants protrude above frame top near its outboard (east) extremity. Bottom: exposed interior of concretion reveals fastening bent eastward toward the shoreline. (Photos H. Wadsworth.)
26 (fig. 42). The head of the fastening in the broken inboard extremity of floor timber 25 is 0.10 m from the outer planking surface. Because its concreted upper extremity has been broken within the timber since antiquity, it is not known if it ever protruded above the frame top. No wood adheres to the concretion, nor were any wood grain impressions observed. The head of the fastening near the outboard extremity of half-frame 24 is flush against the single layer of planking.

**Catalog of Iron Fastenings**

*Fe1.* Nail (fig. 43:A): incomplete; cast replica MPL 0.167 m, with head 0.011 m Th and shaft L 0.156 m; head rounded as viewed from above, maximum D 0.032 m, hammered conical in section; shaft 0.013 m square at head, 0.0095 m square at broken extremity. Provenance: loose in sand in Y3.

*Fe2.* Nail (fig. 43:B): incomplete; cast replica MPL 0.098 m, with head 0.008 m Th and shaft L 0.09 m; head round as viewed from above, maximum D 0.039 m, hammered conical in section; rectangular shaft 0.01 x 0.012 m at head, 0.0085 m square at the broken extremity, slightly bent. Provenance: loose in sand in Y3.

*Fe3.* Nail (fig. 43:C): incomplete; cast replica MPL 0.045 m, with head 0.006 m Th and shaft L 0.039 m; head rounded as viewed from above, D 0.035 m, flat and bent in section; shaft 0.011 m square at head, 0.0085 x 0.0095 at broken extremity, slightly bent at head. Provenance: loose in sand in Y2.

*Fe4.* Nail (fig. 43:D): incomplete; cast replica MPL 0.04 m, with head 0.0085 m Th and shaft L 0.0315 m; head rounded and irregular as viewed from above, maximum D 0.02 m, hammered conical in section; rectangular shaft 0.0077 x 0.0085 m at head, 0.007 m square at broken extremity. Provenance: loose in sand in Y2.

*Fe5.* Tack (fig. 43:E): incomplete; cast replica MPL 0.055 m, with head 0.005 m Th and shaft L 0.05 m; head rounded and irregular as viewed from above, representative D 0.026 m, flat and bent in section; rectangular shaft 0.0088 x 0.0092 m at head, 0.003 m square just before tapering to sharp tip, slightly bent. Provenance: loose in sand in Y2.
Fig. 42. Schematic hull plan with positions of copper or bronze fastenings (F) and iron nails (N) in frame tops. (After fig. 3.)
Fig. 43. Cast replicas of iron nail fragments and tack. A: Fe1; B: Fe2; C: Fe3; D: Fe4; E: Fe5. (Drawings D. Meier.)
LEAD SHEATHING

A number of lead sheathing fragments were recovered from the wreck site. Curiously, however, no lead has yet been found attached to the planking, which has been inspected at various points for a distance of some 0.85 m (an arm’s reach) from the perimeter of the hull remains. Two planking fragments found floating on the site were also examined for tack holes but none were found. This absence of direct evidence for hull sheathing is disturbing, even in view of the abundance of fragments collected over the years. Yet the presence in most fragments of tack hole patterns that are paralleled by patterns on known lead-sheathed hulls, and the fact that the average thickness of the Caesarea fragments is perfectly consistent with sheathing on other hulls (see Chapter 8), tend to support the identification of the fragments as sheathing remains.

The lead fragments are in relatively good condition and 11 representative samples (PbI to PbII) were recorded. Lead thicknesses average ca. 0.00135 m, varying from ca. 0.0009 m to 0.0018 m (figs. 44–45). The largest fragment (PbI, fig. 44) is roughly triangular in its preserved shape, with maximum dimensions of ca. 0.22 x 0.29 m. On one surface are small spots and patches of a black substance that might be the remnants of pitch or a similar material, but it has not been analyzed. No indication of the use of textiles or other materials in concert with the black substance are evident. Tack holes are spaced 0.055–0.065 m apart and oriented on diagonal lines across the lead; no score marks between the holes were detected on this or any fragment.

Tack holes on all sheathing fragments are uniformly 0.005 m in diameter except where distorted. Tack head impressions are apparent on numerous pieces and range from 0.015 m to 0.017 m in diameter. No impressions indicative of protrusions on the undersides of the tack heads were detected in the lead.

LEAD BOX AND PIPES

A lead box with an attached pipe was recovered from the general area of the hull in 1985, and a single lead pipe was raised from the area west of the hull in 1987. No lead isotope analyses have been performed as yet.
Fig. 44. Lead sheathing fragment *PbI*. (Photo Z. Friedman.)
Fig. 45. Lead sheathing fragments and lead pipe Pb13. Top: tack head impressions are clearly visible. Bottom: sheathing fragments and lead pipe Pb13. (Photos Z. Friedman.)
Lead Box with Pipe

Pb 12. Open-topped box fitted with lead pipe (figs. 46-52): the box has holes probably for two other pipes. No soldered seams are evident in the lead, which is 0.0017-0.002 m thick. A few small holes in the bottom of the box are the result of corrosion, as is a large jagged opening at one end above the pipe. Three sides are significantly bent and distorted, but the original dimensions can be reconstructed as ca. L 0.30 x W 0.15 x H 0.21 m, yielding a capacity of 9.45 liters. There are no marks on the exterior of the box or pipe.

One hole 0.05 m in diameter is located near the center of one long side, about 0.05 m from the upper edge. A flange fashioned around the circumference of the hole from the box wall itself projects out approximately 0.01 m from the box face. Around the circumference of this hole, the interior of the box is lined with a second layer of lead, the thickness of which approximates that of the outer wall. The inner layer reaches some 0.03 to 0.07 m from the hole in all directions and reinforces the area around the hole. This is most apparent immediately above the hole. This inner layer extends for about 0.03 m toward the top of the box, beyond which the box’s lead wall is bent over into the interior. The method of affixing the inner layer of lead is not known, but soldering is likely. At the end of the box opposite the pipe is a hole similar in dimensions to the one just described. This is an estimate, however, as this portion of the box is crushed. A flange fashioned from the box wall projects approximately 0.01 m from the wall surface around the hole; the lower edge of the flange is almost flush with the bottom of the box.

A flange essentially identical to those of the other two holes receives and encases the attached pipe, extending approximately 0.01 m back to the box wall. The means of fastening the pipe on the interior of the box is unknown, but again soldering is likely. The pipe is made of lead ca. 0.003 m thick, has an outer diameter of approximately 0.05 m and is preserved for a length of some 0.25 m. A soldered seam along its length on the upper surface displays a distinct ridge at one side.

Lead Pipe

Pb 13. Pipe fragment (figs. 45, 53): pipe is oval in section with a thick soldered seam along its length; one end is bent and flattened. MPL ca. 0.36 m; maximum outer D 0.039 m; minimum outer D 0.03 m; maximum inner D 0.033 m; minimum inner D 0.025 m; lead 0.0028-0.003 m Th. There are no marks on the exterior.
Fig. 46. Lead box with attached pipe Pb12. (Photo M. Little.)
Fig. 49. Schematic reconstruction of Pb12. (Drawing author.)
Fig. 50. Detail of Pb/t2 box pipe joint. Note soldered seam on pipe. (Photo: M. Little.)
LEAD RINGS

Ten rings of various sizes have been recovered from the sand around and on top of the wreck. The condition of the lead is in all cases quite good, but due either to corrosion, poor manufacturing practices, or both, the sectional dimensions of most rings vary around their circumferences. Sectional shapes range from circular to rectangular, and given sectional dimensions are representative unless otherwise noted. No lugs, splits, or holes are exhibited by the rings. Only one shows what might be wear marks, though six are noticeably stretched, bent, or otherwise distorted. On seven rings, shallow, narrow lines or somewhat larger surface depressions are evident, probably having formed on the upper surface as the lead cooled after being poured in open-face molds. These rings could be brailing rings from the sails of the ship, or they could be line or net “trips” associated with fishing activity.

Catalog of Lead Rings

Pb14. Ring: max. outer dimensions 0.055 x 0.056 m; max. inner dimensions 0.031 x 0.033 m; sectional dimensions 0.0075 x 0.011 m; weight 94.7 g. Provenance: loose in sand.

Pb15. Ring: max. outer dimensions 0.049 x 0.052 m; max. inner dimensions 0.0315 x 0.035 m; sectional dimensions 0.0035 x 0.0095 m; one shallow narrow groove is evident on one face around the full circumference; weight 47.4 g. Provenance: loose in sand.

Pb16. Ring: distorted shape; max. outer dimensions 0.05 x 0.05 m; max. inner dimensions 0.027 x 0.028 m; sectional dimensions 0.0086 x 0.011 m; weight 93.7 g. Provenance: loose in sand.

Pb17. Ring: distorted shape; max. outer dimensions 0.04 x 0.047 m; max. inner dimensions 0.025 x 0.03 m; sectional dimensions 0.005 x 0.008 m; one shallow depression on one surface is 0.025 m long; weight 45 g. Provenance: loose in sand.

Pb18. Ring: max. outer dimensions 0.039 x 0.044 m; max. inner dimensions 0.022 x 0.032 m; sectional dimensions 0.007 x 0.0075 m; one shallow depression 0.02 m long on one surface; weight 47.1 g. Provenance: loose in sand.

Pb19. Ring: distorted shape; max. outer dimensions 0.04 x 0.043 m; max. inner dimensions 0.027 x 0.029 m; sectional dimensions 0.006 x 0.01 m; one shallow narrow groove 0.055 m long is evident on the widest face; weight 45.4 g. Provenance: loose
in sand.

**Pb20.** Ring: distorted shape; max. outer dimensions 0.032 x 0.039 m; max. inner dimensions 0.022 x 0.028 m; sectional dimensions 0.0044 x 0.006 m; two shallow narrow grooves are evident on one face, of lengths 0.01 m and 0.025 m; weight 31.2 g. Provenance: loose in sand.

**Pb21.** Ring: distorted shape; max. outer dimensions 0.031 x 0.037 m; max. inner dimensions 0.018 x 0.023 m; minimum and max. sectional dimensions 0.0052 x 0.0057 m to 0.008 x 0.0082 m; weight 33.3 g. Provenance: loose in sand.

**Pb22.** Ring (fig. 54): max. outer dimension 0.05 m; max. inner dimension 0.037 m; minimum/max. sectional dimensions 0.0058 x 0.006 m to 0.0071 x 0.0073 m; shallow narrow grooves are evident over ca. 30 percent of the circumference on one face. Provenance: loose in sand.

**Pb23.** Ring (fig. 55): distorted shape; max. outer dimension 0.043 m; max. inner dimension 0.03 m; minimum/max. sectional dimensions 0.0049 x 0.0065 m to 0.0059 x 0.0097 m; possible wear marks; shallow narrow grooves are evident over ca. 20 percent of the circumference on one face. Provenance: loose in sand.

**CORDAGE**

In 1983 a coil of rope was found on the site, but no samples could be recovered (Raban 1985: 176, fig. 23). In 1986 portions of two large ropes (*R1* and *R2*), one (*R1*) flattened in section, were uncovered at approximately the level of the frame/plank interface just west of the west (inboard) extremity of floor timber 13 (figs. 56–59). A third, smaller diameter rope fragment lay 0.20 m beneath them, but nothing of this rope was recovered. Different lengths of the large round and flat ropes discovered in 1986 are believed to have been exposed again in 1988 beneath the planking at the inboard edge between frames 10 and 13. As noted above, rope fragment *R3* was also found within the watercourses of three half-frames and at the inboard extremity of a floor timber.

**Catalog of Rope Fragments**

*R1*. Rope fragment (figs. 56–58): flattened in section, of three strands laid left;\(^5\) W 0.045 m, Th 0.02 m; strands W 0.023 m, and Th 0.013 m, laid right, consisting of
Fig. 54. Lead ring Pb22 (scale in centimeters). (Photos Z. Friedman.)

Fig. 55. Lead ring Pb23 (scale in centimeters). (Photos Z. Friedman.)
Fig. 57. Rope fragment R1, of *Stipa tenacissima*, esparto grass (scale in centimeters). (Photo M. Little.)
Fig. 58. Photomicrographs of rope R1 (500X). Top: layers of cells at the inner sides of fiber sclereid bundles are rich in broad papils (short hairs) that are characteristic of *Stipa tenacissima* leaves. Bottom: long and short epidermis cells of *Stipa tenacissima* leaves alternate with one another. The wavy walls of the long cells are clearly visible. (Photo U. Körber-Grohne.)
Fig. 59. Rope fragment R2 (scale in centimeters). (Photo M. Little.)
yarns D ca. 0.003 m, laid left. Provenance: 0.15 m west of inboard extremity of floor timber 13, at planking level. Botanical analysis indicates the rope consists of rolled leaves of *Stipa tenacissima*, esparto grass. The following is a summary of the reports submitted by Udelgard Körber-Grohne of the Institut für Botanik, Universität Hohenheim, Stuttgart, Germany (Raban et al. 1989: 193). Under the stereo-microscope (10X–40X), it is evident that the raw material consists of relatively thick and strong plant material with a diameter of 0.001 m and more. It therefore cannot represent fully processed fibers of flax or hemp. Under greater magnification (100X–400X), three types of cellular tissue can be discerned. All are characteristic of the leaves of *Stipa tenacissima*:

- Long and short epidermis cells that alternate with one another. The former have wavy, undulating walls and are some 16–18 millimicrons broad (fig. 58:Top [500X]).
- Bundles of fiber sclereids that lie directly beneath the epidermis. Only a thin layer of other cells separate the bundles from each other.
- Layers of cells (at the inner sides of the fiber bundles) that are rich in broad papils (short hairs). The papils are ca. 26–34 millimicrons long and 10 millimicrons broad at the base (fig. 58:Bottom [500X]).

R2. Rope fragment (fig. 59): round in section, of three strands laid left; D 0.05 m; strands D 0.0225 m, laid right, consisting of yarns D ca. 0.003 m, laid left. Provenance: 0.15 m west of inboard extremity of floor timber 13, at planking level.

R3. Rope fragment (fig. 60): round in section, of three strands laid left; D 0.015 m; strands D ca. 0.008 m, laid right. Provenance: watercourse of half-frame 10, and also noted within watercourses of half-frames 12 and 14 and at outboard extremity of floor timber 33 (figs. 7, 8, 24, 25).

**PINE CONE**

A well preserved ovate pine cone (L 0.07 m, max. D 0.045 m) with pyramidal scale apices was discovered concreted between frames 12 and 13 about 0.93 m from the finished inboard extremity of half-frame 12. It lay 0.04 m below the level of the frame tops (figs. 61–62). Unfortunately it was not raised for study, but visual inspection indicates it is of the species *Pinus pinea*.6
Fig. 60. Rope fragment $R3$, part of the rope found within watercourses of half-frames 10, 12, 14, and at outboard extremity of floor timber 33 (scale in centimeters). (Photo M. Little.)
Fig. 61. *Pinus pinea* pine cone *in situ* between frames 12 and 13 (scale in centimeters). (Photo M. Little.)
Notes

1. Wood identifications were made by Donna J. Christensen, Center for Wood Anatomy Research, U.S. Forest Products Laboratory, Madison, Wisconsin, and by the staff of the archaeometric laboratories at Tel Aviv University.

2. This scheme was certainly not, however, inviolate in Graeco-Roman ships. See a review of more than ten exceptions in Carre 1993: 14–15.

3. Analysis performed by Dennis James of the Center for Chemical Characterization and Analysis, Texas A&M University.

4. Analysis performed by Dennis James of the Center for Chemical Characterization and Analysis, Texas A&M University.

5. To avoid confusion regarding left-lay rope as opposed to that laid right, the direction of twist is here termed according to the following definition. A rope, the strands of which appear to have been turned to the left as the rope is viewed approaching the observer, is described as left-laid (also known as Z twist). Conversely, strands that look twisted to the right as the rope approaches the viewer constitute a rope laid right (S twist). I thank Bill Charlton for calling to my attention the possibility of confusion on this point.

6. Species identification confirmed by M.E. Kislev of the Department of Life Sciences, Bar-Ilan University, Ramat-Gan, Israel.
CHAPTER IV

WOODS USED IN GRAECO-ROMAN
AND EARLY BYZANTINE MEDITERRANEAN SHIPS

The Caesarea hull, with planking and frames fashioned from pine trees, is among relatively few known Graeco-Roman hulls that display softwood planks and frames and represents the largest ship among them. A brief examination of the ancient literature indicates an abundance of pine was available to Greek and Roman shipwrights, and a review of woods used in Greek and Roman hulls shows that pine is the most common planking material found on the wrecks cataloged below. Some relationships between materials, construction techniques, and hull size are illuminated through a consideration of literary and archaeological evidence. An overview of the major pine and evergreen oak species of the Mediterranean and their current distributions, however, demonstrates the difficulty of determining where the Caesarea ship was built.¹

LITERARY EVIDENCE FOR THE USE OF PINE

From the fourth century B.C.E. through the fifth century A.D., pine is consistently mentioned in Greek and Latin literature as one of the best woods for shipbuilding. According to Theophrastus (HP 5.7.1–3, 5.7.5), who wrote in the late fourth century B.C.E., pine, silver fir, and cedar were acceptable.² He recommends silver fir for triremes and longships because it is light. Merchant ships are to be built of πεύκη, pine, because it resists decay, but he notes that another kind of pine, πιτυς, soon rots (presumably in saltwater).³ Vegetius (4.34) includes pine along with cypress, fir, and larch as the best woods for naval galleys.

A brief overview of the Graeco-Roman literature makes it clear that suitable wood for ships was found over a large portion of the ancient Mediterranean world, although few writers discuss specifically the use of pine in shipbuilding.⁴ Because the
Caesarea hull appears to have been built exclusively of pine planks and frames, the following survey is concerned primarily with references to pine or to unspecified species of timber used for ship construction.

**Spain and the Balearic Islands**

According to Strabo (3.2.4, 3.2.6, 3.5.3), a Roman geographer and historian of the first centuries B.C.E. and A.C., the ships of Turdetania (Baetica) were built with native timber. Merchantmen of great size sailed from this region, apparently in large numbers. The men of Gades fitted out the most and largest merchantmen both for the Mediterranean and the Atlantic. Ancient Ebusus and Ophiussa, respectively Iviza and Formentera of the modern Balearics, were called αἱ Πινυόσαται, the Pine Islands (Strabo 3.5.1).

**Italy**

Theophrastus (HP 5.8.1–3) praises the pines and firs of Latium and the Italian hill country but states that they are surpassed in terms of height and girth by the trees on Corsica. In a speech regarding the Athenian expedition to Sicily (Thucydides 6.90.3), Alcibiades refers to the great abundance of Italian timber suitable for ships. Diodorus Siculus (14.42.4), writing in the first century B.C.E., relates that Dionysius of Syracuse sent half of his woodcutters to Italy for shipbuilding timber in preparation for war with Carthage. About 240 B.C.E., Hiero II of Syracuse obtained from Italy some of the wood for treenails and frames for his grain ship Syracusia (Athenaeus 5.206f). Pisa had a reputation for ship timber, and Liguria had great reserves of it, including trees up to eight feet in diameter (Strabo 5.2.5, 4.6.2). According to Dionysus of Halicarnassus (20.15.1–2, 1.37.4), at about the same time, the Sila forest of Calabria was full of pine and many other woods suitable for ships and houses, and he attests to the bountiful and easily accessible forests of Italy in general. During the reign of Majorianus in the middle of the fifth century, rich reserves of ship timber could still be found on both sides of the Apennines (Sidonius Apollinaris, Carmina 5.441–45). In A.D. 526 Theodoric ordered that cypress and pine from the coasts of Italy and fir from the Po valley be used to construct 1000 dromons (Cassiodorus, Variae 5.16–18, 5.20).

**Mount Aetna and Sicily**

Diodorus Siculus (14.42.4) refers to the heavy stands of excellent pine and fir on
Mt. Aetna. Dionysius of Syracuse dispatched half of his woodsmen to the slopes of the volcano for shipbuilding timber during preparations for the war against the Carthaginians. Later, Hiero II of Syracuse collected much of the wood for the Syracusia from the same area and from elsewhere in Sicily (Athenaeus 5.206f).

Macedonia, Thrace, and the Southern Black Sea Coast

Theophrastus (HP 4.5.5) credits Macedonia, certain parts of Thrace, Phrygian Mt. Ida, and Mysian Olympus with possessing acceptable ship timber. More specifically, he mentions the pine of Macedonia (HP 3.3.1), an important source of ship timber for Athens in the fifth and fourth centuries B.C.E. (Xenophon, Historia Graeca 6.1.11; Thucydides 4.108.1). Shortly after 180 B.C.E., Perseus sent shipbuilding timber to Rhodes (Livy 11.5.29; Polybius 25.4.9–10), but following his defeat at Pydna in 168 B.C.E., Macedonia was prohibited by Rome from cutting or allowing other nations to cut ship timber (Livy 45.29.14). On the east coast of the Black Sea, at the foot of the Caucasus mountains, was the city of Greater Pityus (Strabo 11.2.14), which appears to have received its name from the Greek πιτυς. This city was in the region of Colchis, where there was much shipbuilding timber and where Mithridates acquired his naval supplies (Strabo 11.2.15, 11.2.17, 11.2.18).

Cilicia

Cilician Sinope had acceptable ship timber, according to Theophrastus (HP 4.5.5). Diodorus Siculus (11.60.5, 11.75.2, 11.77.1) notes that on three different occasions in the fifth century B.C.E., the Persians made ready (built?) or gathered great numbers of warships on the Cilician coast. Strabo (14.5.3) later relates that Antony assigned to Cleopatra the region near the port of Harmaxia because its cedar was suitable for the construction of Egyptian naval vessels.

Cyprus

The people of Cyprus used πιτυς for their ships because it was available and was apparently superior to the local πεικη (Theophrastus, HP 5.7.2). Part of the Persian fleet was gathered from Cyprus or partly supplied by Cyprians on more than one occasion (Diodorus Siculus 11.60.5, 11.75.2). In the second half of the fourth century, Arrian Marcellinus (14.8.14) noted that a ship could be built here from keel to topsails with local materials.
LITERARY EVIDENCE FOR SOFTWOOD AND HARDWOOD SHIPS, PLANKS, AND FRAMES

In contrast to the abundant literary testimony to the general availability of timber around the Mediterranean for ship construction, there are few references to the use of particular woods for specific hull components. Dio Chrysostom (Oratio 64.10) mentions a pine plank 3 fingers thick. Theophrastus (HP 4.2.8, 5.4.3) and Pliny (Nat. 13.19.63, 16.79.218) both recommend black acacia for frames because of its resistance to rot, while noting that oak does rot in saltwater. A partial record of payments made to shipwrights and sawyers in an Egyptian boatyard of perhaps the mid-third century includes references to two types of wood. The account registers payments of 8 drachmas per day on Phaophi 17, 18, 19, and 27 to each of two sawyers to cut persea wood (Mimusops schimperi). Subsequently, on Hathyr 2, 3, 4, and 7, the sawyers are paid the same wages to cut frames of acacia. Casson (1990) convincingly suggests the persea wood is intended for hull planks for the boat.

More generally, Aristophanes (Equites 1310) has a small galley describe itself as built of πετρική (pine) and "timber." Theophrastus (HP 5.7.5) notes that oak is used for shipbuilding, Vergil (Aeneid 5.753, 11.326) refers to ship timbers of oak, and King Latinus offers the Trojans 20 ships of Italian oak. Pliny (Nat. 16.81.224) observes that pine and cypress most effectively resist rot and wood worms. Pomey (1973b: 492–500) argues that a passage in Ovid (Epistulae 16.107–11) indicates the use of pine planking and oak frames in ships. Moreover, he points out that pine, unlike oak, was used to such an extent that it was employed by metonymy for ships by Vergil (Aeneid 10.206; Eclogae 4.38) and Ovid (Epistulae 18.158; Amores 2.11.2; Metamorphoses 2.184–85), as were fir and alder by numerous authors (Pomey 1973b: 494–95, 495 n. 2; Torr 1964: 32, n. 83, 33).

The archaeological evidence generally confirms the use of these materials in Greek, Roman, and early Byzantine times. Planks of the vast majority of wrecks of seagoing ships are of softwoods, mostly pine. The frames, in turn, are most frequently found to be oak or other hardwoods (Table 1). This scheme was tentatively noted by Frost (1981b: 69, 72) in the final report on the Marsala shipwreck.
<table>
<thead>
<tr>
<th>Site</th>
<th>Planks Inner/Outer</th>
<th>Frames</th>
<th>Length (m)</th>
<th>Date (Century)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ma’agan Michael</td>
<td>pine</td>
<td>pine</td>
<td>13</td>
<td>5/4 B.C.E.</td>
</tr>
<tr>
<td>Kyrenia</td>
<td>pine</td>
<td>pine</td>
<td>14</td>
<td>4 B.C.E.</td>
</tr>
<tr>
<td>Vulpiglia</td>
<td>pine</td>
<td>pine?</td>
<td>14</td>
<td>3 B.C.E.</td>
</tr>
<tr>
<td>Marsala</td>
<td>pine</td>
<td>oak, maple</td>
<td>35</td>
<td>3 B.C.E.</td>
</tr>
<tr>
<td>Marsala “Sister”</td>
<td>pine</td>
<td>oak</td>
<td>35</td>
<td>3 B.C.E.</td>
</tr>
<tr>
<td>Athlit Ram</td>
<td>pine</td>
<td>oak</td>
<td>30</td>
<td>3/2 B.C.E.</td>
</tr>
<tr>
<td>Punta Scaletta</td>
<td>oak</td>
<td>oak</td>
<td>30</td>
<td>2 B.C.E.</td>
</tr>
<tr>
<td>Apollonia 1</td>
<td>pine</td>
<td>walnut</td>
<td>30–35</td>
<td>2–1 B.C.E.</td>
</tr>
<tr>
<td>Spargi</td>
<td>pine</td>
<td>oak?</td>
<td>30</td>
<td>2 B.C.E.</td>
</tr>
<tr>
<td>Cavalière</td>
<td>pine</td>
<td>pine</td>
<td>13</td>
<td>2/1 B.C.E.</td>
</tr>
<tr>
<td>Gr. Congloué</td>
<td>pine/pine</td>
<td>oak chocks, pine half-frames</td>
<td>23</td>
<td>2/1 B.C.E.</td>
</tr>
<tr>
<td>Pozzino</td>
<td>fir, oak</td>
<td>oak</td>
<td></td>
<td>2/1 B.C.E.</td>
</tr>
<tr>
<td>La Roche Fouras</td>
<td>pine?</td>
<td>oak</td>
<td></td>
<td>2/1 B.C.E.</td>
</tr>
<tr>
<td>Cap Gros</td>
<td>pine</td>
<td>pine</td>
<td></td>
<td>2–1 B.C.E.</td>
</tr>
<tr>
<td>Miladou</td>
<td>pine</td>
<td>alder, ash, fig, poplar, pine</td>
<td>15</td>
<td>2–1 B.C.E.</td>
</tr>
<tr>
<td>Agde D</td>
<td>oak</td>
<td>fir</td>
<td></td>
<td>1 B.C.E.</td>
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<tr>
<td>Albenga</td>
<td>fir</td>
<td>oak</td>
<td>40</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Antikythera</td>
<td>elm</td>
<td>pine?</td>
<td>30</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Mahdia</td>
<td>elm /elm</td>
<td>elm</td>
<td>30</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>St. Jordi 1</td>
<td>pine</td>
<td>oak</td>
<td>25</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Dramont A</td>
<td>pine</td>
<td>elm</td>
<td>25</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Sa Nau Perduda</td>
<td>pine</td>
<td></td>
<td></td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>M. de Giens</td>
<td>elm /fir</td>
<td>oak, elm, walnut</td>
<td>38</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Planier 3</td>
<td>pine</td>
<td>walnut</td>
<td>15–20</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Titan</td>
<td>pine or fir</td>
<td></td>
<td>≤25</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Los Ullastres</td>
<td>fir</td>
<td>elm</td>
<td></td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Site</td>
<td>Planks Inner/Outer</td>
<td>Frames</td>
<td>Length (m)</td>
<td>Date (Century)</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------</td>
<td>----------------</td>
<td>------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Comacchio</td>
<td>elm</td>
<td>oak</td>
<td>22</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Cap del Vol</td>
<td>fir</td>
<td>oak</td>
<td>18</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Grand-Ribaud D</td>
<td></td>
<td>oak, willow</td>
<td>18</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Plavac A</td>
<td>spruce?</td>
<td>oak or chestnut</td>
<td>25–30</td>
<td>1 B.C.E/1 A.C.</td>
</tr>
<tr>
<td>Kinneret</td>
<td>cedar, pine</td>
<td>oak, willow, hawthorn, redbud</td>
<td>9</td>
<td>1 B.C.E.–</td>
</tr>
<tr>
<td>Caesarea</td>
<td>pine</td>
<td>pine</td>
<td>40</td>
<td>1 A.C.</td>
</tr>
<tr>
<td>Ladispoli</td>
<td>pine</td>
<td>oak, elm, poplar</td>
<td>18</td>
<td>1 A.C.</td>
</tr>
<tr>
<td>Monfalcone</td>
<td>fir</td>
<td>walnut</td>
<td>&gt;11</td>
<td>1 A.C.</td>
</tr>
<tr>
<td>Diano Marina</td>
<td>conifer</td>
<td>conifer</td>
<td>22–25</td>
<td>1 A.C.</td>
</tr>
<tr>
<td>Lake Nemi 1,2</td>
<td>pine</td>
<td>oak</td>
<td>71, 73</td>
<td>1 A.C.</td>
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<tr>
<td>St.-Gervais 3</td>
<td>pine</td>
<td>elm, walnut, maple, pine</td>
<td>17</td>
<td>1 A.C.</td>
</tr>
<tr>
<td>Culip 4</td>
<td>pine</td>
<td>pine</td>
<td>9–10</td>
<td>1 A.C.</td>
</tr>
<tr>
<td>Grand-Bassin C</td>
<td>cedar, oak</td>
<td>oak</td>
<td></td>
<td>2 A.C.</td>
</tr>
<tr>
<td>Proccchio</td>
<td>spruce</td>
<td>elm</td>
<td>&gt;18</td>
<td>2 A.C.</td>
</tr>
<tr>
<td>Laurons 2</td>
<td>pine, cedar</td>
<td>pine, oak</td>
<td>15</td>
<td>2 A.C.</td>
</tr>
<tr>
<td>Torre Sgarrata</td>
<td>pine</td>
<td>oak</td>
<td>24</td>
<td>2 A.C.</td>
</tr>
<tr>
<td>Bourse</td>
<td>pine, larch</td>
<td>pine, ash, poplar</td>
<td>23</td>
<td>2/3 A.C.</td>
</tr>
<tr>
<td>Monaco</td>
<td>pine or fir</td>
<td></td>
<td>12–15</td>
<td>2/3 A.C.</td>
</tr>
<tr>
<td>Punta Scifo</td>
<td>oak</td>
<td></td>
<td></td>
<td>2/3 A.C.</td>
</tr>
<tr>
<td>Laurons 3</td>
<td>pine</td>
<td></td>
<td>&lt;15</td>
<td>3 A.C.</td>
</tr>
<tr>
<td>Pommègues</td>
<td>pine</td>
<td></td>
<td></td>
<td>3 A.C.</td>
</tr>
<tr>
<td>San Pietro</td>
<td></td>
<td>elm</td>
<td></td>
<td>2/3 A.C.</td>
</tr>
<tr>
<td>Musée des Docks</td>
<td>pine</td>
<td>pine</td>
<td>20–25</td>
<td>3 A.C.</td>
</tr>
<tr>
<td>Laurons 1</td>
<td>pine</td>
<td>oak</td>
<td>&gt;13</td>
<td>3–4 A.C.</td>
</tr>
<tr>
<td>Fiumicino 1</td>
<td>oak</td>
<td></td>
<td>19</td>
<td>3–5 A.C.</td>
</tr>
<tr>
<td>Fiumicino 2</td>
<td>oak</td>
<td></td>
<td>17</td>
<td>3–5 A.C.</td>
</tr>
<tr>
<td>Fiumicino 3</td>
<td>larch</td>
<td></td>
<td>9</td>
<td>3–5 A.C.</td>
</tr>
<tr>
<td>Site</td>
<td>Planks Inner/Outer</td>
<td>Frames</td>
<td>Length (m)</td>
<td>Date (Century)</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------------------</td>
<td>---------------</td>
<td>------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Fiumicino 6</td>
<td>larch</td>
<td>chestnut?</td>
<td>6</td>
<td>3–5 A.C.</td>
</tr>
<tr>
<td>P. de la Luque B</td>
<td>cedar</td>
<td></td>
<td>20</td>
<td>3/4 A.C.</td>
</tr>
<tr>
<td>Laurons 4</td>
<td>pine</td>
<td></td>
<td></td>
<td>4 A.C.</td>
</tr>
<tr>
<td>Lazzaretto</td>
<td>cypress</td>
<td>pine</td>
<td></td>
<td>4 A.C.</td>
</tr>
<tr>
<td>Yassi Ada</td>
<td>cypress</td>
<td>cypress</td>
<td>20</td>
<td>4 A.C.</td>
</tr>
<tr>
<td>Port-Vendres 1</td>
<td>pine, cypress, olive</td>
<td>pine, oak</td>
<td>&gt;20</td>
<td>4/5 A.C.</td>
</tr>
<tr>
<td>St.-Gervais 2</td>
<td>pine, fir, alder</td>
<td>elm, oak</td>
<td>15–18</td>
<td>6/7 A.C.</td>
</tr>
<tr>
<td>Pantano Longarini</td>
<td>cypress</td>
<td>oak</td>
<td>30</td>
<td>7 A.C.</td>
</tr>
<tr>
<td>Yassi Ada</td>
<td>pine</td>
<td>elm</td>
<td>20</td>
<td>7 A.C.</td>
</tr>
</tbody>
</table>
WOOD TYPES IN EVIDENCE FOR PLANKS AND FRAMES

Softwood Planks and Frames

The Caesarea hull aside, I have been able to identify 13 and possibly 14 vessels dated to the Greek, Roman, and early Byzantine periods built either entirely or primarily with both planks and frames of softwoods.

Ma'agan Michael (ca. 400 B.C.E., L ca. 13 m): planks and frames, as almost all preserved hull components, are Aleppo pine, *Pinus halepensis* (Rosloff 1990: 4 and personal communication; Kahanov 1991: 5; Linder 1992: 28, 31).

Kyrenia (late fourth century B.C.E., L ca. 14 m): planks and frames are probably of *Pinus halepensis* Miller, Aleppo pine (Steffy 1985b: 87).

Vulpiglia (ca. 280 B.C.E., L undetermined): fragments of one frame and one piece of planking may be pine (Parker 1985: 123).

Cavalière (late second or early first century B.C.E., L ca. 13 m): *Pinus leucodermis* Antoine and *Pinus sylvestris* L. or *Pinus uncinata* Raymond were used for planks and frames (Charlin, Gassend, and Lequément 1979: 77).

Grand Congloué (110–70 B.C.E., L ca. 23 m): half-frames and planks are Aleppo pine (*Pinus halepensis*), while only the chocks spanning the half-frames are oak (Benoît 1961: 149–50). The representation in Benoît of these chocks fastened atop the half-frames is not paralleled in the archaeological reports I have read. Perhaps they were instead chocks fastened to the under surfaces of the floor timbers, as was clearly done on the Kyrenia hull, or even small floor timbers themselves. The possibility that this feature was not understood and reported inaccurately is not unlikely given the nature of this excavation, which occurred early in the history of modern underwater archaeology. See Long 1987.

Cap Gros (end of the second to first half of the first century B.C.E., L undetermined): only a small percentage of the hull has been exposed and studied. Identified planks are *Pinus halepensis*, as are three floor timbers and two pairs of half-frames (Joncheray 1989a: 65).

Diano Marina (mid-first century, L ca. 22–25 m): pine planking and oak frames were used, according to earlier reports (Pallarés 1983a: 85; 1983e: 260; 1985b: 590), but recently the hull materials have been attributed simply to the conifer family (Pallarés 1991: 172).
Culip 4 (A.D. 70–80, L ca. 9–10 m): frames and planks are identified as either *Pinus sylvestris* L. or *Pinus nigra* Arn. (Parker 1992a: 158).

Laurons 2 (late second century, L ca. 15 m): one floor timber and three half-frames were identified as *Pinus halepensis* and one other half-frame is *Quercus pedunculata* or *sessiflora*. Three samples of planking are *Pinus halepensis*, one is cedar (Rival 1991: 86).

Bourse (late second or early third century, L ca. 23 m): of 56 planks sampled, 26 are *Pinus halepensis*, 22 are *Pinus sylvestris*, and 1 is spruce. Of 135 frame samples, 127 are *Pinus halepensis*; 5 are ash and 3 are poplar (Gassend 1982: 120).

Pommègues (second half of third century, L undetermined): samples from two planks and two frames are all identified as *Pinus leucodermis* Antoine (Gassend 1979: 107, n. 1).

Musée des Docks (late third century, L ca. 20–25 m): Benoît (1958: 11) indicates the wood is *Pinus halepensis*, while the frames are reported by Basch (1972: 51) to be *Pinus leucodermis*. If both identifications are correct, the planking would be *Pinus halepensis*.

Cala del Lazzaretto (after A.D. 315, L undetermined): two planking fragments and 1 frame were raised. The planks are cypress, the frame is pine (Riccardi 1991: 11).

Yassi Ada (second half of fourth century, L ca. 20 m): the ship was built with planks and frames of Mediterranean cypress (*Cupressus sempervirens*) (van Doorninck 1976: 130).

Port-Vendres 1 (late fourth or early fifth century, L ca. 20 m): of eight sampled floor timbers, seven are *Pinus halepensis* and one is *Quercus ilex*. All three identified half-frames are *Pinus halepensis*. Seven hull planks were also identified: two are of *Pinus halepensis*, three are cypress (*Cupressus* sp.), and two are olive, *Olea europaea* (Rival 1991: 86, 269, table 11).

**Softwood Planks and Hardwood Frames**

Of the wrecks I have been able to catalog, those with softwood planks and hardwood frames occur twice as often as do those with softwood planks and frames.

Marsala (mid-third century B.C.E., L ca. 35 m?): the Punic ship and its “Sister ship” have pine planks; frames of the Punic ship are predominantly *Quercus robur*, but
some are maple. Two frame samples from the "Sister ship" are *Quercus cerris* (Frost 1981b: 69, 87).


*Spargi* (120–100 B.C.E., L ca. 30–35 m): the planking is pine (Lamboglia 1971: 208) and the frames apparently are oak (du Plat Taylor 1965: 112).

*La Roche Fouras* (late second or early first century B.C.E., L undetermined): the wreck has frames of oak or perhaps another hardwood; the planks resemble pine (Joncheray 1976c: 110, 112).

*Miladou* (end of the second to first half of the first century B.C.E., L ca. 15 m): frames were cut from trees of at least five different species: alder (*Alnus* sp.), poplar (*Populus* sp.), ash (*Fraxinus excelsior*), fig (*Ficus carica*), and Aleppo pine (*Pinus halepensis*). The planks are Aleppo pine (Dumontier and Joncheray 1992: 137, 174). This hull is included under this subhead because it appears that the majority of the frames are hardwoods.

*Agde D* (first century B.C.E., L undetermined): the frames are identified as oak, the planking as fir (Parker 1992a: 44).

*Albenga* (early first century B.C.E., L ca. 40 m): identified frames are *Quercus sessiflora*. One piece of hull planking is fir (*Abies alba*). Another planking fragment is oak, but it is thought to be a ceiling plank (Lamboglia 1953: 203-8).

*St. Jordi 1* (100–80 B.C.E., L undetermined): planks are pine and frames are *Quercus sessiflora ex-robur* (Colls 1987: 24, 31).

*Dramont A* (first half of first century B.C.E., L ca. 25 m): the ship was built with pine (*Pinus sylvestris*) planks and elm frames (Santamaria 1975: 194, n. 4; Gianfrotta and Pomey 1981: 270).

*Planier 3* (50–25 B.C.E., L ca. 15–20 m): pine planks and walnut frames make up the hull remains (Gianfrotta and Pomey 1981: 270).

*Los Ullastres* (50 B.C.E.–A.D. 25, L ca. 18 m): this wreck comprises fir planks and probably elm frames (Foerster Laures 1978: 162). Parker (1992a: 439) adds that some frames are of beech.

*Cap del Vol* (20–15 B.C.E., L ca. 18–19 m): evergreen oak frames and silver fir planks are reported (Foerster Laures 1980: 247, 252).
Kinneret (first century B.C.E. or A.C., L ca. 9 m): most of the planks of this small fishing boat from an inland lake were cut from Cedrus libani, true cedar; one was of Pinus halepensis. The majority of frames are a species of Quercus, with single examples of willow (Salix), hawthorn (Crataegus), and redbud (Cercis) (Steffy 1987: 325, 327; Wachsmann 1987).

Ladispoli (early first century, L ca. 18 m): five planking samples were found to be Pinus pinaster. Of eight floor timbers sampled, five are Quercus sp., two are Ulmus sp., and one is Populus sp. (Meucci 1993: 21, 22, fig. 1, 23, 50–52, 53, fig. 38; cf. Carre 1993: 24).

Monfalcone (first century, L >11 m): planks are fir, frames are walnut (Parker 1992a: 281).

Lake Nemi (mid-first century, L ca. 71 and 73 m): ship 1 was constructed with planks of Corsican pine (Pinus laricio) and frames of oak (Quercus sessiflora). The second ship appears to have been built with Pinus halepensis planks. Frames were most likely Quercus sessiflora and Quercus pedunculata (Ucelli 1950: 147, 151–52; Gianfrotta and Pomey 1981: 270; Meiggs 1982: 246).

Procchio (A.D. 160–200, L >18 m): planking is of the genus Picea, spruce, and the frames are elm (Parker 1992a: 343).

Torre Sgarrata (late second century, L ca. 24 m): hull planks are pine (Throckmorton 1968: 7; 1969: 282, 288, 290, 297), specifically Pinus sylvestris (Throckmorton 1989: 264). The frames were fashioned from trees of evergreen oak (Throckmorton 1989: 265).

Fiùmico 3 (third to fifth centuries, L ca. 9 m): one of the smaller river boats, it was built with larch planking and oak frames (Testaguzza 1970: 132).

Fiùmico 6 (third to fifth centuries, L ca. 6 m): a typical fishing boat, this too has larch planks, and possibly chestnut frames (Testaguzza 1970: 132).

St.-Gervais 2 (late sixth or early seventh century, L ca. 15–18 m): the frames are elm and oak and the planks are pine, fir, and alder (Jézégou unpublished: 10–11).

Pantano Longarini (ca. A.D. 600–650, L ca. 30 m): the vessel was built with oak frames and cypress planks and wales (Throckmorton and Kapitán 1968: 185–87).

Yassi Ada (A.D. 625, L ca. 20 m): these planks were of pine, the frames of elm (van Doominck 1982: 55).
**Hardwood and Softwood Planks and Hardwood Frames**

*Pozzino* (late second or early first century B.C.E., L undetermined): framing timbers are oak, probably a deciduous species. Planks are white fir and oak, but the frequencies of occurrence are not reported (Riccardi 1990).

*La Madrague de Giens* (60–40 B.C.E., L ca. 38 m): a wide variety of woods were identified. The interior layer of planking is elm and the outer is fir. Elm and walnut were used for half-frames, of which one futtock is also walnut. Floor timbers are deciduous oak and their futtocks were fashioned from elm trees (Couvert 1978: 110–11).

*Grand-Bassin C* (A.D. 120, L undetermined): planks are apparently cedar and oak, and frames are of oak (Parker 1992a: 199).

**Hardwood Planks and Frames**

In contrast to the predominant use of softwoods for planking, two large seagoing vessels and three smaller coastal/river craft have been found with both hardwood frames and planks.8

*Punta Scalaletta* (150–140 B.C.E., L ca. 30 m): oak was used for frames and planks (Lamboglia 1964: 240, opposite p. 240, pl. 2).

*Mahdia* (early first century B.C.E., L ca. 30 m): planks and frames are of the elm family (de Frondeville 1956: 222; du Plat Taylor 1965: 51; Gianfrotta and Pomey 1981: 270).

*Comacchio* (last quarter of first century B.C.E., L ca. 22 m): all 33 identified hull planks are elm. The 23 identified floor timbers are *Quercus robur*, as are 14 of the analyzed futtocks. Three other futtocks are elm (Castelletti et al. 1990a: 150, table 1; Berti 1992: 224).

*Fiumicino 1* (third to fifth centuries, L ca. 19 m): this vessel, the largest from the site, was built with oak planks and frames (Testaguzza 1970: 130).

*Fiumicino 2* (third to fifth centuries, L ca. 16 m): oak planks and frames were used for this river boat (Testaguzza 1970: 131).

**Hardwood Planks and Softwood Frames**

*Antikythera* (early first century B.C.E., L ca. 30 m): plank fragments retrieved from the wreck site are elm; pine timbers that look like frames are also associated with the wreck material. One is attributed to the ship (Throckmorton 1965: 41, 47).
Softwood Planks, Frames Unidentified

_Athlit Ram_ (204–167 B.C.E., L undetermined): the planks and wales found within the ram of this warship are of the red pine group (Steffy 1983: 235; 1991: 17).

_Sa Nau Perduda_ (100–50 B.C.E., L ca. 15–20 m): the site yielded what is probably a plank fragment of _Pinus pinaster_ (Foerster Laures and Pascual 1970: 282).

_Titan_ (middle or late first century B.C.E., L ≤25 m): the planks may be fir (Tailliez 1961: 194) or pine (du Plat Taylor 1965: 88).

_St.-Gervais_ 3 (mid-first century, L ca. 17 m): planks are Aleppo pine. Analyzed frame samples come only from the bow area; of 8 identified, two are maple and two are Aleppo pine; one is walnut, one is elm, and another is _Pinus sylvestris_. The eighth is termed maritime pine (Liou and Gassend 1991: 232), and is therefore either _Pinus pinaster_ or _Pinus maritima_. The wreck is included in this category because the wood types used for the identified frames are at present distributed evenly between softwoods and hardwoods.

_Monaco_ (late second or early third century, L ca. 12–15 m): the planks are thought to be pine or fir (Mouchot 1970a: 181).

_Laurons_ 3 (third century, L undetermined): planks are pine (Ximénès and Moerman 1987: 176). Parker (1992a: 237) argues for a date of no later than A.D. 275, as opposed to the fourth century date suggested by Ximénès and Moerman.

_Laurons_ 1 (third or fourth century, L undetermined): planks are pine (Ximénès and Moerman 1987: 173).

_Pointe de la Luque B_ (late third or early fourth century, L ca. 20 m): hull planks are cedar (Gianfrotta and Pomey 1981: 269).


Hardwood Planks, Frames Unidentified

_Punta Scifo_ (ca. A.D. 200, L undetermined): bits of oak planking are reported on this wreck site of some 50 x 50 m (Pensabene 1978: 107).

Hardwood Frames, Planks Unidentified

_Grand-Ribaud D_ (last decade of the first century B.C.E., L ca. 18 m): two frame fragments are of deciduous oak; another is willow (Rival, Hesnard, and Carre 1988: 108–9).
Plavac A (late first century B.C.E.–early first century A.C., L ca. 25–30 m): according to Parker (1992a: 318), “the hull was at least partly constructed of chestnut or oak (for frames) and spruce.” Because the spruce is not specifically identified as planking, the wreck is placed in this category.

San Pietro (first half of third century, L undetermined): what are thought to be fragments of 2 elm frames were recovered from the vessel (Ward-Perkins and Throckmorton 1965: 206–7).

WOOD TYPES IN EVIDENCE FOR WOODEN FASTENINGS

Treenails

Regarding the 35 wrecks from which treenails have been identified (Table 2), 22 (ca. 63 percent) display hardwood treenails, whereas on 15 wrecks (ca. 43 percent) — some wrecks display both — softwoods are in evidence. (See Chapter VII regarding the use of treenails as primary fastenings of frames to planking and as plugs surrounding nails serving the same purpose.) Oak or evergreen oak treenails were found on the following wrecks: Marsala (Frost 1981b: 126), Jeanne-Garde B (Carazzé 1977: 302), Grand Congloué (Benoît 1961: 190, pl. 34b, 191, fig. 102), Lake Nemi — those that did not penetrate the frames completely (Ucelli 1950: 152; Gianfrotta and Pomey 1981: 270), Laurons 2 (Rival 1991: 86), Torre Sgarrata (Throckmorton 1989: 264), Laurons 1 and 3 (Ximénès and Moerman 1987: 173, 177), fourth-century Yassi Ada (van Doorninck 1976: 130), and St.-Gervais 2 (Jézégou 1985: 354).

The treenails on the Giens wreck might be elm or ash (Couvert 1978: 110–11). Those in the hull at Comacchio are dogwood, linden, and oak (Castelletti et al. 1990a: 150, table 1), and at Grand-Bassin (C) they are olive, fir, and palm wood (Parker 1992a: 199). Of seven identified from the Bourse wreck, one is cypress and six are olive (Gassend 1982: 120). Olive was also utilized on the ship that wrecked at Cap Gros (Joncheray 1989a: 65), on Wreck 1 at Port-Vendres (Rival 1991: 88, 269, table 11), and on Culip 4 (Parker 1992a: 158). A wreck at Miladou exhibits treenails of (apparently both) cork oak (Quercus suber) and fir (Abies pectinata) (Dumontier and Joncheray 1992: 137). The three treenail samples from the wreck at Ladispoli have been identified as poplar (Meucci 1993: 21, 23, 51, fig. 36). 9 Gassend (1979: 107, n. 1) states that 11 samples of chevilles from the third-century wreck at Pommègues
Table 2. Woods Used for Treenails, Tenons, and Tenon Pegs on Greek, Roman, and Early Byzantine Ships.

<table>
<thead>
<tr>
<th>Site</th>
<th>Treenails</th>
<th>Tenons</th>
<th>Tenon Pegs</th>
<th>Length (m)</th>
<th>Date (Century)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ma’agan Michael</td>
<td>pine</td>
<td>oak</td>
<td>oak</td>
<td>13</td>
<td>5/4 B.C.E.</td>
</tr>
<tr>
<td>Kyrenia</td>
<td>pine</td>
<td>oak</td>
<td>oak</td>
<td>14</td>
<td>4 B.C.E.</td>
</tr>
<tr>
<td>Marsala</td>
<td>oak</td>
<td>oak</td>
<td>oak</td>
<td>35</td>
<td>3 B.C.E.</td>
</tr>
<tr>
<td>Marsala “Sister”</td>
<td>olive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Athlit Ram</td>
<td>oak</td>
<td></td>
<td></td>
<td></td>
<td>2 B.C.E.</td>
</tr>
<tr>
<td>Jeanne-Garde B</td>
<td>oak</td>
<td></td>
<td></td>
<td></td>
<td>2 B.C.E.</td>
</tr>
<tr>
<td>Apollonia 1</td>
<td></td>
<td>oak</td>
<td></td>
<td>15</td>
<td>2–1 B.C.E.</td>
</tr>
<tr>
<td>Cavalière</td>
<td>fir</td>
<td>oak</td>
<td>oak, fir</td>
<td>13</td>
<td>2/1 B.C.E.</td>
</tr>
<tr>
<td>Gr. Congloué</td>
<td>oak</td>
<td></td>
<td>probably acacia</td>
<td>23</td>
<td>2/1 B.C.E.</td>
</tr>
<tr>
<td>Pozzino</td>
<td></td>
<td>oak</td>
<td></td>
<td></td>
<td>2/1 B.C.E.</td>
</tr>
<tr>
<td>Cap Gros</td>
<td>olive</td>
<td></td>
<td></td>
<td></td>
<td>2–1 B.C.E.</td>
</tr>
<tr>
<td>Miladou</td>
<td>cork oak, fir</td>
<td>oak</td>
<td></td>
<td>15</td>
<td>2–1 B.C.E.</td>
</tr>
<tr>
<td>Agde D</td>
<td></td>
<td>oak</td>
<td></td>
<td></td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Albenga</td>
<td>softwood</td>
<td></td>
<td></td>
<td>40</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Antikythera</td>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Mahdia</td>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>St. Jordi 1</td>
<td>pine</td>
<td>oak</td>
<td>elm</td>
<td></td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>M. de Giens</td>
<td>elm? ash?</td>
<td>oak</td>
<td>oak, elm, ash</td>
<td>38</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Planier 3</td>
<td>fir</td>
<td></td>
<td>oak</td>
<td>15–20</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Comacchio</td>
<td>linden, oak, dogwood</td>
<td>oak</td>
<td>linden</td>
<td>22</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Kinneret</td>
<td></td>
<td>oak</td>
<td></td>
<td>9</td>
<td>1 B.C.E.–1 A.C.</td>
</tr>
<tr>
<td>Caesarea</td>
<td>oak</td>
<td></td>
<td>oak</td>
<td>40</td>
<td>1 A.C.</td>
</tr>
<tr>
<td>Site</td>
<td>Treenails</td>
<td>Tenons</td>
<td>Tenon Pegs</td>
<td>Length (m)</td>
<td>Date (Century)</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------</td>
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<td>----------------</td>
</tr>
<tr>
<td>Ladispoli</td>
<td>poplar</td>
<td>walnut</td>
<td>chestnut</td>
<td>18</td>
<td>1 A.C.</td>
</tr>
<tr>
<td>Diano Marina</td>
<td>softwood</td>
<td></td>
<td></td>
<td>22–25</td>
<td>1 A.C.</td>
</tr>
<tr>
<td>Lake Nemi 1, 2</td>
<td>oak, pine, fir</td>
<td></td>
<td></td>
<td>71, 73</td>
<td>1 A.C.</td>
</tr>
<tr>
<td>Culip 4</td>
<td>olive</td>
<td></td>
<td></td>
<td>9–10</td>
<td>1 A.C.</td>
</tr>
<tr>
<td>Grand-Bassin C</td>
<td>olive, fir, palm wood</td>
<td>oak</td>
<td>olive</td>
<td></td>
<td>2 A.C.</td>
</tr>
<tr>
<td>Laurons 2</td>
<td>oak</td>
<td>oak</td>
<td>oak, beech, elm</td>
<td>15</td>
<td>2 A.C.</td>
</tr>
<tr>
<td>Torre Sgarrata</td>
<td>oak</td>
<td>oak</td>
<td>laurel</td>
<td>24</td>
<td>2 A.C.</td>
</tr>
<tr>
<td>Bourse</td>
<td>olive, cypress</td>
<td>oak</td>
<td>cypress, olive</td>
<td>23</td>
<td>2/3 A.C.</td>
</tr>
<tr>
<td>Laurons 3</td>
<td>oak</td>
<td>oak</td>
<td>oak</td>
<td>&lt;15</td>
<td>3 A.C.</td>
</tr>
<tr>
<td>Monaco</td>
<td></td>
<td>acacia</td>
<td>oak</td>
<td>12–15</td>
<td>2/3 A.C.</td>
</tr>
<tr>
<td>Musée des Docks</td>
<td>fir</td>
<td></td>
<td></td>
<td>20–25</td>
<td>3 A.C.</td>
</tr>
<tr>
<td>Laurons 1</td>
<td>oak</td>
<td>oak</td>
<td>oak</td>
<td>&gt;13</td>
<td>3–4 A.C.</td>
</tr>
<tr>
<td>Fiumicino 1</td>
<td>softwood</td>
<td></td>
<td></td>
<td>19</td>
<td>3–5 A.C.</td>
</tr>
<tr>
<td>Fiumicino 2</td>
<td>softwood</td>
<td></td>
<td></td>
<td>17</td>
<td>3–5 A.C.</td>
</tr>
<tr>
<td>Lazzaretto</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4 A.C.</td>
</tr>
<tr>
<td>Yassi Ada</td>
<td>oak</td>
<td>oak</td>
<td>cypress</td>
<td>20</td>
<td>4 A.C.</td>
</tr>
<tr>
<td>Port-Vendres 1</td>
<td>olive</td>
<td>olive</td>
<td>pine</td>
<td>&gt;20</td>
<td>4/5 A.C.</td>
</tr>
<tr>
<td>St.-Gervais 2</td>
<td>oak</td>
<td></td>
<td></td>
<td>15–18</td>
<td>6/7 A.C.</td>
</tr>
<tr>
<td>Pantano Longarini</td>
<td>pistachio</td>
<td></td>
<td></td>
<td>30</td>
<td>7 A.C.</td>
</tr>
<tr>
<td>Yassi Ada</td>
<td>white oak</td>
<td></td>
<td></td>
<td>20</td>
<td>7 A.C.</td>
</tr>
</tbody>
</table>
were analyzed. Six were cypress, three were olive, and two were *Pinus leucodermis* Antoine. He does not distinguish, however, between treenails and tenon pegs.

The Kyrenia treenails are probably *Pinus halepensis* (Steffy 1985b: 87); those on the St. Jordi 1 wreck are definitely pine (Colls 1987: 35). At Cavalière they are fir (*Abies pectinata* D.C., *Abies alba* Miller) (Charlin, Gassend, and Lequément 1979: 77), as they are in the hulls at Planier (3) and in the Musée des Docks (Couvert 1978: 111, n. 3). The treenails that extended completely through the planks and frames of the Nemi barges were pine and fir (Ucelli 1950: 152; Gianfrotta and Pomey 1981: 270). No details are available for the treenails in the wrecks at Albenga (Lamboglia 1953: 203–4, 206, fig. 59, 207), Diano Marina (Pallarés 1985a: 642), and Fiumicino (1 and 2) (Testaguzza 1970: 130, 132). They are simply termed “softwood.”

**Tenons and Tenon Pegs**

The tenons and tenon pegs employed on ancient Greek and Roman ships of all sizes were most often oak, though exotic woods were sometimes used (Table 2). Softwood tenons were not utilized.\(^{10}\) I have found six hulls in which softwood (cypress, pine, fir, laurel) tenon pegs are in evidence. On the Pozzino wreck some tenon pegs are reportedly reinforced with copper nails (Riccardi 1990). This is uncommon.\(^{11}\)


Tenons of acacia seem to have been used on the wrecks at Grand Congloué and Monaco (B:noît 1961: 145–46, 152); those on the wreck near Mahdia are acacia or
boxwood and possibly olive (Benoît 1961: 152, n. 3). They are olive on the Marsala "Sister ship" (Frost 1981b: 69, 71), at Cap Gros (Joncheray 1989a: 65), at Cala del Lazzaretto (Riccardi 1991: 11), and on Wreck 1 at Port-Vendres (Rival 1991: 88, 269, table 11). The single identified tenon sample from the wreck at Ladispoli is walnut, *Juglans regia* (Meucci 1993: 21, 51, fig. 36). Unpegged and widely spaced pistachio tenons were used on the Pantano Longarini ship (Throckmorton and Throckmorton 1973: 263).

Pegs securing the tenons in their mortises are oak or evergreen oak at Ma'agan Michael (J.P. Rosloff, personal communication), Kyrenia (Steffy 1985b: 87), Marsala (Frost 1981b: 69), Cavalière (Gianfrotta and Pomey 1981: 270), Grand Congloué (Benoît 1961: 152), Antilythera (Throckmorton 1965: 41), Planier 3 (Gianfrotta and Pomey 1981: 270), Kinmeret (Steffy 1987: 325), Laurons 1 and 3 (Ximénes and Moerman 1987: 174, 177), Monaco (Benoît 1961: 145–46), and within the Athlit ram (Steffy 1983: 235; 1991: 17). The samples taken from the wreck at Miladou are (apparently both) evergreen oak and *Quercus suber*, cork oak (Dumontier and Joncheray 1992: 137). Those on Wreck D at Agde are probably oak (Parker 1992a: 44).

Tenon pegs are variously of evergreen oak, ash, and elm at Giens (Couvert 1978: 110), elm at St. Jordi (1) (Colls 1987: 35), and linden (*Tilia* sp.) at Comacchio (Castelletti et al. 1990a: 150, table 1). At Ladispoli, one tenon peg sample is identified as *Castanea sativa*, European chestnut (Meucci 1993: 21, 51, fig. 36). Two samples from the Lauron 2 hull are *Quercus ilex*, one is beech (*Fagus sylvatica*), and one is *Ulmus campestris* (Rival 1991: 86). Olive pegs were identified on Grand-Bassin C (Parker 1992a: 199), and of six identified pegs from the Bourse wreck, two are olive wood (Gassend 1982: 120).

The remaining four identified pegs from the wreck at Bourse are cypress (Gassend 1982: 120), as are the pegs on the wreck at Cala del Lazzaretto (Riccardi 1991: 11). They were *Cupressus sempervirens* in the fourth-century hull at Yassi Ada (van Doorninck 1976: 123, fig. 8, 130), but *Laurus nobilis* pegs were used in the Torre Sagarrata hull (Throckmorton 1989: 264). Wreck 1 at Port-Vendres exhibits tenon pegs of *Pinus halepensis* (Rival 1991: 88, 269, table 11), and some are *Abies alba* on the wreck at Cavalière (Rival 1991: 86).
PATTERNS IN USE OF MATERIALS

It must be remembered that for many reasons, the wood identifications cataloged above vary in their reliability. Moreover, wood components have been more thoroughly sampled and identified in some wrecks, less in others, and material usage is incompletely attested according to the extent and quality of preservation as well. Yet even given these caveats, notable usage patterns do emerge from the information at hand. With regard only to the seagoing hulls listed above, the largest number were planked with wood identified as pine or possibly pine (30–34), followed by fir (7–9) and oak (5), cypress (4), elm (2), and cedar (3). Oak frames are most often in evidence (18–20 instances), followed rather closely by pine (15–17), then elm (10), walnut (5), and poplar (3). Overall, pine is the most frequently occurring of the major woods, then oak, elm, and fir. (Quantities represent strict occurrence on wrecks: for example, the Giens hull is included in both the fir and elm planking categories.)

Meiggs (1982: 118–19) holds that fir was normally the first choice of Greek and Roman shipwrights, and cites primarily Greek sources. Yet Theophrastus’ recommendation of fir for longships is not borne out by the wood within the Athlit ram. Indeed, nautical archaeology suggests that, if fir was preferred, it was in the Greek period or earlier.12 The appearance of cypress planks and frames in the fourth or fifth and early seventh centuries (at Yassi Ada, Port-Vendres, and Pantano Longarini, respectively) confirms well the references in Vegetius (4.34) and Cassiodorus (Variae 5.16–18, 5.20), not only with regard to genus but in temporal terms as well.

The virtually standard use of pine, fir, and other softwoods for the planking of small and moderate-sized vessels must be in part a reflection of Graeco-Roman shipbuilding methods. Coupled with numerous references in the ancient literature to softwoods for ship timber and the employment of the words pine, fir and alder by metonymy for “ship,” the archaeological evidence suggests that ancient writers were more concerned with woods for planking than for frames. This is not surprising, because in ancient mortise-and-tenon built hulls the planking shell was the major structural member and the component claiming the greatest expenditure of time and effort. Thousands of mortises had to be cut to stringent specifications and planks sometimes required appreciable trimming to conform to the desired dimensions and curvatures. Softwoods must have been the most attractive materials to use under such
circumstances. Another important factor governing this pattern of usage may have been simple availability of materials. It has been suggested that topography limited access to some species and so biased procurement toward more easily obtainable woods such as Aleppo pine (Rival 1991: 28, 89, 298). The catalogs above do seem to confirm that coniferous trees more readily provided builders of all but quite large ships with timbers in the wide range of shapes and dimensions required by the process of first erecting a number of strakes and then fitting frames (cf. Steffy 1985b: 92).

The belief that oak rotted in sea water may partly account for its infrequent employment as planking material on the wrecks listed, but the fact that hardwood planks have been identified on seagoing ships only some 30 m or more in length is provocative. Structural and labor advantages may explain the evidence (see Relationships Between Vessel Size and Plank Thickness in Chapter V).

A preference for hardwood frames is clearly indicated by their occurrence on 40–42 wrecks (an average of ca. 71 percent), as opposed to 17–19 wrecks exhibiting the utilization of softwood frame components. That this preference may be attributed to a perceived structural advantage offered by hardwoods (as for planking) is suggested by the fact that softwood frame components are not found on wrecks of ships over about 25 m in length, with the possible exception of the Antikythera wreck (cf. Rival 1991: 61, 90).

A similar but less pronounced preponderance of hardwood treenail fastenings for planks and frames is evident, but the use of both softwood and hardwood treenails as plug-treenails pierced by nails raises other issues (see Plug-Treenails in Chapter VII). I have been able to discern no significant patterns that suggest shipwrights were mindful of using particular woods for treenails according to the woods being used for plank and frames in a specific hull.

All cataloged tenons have been fashioned from hardwood trees. Only six wrecks display softwood tenon pegs and all but one (Cavalière) date to the late second century or thereafter. It may be significant that those at Bourse, Yassi Ada, and Port-Vendres reveal structural details associated with the development of frame-first construction techniques. The wrecks at Torre Sgarrata and Lazzaretto are not well enough documented to evaluate in this regard, but perhaps softwood tenon pegs in the later Roman period were associated with the gradually diminishing importance of planking shells to the overall strength of the hull (see Chapters XVI and XVII).
PROVENANCE OF THE CAESAREA HULL

The distribution of pines and evergreen oaks in the modern Mediterranean region can provide clues to the provenance of the Caesarea hull but little more. Pines growing around the Mediterranean today are broadly subdivided into the white, red, and yellow pine groups (cf. Farjon 1984; Meiggs 1982; Mirov 1967; Mirov and Hasbrouck 1976; Rushforth 1987). They are also roughly classified as either coastal or mountain trees. The mountain pines were the most desirable for the building of Greek and Roman ships because they grow larger and stronger, the best providing lengths of over 60 ft (18.29 m) according to Meiggs (1982: 44, 119, 241).

Two primary species within the white pine group are Pinus cembra (Swiss stone pine) and Pinus peuce (Macedonian white pine). The Swiss pine is a high mountain variety (altitudes of 1200–2585 m) of southern Europe found from the Alps to the Carpathians. Pinus peuce occurs in southern Yugoslavia and adjacent regions of Albania, Bulgaria, and Greece. It too is a mountain tree, growing at elevations of 800–2100 m.

Three species are prominent in the red pine group, including the most common pine in Europe today, Pinus sylvestris. Also known as the Scots pine, it is ill-suited to the warmer and drier climate of the southern Mediterranean, but grows as far south as Spain and Turkey and extends into Macedon from forests near the Black Sea. It ranges from Scotland almost to the Pacific at elevations from sea level to 2600 m. The species Pinus nigra comprises the European black pines and includes many wide-ranging subspecies. They are primarily mountain trees that grow at elevations of 250 to 1800 m. Found in Morocco, they range through Spain, southern France, North Italy, Austria, the Balkan peninsula, the Crimea, Asia Minor, the Aegean islands, Cyprus, Sicily, and Corsica. Pinus uncinata, also a mountain type, grows in central Spain, the Pyrenees, and the central and western Alps. Another species grouped taxonomically with the red pines is Pinus brutia, the Calabrian pine. It has been recorded in modern times on the Greek mainland, the Aegean islands, but particularly in Turkey, Crete, Cyprus, Syria, Lebanon, and Iraq. This coastal tree grows at elevations of 100–1500 m and is thought by some to have originated in Italy, as the name implies. It is closely related to the Aleppo pine.

The yellow pine group includes Pinus halepensis, or Aleppo pine, the most widespread of the Mediterranean pines. It may appear at elevations of up to 1700 m,
but generally is found on coasts and coastal plains. Often twisted by the wind and rarely attaining heights exceeding 50 ft (15.24 m), it is knotty and not particularly strong. It grows in northern Africa from Libya to Morocco, Spain and the Balearic islands, France, Italy, Corsica, Sicily, the Yugoslavian coast, Greece, and Asia Minor, but rarely in the Aegean islands and the Near East. The French Maritime pine (Pinus pinaster or Pinus maritima) grows near the sea in the western Mediterranean. It is stronger, taller, and straighter than other coastal pines, and occurs at elevations of up to about 1000 m, though up to 2000 m in Morocco. It can be found in Algeria and Morocco through Europe to Greece, including Corsica and Sardinia. The Bosnian pine, Pinus leucodermis, grows at elevations between 1000 and 2500 m. It is generally confined to Yugoslavia, Albania, Bulgaria, Greece, and the central Italian coast of the Adriatic.

Pinus pinea, the umbrella or Italian stone pine, is a coastal variety with anatomical characteristics that seem to be a mixture of those found in the white and yellow pine groups. It is a tree of poor quality wood that now ranges from Portugal to Lebanon. The wide distribution is partly due to cultivation since antiquity for its cones and edible seeds.

The evergreen oaks range across the entire Mediterranean basin today. In the west, including northern Africa, the kermes oak or Quercus cocciifera rarely exceeds 20 ft (6.1 m) in height and is very strong. Quercus ilex (holm oak) is prominent in the coastal and middle elevations of the western regions, frequently reaching heights of 50 ft (15.24 m). Quercus calliprinos is found along the Levantine coast. It is quite similar to the kermes variety, but thicker and taller. The Turkey oak (Quercus cerris) grows in Turkey and central and southeastern Europe today.

What can this information assembled reveal about where the Caesarea ship was built? The planks and frames cannot be identified beyond the level of the white, red, and yellow pine groups. Today, species of the red pine group are widely distributed, while those of the yellow pine group rarely occur in the Aegean and the Near East. Poplar trees now range from northern Africa through Eurasia. The major species of the white pine group, however, are now confined primarily to the area delimited by the Alps in southwestern Europe and the Carpathians in the northeast, aside from southern Yugoslavia and adjacent areas. Unfortunately, it can be only proposed that some of the wood for the Caesarea hull was perhaps obtained from the regions where species of the white pine group now grow.
It is emphasized that this suggestion is based upon current distribution patterns that, in addition to being quite imprecise now, could have been appreciably different two millennia ago. The modern distribution of *Pinus leucodermis*, from which part of the ship that wrecked at Cavalière was built, similarly causes the excavators to suggest only tentatively and generally that the wood came from Italy or Yugoslavia (Charlin, Gassend, and Lequément 1979: 77). Other attempts to localize the construction of particular hulls have met even more difficulties (Couvert 1978: 111; Western 1967; Meucci 1993: 50). As a final note, current ignorance of the timber trade precludes any definitive statements about where ancient ships were built (Frost 1981b: 69).15
Notes


2. Pliny (Nat. 16.76.195–98, 16.76.203) gives a brief review of the locations where good and bad fir and cedar may be found. The great cedars of Lebanon and Syria are well attested. See Theophrastus, HP 4.5.5, 5.8.1; Diodorus Siculus 19.58.2–5; Meiggs 1982: 49–87; Liphshitz and Biger 1991.

3. See Meiggs (1982: 112–13) for a discussion of the use of πίτυς and πεύκη in Homer and Theophrastus. In Theophrastus the two terms are generally thought to designate coastal pine and mountain pine, respectively.

4. See also Thirgood (1981) and Johnson (1927). Thirgood reviews references to shipbuilding timber in Graeco-Roman times, but the primary source citations are sometimes incomplete or wrong. Johnson is concerned with naval materials.


6. The island of Salamin was called Pityoussa (Strabo 9.1.9).

7. See Amigues 1990 (90–92), who argues that the term κέλλησις may in fact mean mortise-and-tenon joint, in which case a passage in Theophrastus (HP 5.7.2) may be interpreted as an observation that oak is not compatible with either πεύκη or silver fir when fastened to them with mortise-and-tenon joints. See Amigues 1990 and Salvat 1979 regarding the identification of other terms for various hull components.

8. The County Hall ship of London was built completely with northern European oak. Although this third-century coastal/river vessel was constructed in standard Graeco-Roman fashion with mortise-and-tenon joints, its place of discovery prevents inclusion in the catalog. See Marsden 1972; 1974.

9. Gassend (1979: 107, n. 1) states that 11 samples of chevilles from the third-century wreck at Pormêges were analyzed. Six are cypress, three are olive, and two are Pinus leucodermis Antoine. He does not distinguish, however, between treenails and tenon pegs.
10. Gianfrotta and Pomey (1981: 270) list as pine the tenons in the Dramont A wreck. This is somewhat suspect in view of the dynamics of mortise-and-tenon joinery and in light of a discrepancy between Gianfrotta and Pomey and another source regarding the Mahdia wreck. In the table on p. 270, the Mahdia treenails are listed as of olive and boxwood or acacia, while Benoît (1961: 152, n. 3) states these woods were used for the tenons of the ship. Therefore, the unusual notion of softwood tenons, coupled with a potential error in Gianfrotta and Pomey regarding the Mahdia treenails, raises the possibility that Gianfrotta and Pomey erred in reporting as pine the tenons in the Dramont A hull. Of course, these scholars might be in possession of more accurate or new information not available to Benoît.

11. Perhaps these are instead some of the nails within plug-treenails that fastened the frames to the planking (see Plug-Treenails in Chapter VII).

12. The second strake of the late-14th century B.C.E. wreck at Uluburun, Turkey, is probably fir (Abies sp.); the ship is thought to have measured about 15 m (Pulak 1987: 129, 131). Almost nothing survived of the hull of the small vessel that sank at Cape Gelidonya in the second half of the 13th century B.C.E. Of the six worked timbers recovered, three belong to the genus Cupressus and two and probably three others belong to that of Quercus (Bass 1967: 164; Western 1967: 168-69).

13. References for this discussion, aside from those cited, are Meiggs (1982: 45) and Encyclopaedia Britannica, 1967 edition, s.v. “oak.”


CHAPTER V

PLANKING ON GRAECO-ROMAN MEDITERRANEAN SHIPS

Details of planking thickness, mortise-and-tenon joinery, and scarfs found on the Caesarea hull are compared below with those of other Graeco-Roman hulls. The Caesarea planking can thus be evaluated with respect to other large Roman vessels and its relation to the planking in smaller ships can be examined as well. This in turn may help illuminate similarities and differences in how shipwrights approached the construction of large and small hulls. The study of these details is valid, however, only if comparisons are confined to ships built not later than about the end of the third century A.C. By then the commencement of the move from “shell-first” to “frame-first” techniques had effected changes in hulls that would compromise conclusions based on the study of earlier practices.

PLANKS AND MORTISE-AND-TENON JOINTS

Juvenal, writing early in the second century A.C., refers to the planking thickness of a merchant ship as four fingers’ breadth at the least, seven at the most (Saturnae 12.58–59). Dio Chrysostom (a.d. 40–after 112) relates that it is not a pine plank with a thickness of three fingers’ breadth that keeps sailors safe, but Fortune herself (Oratio 64.10). Diogenes Laertius (first half of third century) writes of a ship’s side (thus the hull planking) four fingers’ breadth in thickness, and that the passengers are only that far from death (1.103). If one finger’s breadth was approximately 0.0185 m,¹ the minimum planking thickness mentioned above is 0.0555 m (Dio Chrysostom), whereas Juvenal appears to recommend a minimum of 0.074 m and a maximum of 0.1295 m.

Current archaeological evidence suggests Juvenal was writing about the larger ships of his time, and that Dio Chrysostom was not talking about a small vessel. The largest Graeco–Roman ships excavated to date were built with one or two layers of planking 0.086–0.10 m in overall thickness, with one possible exception (see Punta Scaletta below). Planks of approximately three fingers’ breadth in thickness are found
on wrecks of ships that appear to have been of an intermediate length, ca. 20–25 m.

At 0.094 m in thickness (except for one unprovenanced fragment), the Caesarea hull planking is typical of large ships and falls comfortably between the limits given by Juvenal. The dimensions and spacing of the staggered mortise-and-tenon joints on the Caesarea hull are consistent with those of large sea-going Roman hulls built with a single thick layer of planking, and in turn differ from mortise-and-tenon fastenings on large and medium-sized ships built with two layers of planking, and of course from those on smaller ships with a single layer of planking.2

**Large Hulls (L ≥ ca. 30 m) with a Single Planking Layer**

Hull planking found on wrecks of large Graeco-Roman merchant ships is thick. The joinery is characterized by mortises and tenons set no farther apart than their own width (usually closer) and staggered along the thickness of the plank edge to avoid splitting it. Although it is not known if staggered mortises were used in large warships, the scant evidence we have for them should not be ignored, because it may help provide a better frame of reference for the study of big merchant ships. For this reason the Marsala3 and Athlit wrecks are included below. Similarly, the Nemi barges, although neither sea-going nor mercantile in nature, dwarf all known Graeco-Roman wreck remains. Therefore any unique or peculiar aspects of construction, in addition to similarities to other vessels, might provide important clues that can advance an understanding of other large Graeco-Roman hulls.

**Marsala** (mid-third century BCE, L ca. 35 m [?]): galley; mortises are staggered in the keel, but the planking averages just a little over 0.03 m thick, the "spray deflectors" a little more, which makes it unlikely that plank mortises were staggered. The mortises are not significantly staggered even in Spray Deflector P-13—presumably one of the thickest strakes, aside from the garboards and wales—the thickness of which tapers from 0.05 m at the lower edge to 0.04 m at the upper edge. In Port Strakes 12 and 13 between frames 18 and 26, center-to-center spacing of tenon pegs ranges from 0.095 m to 0.14 m, averaging 0.113 m; distances between two-thirds of the pegs are less than 0.12 m.

In a drawing of the area of the S scarf in P-13, the tenon pegs range from 0.10 m to 0.155 m apart center-to-center and average 0.125 m. Mortise widths are 0.045 m to 0.055 m, depths 0.04–0.07 m. Distances between mortises are 0.05–0.10 m, averaging 0.073 m. Mortise thicknesses are less than 0.01 m, but more precise figures
are impossible to determine due to the scale of the drawing (Frost 1981b: 128, fig. 64:B). In a schematic of a diagonal scarf, the mortises and tenons not fastening the scarf are smaller and more rounded than those of P-13 (Basch and Frost 1975: 225; Frost 1981b: 126, 128, 241, fig. 64; Johnstone 1981: opposite p. 224, fig. 138).

*Athlit Ram* (204–167 B.C.E., L undetermined): warship; the six side planking pieces recovered from within the ram are ca. 0.04 m thick; the two bottom planks average 0.075 m in thickness. In the preserved planking, details of mortise-and-tenon joinery are available only for the wales. Those in the port wale are 0.068–0.082 m wide, averaging ca. 0.077 m. Depths, when ascertainable, range from 0.085 m to 0.12 m. The majority of mortises are 0.011 m thick, and the tenons almost always filled them tightly. The tenon pegs are set ca. 0.03 m from plank seams, with diameters of 0.009–0.011 m where they pierce the tenons; their average diameter at the inner wale surface, where preserved, is 0.014 m. Center-to-center spacing averages 0.117 m, ranging from 0.10 m to 0.135 m. The actual distance between mortises thus averages 0.04 m. The starboard wale’s joinery details are essentially the same (Steffy 1983: 236, fig. 5, 237, fig. 6, 238–40; 1991: 20–25).

*St. Jordi I* (100–80 B.C.E., L undetermined): the single planking layer is 0.07–0.09 m thick, with individual planks measuring up to 0.60 m wide. Staggered mortises are 0.075–0.086 m wide at the plank edge, 0.038–0.042 m thick, and 0.065–0.08 m deep. Tenons fit the mortises well in width and depth, but are much thinner. They measure 0.076–0.08 m wide at the plank face, 0.024–0.03 m thick, and 0.13–0.14 m long. Tenon pegs 0.01–0.013 m in diameter extend completely through the planks. They are set ca. 0.13–0.15 m apart center-to-center, as the distance between mortises is 0.05–0.06 m. Strangely, tenons are reported to be pegged twice in the lower plank mortise and once in the upper plank mortise (Coils 1987: 24, 25, fig. 6, 26, fig. 7, 27, fig. 8, 32–35). This technique is unparalleled in the archaeological literature I have been able to read, as are the thicknesses of the mortises and tenons. (This wreck is included in this section because of its planking thickness. See below, Relationships Between Vessel Size and Plank Thickness.)

*Antikythera* (early first century B.C.E., L ca. 30 m): the best preserved plank retrieved from the wreck was ca. 0.45 long and 0.165 m wide when measured by Throckmorton. He estimates it was originally some 0.09 m thick, based on the distances between the heads of nails in the fragment and the outer surface of the fragment. Staggered rectangular mortises measured about 0.065–0.095 m wide, 0.007
m to 0.01 m thick, 0.075 m deep, and were spaced 0.01–0.03 m apart. Tenon pegs were approximately 0.009–0.015 m in diameter and 0.065 m to 0.138 m apart center-to-center; they were set 0.01–0.02 m from the plank edges (Throckmorton 1964b: 208, fig. 3; 1965: 41, 42–43, figs. 5–10, 45, fig. 15; 1972: 70, fig. 6).

Lake Nemi (mid-first century, L ca. 71 and 73 m): single layers of planking 0.10 m thick had staggered rectangular mortises 0.10 m wide and deep and 0.016 m thick. They were cut every 0.095–0.10 m along the planks. The tenon pegs, ca. 0.016 m in diameter, were correspondingly some 0.20 m apart center-to-center, set 0.04 m to 0.05 m from planking seams. An interesting aspect of this planking is that large copper nails approximately 0.72 m long were periodically driven into the edge of a plank, completely through its width and that of the next lower plank, and then for some distance into the width of the next, even lower plank (Ucelli 1950: 153, fig. 153).

Large Hulls of Two Planking Layers

Ships of significant size built with two layers of planking exhibit mortise-and-tenon joints that are somewhat wider, thicker, and spaced relatively farther apart than those found in a single thick layer of planking. Because of the relatively greater distance between mortises on these ships, compared to those on large hulls of one planking layer, mortises are staggered only slightly, if at all. Inclusion in this category of the hulls at Punta Scaletta, Spargi, and Albenga is based upon a discussion of correlations between planking thickness and vessel size (see below, Relationships Between Vessel Size and Plank Thickness).

Punta Scaletta (150–140 B.C.E., L ca. 30 m): no mortise-and-tenon information is available, and the thickness of hull planking is uncertain. A drawing of the remains on the seabed with a proposed body section in dotted lines depicts one layer of planks approximately 0.065 m thick, with an underlying layer of planks in the position of a belt of wales measuring some 0.07 m in thickness (Lamboglia 1964: opposite p. 240, pl. 3). Parker (1992a: 359) adds that "at the bow, at least two thicknesses of planking were observed." If a hull of two planking layers is represented, as noted by Casson (1986: 204, n. 18), the overall thickness of ca. 0.135 m would be the greatest yet found on the main body (i.e., strakes not near the keel) of a Graeco-Roman seagoing ship. It would match well the maximum thickness of seven digitā (ca. 0.1295 m) recommended by Juvenal and is quite reasonable in view of the proposed original
length of the ship. Furthermore, the practice of simply fastening wales to the exterior planking surface and not integrating them into the shell of the hull, as suggested by the drawing in Lamboglia, is unparalleled except on the St.-Gervais 2 wreck of the late sixth or early seventh century (Jézégou 1985: 352, fig. 2, 354). Although the only information pertaining to wales of large hulls comes from Athlit and the Nemi ships, which are not necessarily representative of merchant ships, we have no evidence that the methods of incorporating wales into large merchant ships differed significantly from those on the Athlit and Nemi vessels and smaller Graeco-Roman vessels such as the Kyrenia ship. Nor does there seem to be any other distinct evidence suggestive of actual belts of wales on the Punta Scaletta hull. All of this makes attractive the possibility of a second layer of planks. So too does the remainder of the material presented in this section, which also suggests the ship could have been built with an outer layer of softwood planking (see below, Relationships Between Vessel Size and Plank Thickness).

**Spargi** (120–100 b.c.e., L ca. 30–35 m): two small planking fragments covered with lead sheathing measure ca. 0.035 m thick. In the fragment ca. 0.12 m wide are two mortises ca. 0.045 m wide, 0.009 m thick, and 0.033 m deep. The other fragment displays a part of a mortise ca. 0.01 m thick by 0.039 m deep that is ca. 0.0675 m from the adjacent mortise. All mortises are essentially centered in the thickness of the planks (Lamboglia 1961a: 155, fig. 12:A, B).

**Albenga** (early first century b.c.e., L ca. 40 m): raised from the wreck was a planking fragment ca. 0.04 m thick that held remnants of treenails and the shafts of copper tacks that secured the hull’s lead sheathing. No mortise-and-tenon information is given (Lamboglia 1953: 206, fig. 59). Throckmorton (1972: 76) implies that the shell of the ship consisted of only one layer of planking, but considering the planking thicknesses of other large ships, this thin plank fragment suggests there were two layers at least near the keel, as has been suggested for the wrecks at Mahdia, Grand Congloué, Dramont (A), Titan, and Cavalière (Poméry 1978a: 78, n. 8). Two other pieces of planking some 0.04 m thick that have mortises varying in size probably also represent the outer planking layer, if indeed they are remnants of the hull planking. One fragment has mortises and tenons ca. 0.003 m thick and 0.076 m wide spaced about 0.048 m apart. Those of the second fragment are of the same thickness, but only ca. 0.056 m wide, spaced ca. 0.056 m apart. None of the few mortises in these two samples is staggered (Lamboglia 1953: 207, fig. 60, 208).
*Mahdia* (early first century B.C.E., L ca. 30 m): at least the keel mortises for the inner garboard are staggered. They measure ca. 0.12 m wide and 0.012 m thick, and are 0.07 m apart. Depths are unknown, as are the joinery details for the remainder of the hull. The keel rabbet for the outer garboard is 0.036 m wide, while the thickness of the inner garboard at the top of the keel is 0.14 m (de Frénoisville 1956: 221, fig. 7). In view of the identical configuration of the hull at Giens (see below), there was probably a similar arrangement in this hull: thick garboards and adjacent strakes that thinned to a constant dimension some distance from the keel. Throckmorton (1972: 75) states the ship was built with planking 2 inches (ca. 0.05 m) thick, but because the outer layer at the keel rabbet clearly measures 0.036 m in de Frénoisville, Throckmorton must be referring to the inner layer if his information is to be regarded as correct. This would yield an overall thickness of some 0.086 m in two layers, at least in the lower part of the vessel. The two layers were separated by pitched material meant to improve the watertightness of the hull (de Frénoisville 1956: 222; du Plat Taylor 1965: 48).

*La Madrague de Giens* (60–40 B.C.E., L ca. 38 m): two layers of planking are separated by wool saturated in wax or pitch. The inner garboards, pentagonal in section, are 0.12 m thick at the top of the keel, but at the fourth inner strake from the keel the plank thickness is 0.06 m. The outer garboards are 0.04 m thick, but in order to follow the sharper curvature of the inner planking layer, the second and third outer planks are thicker: they reach dimensions of 0.065 m and 0.055 m, respectively. Thereafter the outer planks are 0.04 m thick. Inner strakes consistently 0.06 m thick have mortises 0.08–0.085 m wide, 0.10–0.12 m deep, 0.012–0.015 m thick, and occur at fairly regular intervals of 0.065–0.075 m. Smaller mortises are cut 0.095–0.10 m apart in the exterior planking. They measure 0.055–0.057 m wide, 0.06 m deep, and 0.007–0.008 m thick. Tapered tenon pegs driven into the inner planks from the interior are 0.015–0.018 m in diameter, while the pegs fastening the exterior tenons in their mortises (driven from the outside) are 0.005–0.01 m in diameter. The tenons in both planking layers are rarely as wide and deep as their mortises, but they are of equal thickness. Further, those used in the inner planks are tapered and rectilinear, while the tenons in the exterior planks are more rounded over their length. The mortises on both layers of planking are not staggered across the plank edges to any significant degree (Pompey 1978a: 76–80, 85, 86, fig. 12, and pl. 29:1).
Moderate-Sized Hulls (L ca. 20–25 m) of One or Two Planking Layers

Overall planking thickness on these ships is somewhat less than on larger ships. Mortise-and-tenon joints are correspondingly a bit smaller, and the spacing between them is slightly greater, even though center-to-center spacing might be similar. Joints are staggered only slightly if at all.

Grand Congloué (110–70 B.C.E., L ca. 23 m): the reported dimensions of the planking and mortise-and-tenon joints are somewhat inconsistent. It is stated that exterior planks near the keel are 0.03–0.04 m thick, and that they overlie inner planks 0.05–0.06 m in thickness. The overall thickness of the planking near the keel thus ranges from about 0.08 m to 0.10 m. Mortises (whether of inner or outer planks is not specified) are 0.05 m to 0.07 m wide, 0.005–0.006 m thick (a typographical error is surely responsible for the published thickness of 0.05–0.06 m), and 0.06–0.08 m long (Benoît 1961: 152). However, in plates 22 and 23 (pp. 134, 135), somewhat different dimensions are represented. The inner garboard is 0.045 m thick at its outboard edge, at which point the next outer plank is ca. 0.028 m, giving an overall thickness of 0.073 m. The outboard edge of the outer second strake is drawn as thinning to ca. 0.022 m, and the overall thickness farther from the keel is therefore indicated to be about 0.067 m. Two inner garboard mortises shown in plate 22 are about 0.008–0.009 m thick and 0.068 m and 0.08 m deep; in the second outer plank they are ca. 0.006 thick and 0.043–0.048 m deep. In plate 24, p. 136, mortises along one edge of one (inner?) plank 0.045 m thick range from 0.057 m to 0.07 m wide at the plank edge; they are 0.006 m thick and 0.078–0.09 m deep. Tenon pegs are 0.10–0.108 m apart center-to-center, and mortises are 0.035–0.045 m apart. Along the opposite plank edge, mortises are 0.053–0.057 wide and 0.057–0.065 m deep; tenon pegs are 0.093–0.11 m apart center-to-center; mortises are 0.042–0.06 m apart. Another plank apparently from the outer layer exhibits mortises 0.005 m thick and 0.039–0.045 m deep; one is 0.042 m wide.

So the drawings disagree with the measurements given in the text, but it seems likely that there was considerable variation in the hull, and the most significant disparity—that of the overall planking thickness near the keel—appears to be resolved by the suggested overall thickness of some 0.067 m farther from the keel, in the manner of the hull at Giens.

Dramont A (first half of first century B.C.E., L ca. 25 m): Santamaria (1975: 191–92, 193, fig. 8, 194) notes as wrong the early reconstructions (Benoît 1960: 50, fig.
19; 1961: 143, pl. 28:1; Throckmorton 1972: 68, fig. 1) showing only outer garboards resting on the bevelled surfaces of the keel, with inner planks beginning near the outboard edge of the outer garboard and received by notches cut into the under surfaces of the frames. Instead, the inner garboards are rabbeted into the keel and the outer garboards overlay the molded surfaces of the keel, the inner garboards, and part of each inner second strake. Inner planks, then, do not fit in notches in frames. Also wrong in these early drawings is the depiction of plug-treenails binding the frames to the planking; none were used.

The interior planking layer is about 0.03–0.04 m thick, the outer layer some 0.025–0.03 m; the layers are separated by an intervening layer of fabric and pitch. One piece of the hull planking from the central part of the ship about 2 m from its central axis was raised for closer study. In this section (whether of the interior or exterior layer is not noted) the pegged tenons are stated to be 0.07 m to 0.09 m apart, and mortises are said to be staggered (Santamaria 1973: 133). But staggering is indicated in neither planking layer in the illustration accompanying the report (Santamaria 1973: 135). The drawing shows that inner tenon pegs are spaced from ca. 0.133 m to 0.178 m apart center-to-center, averaging about 0.16 m, and are set 0.015–0.035 m from the planking seams. The mortises themselves are an average of some 0.078 m apart; the range is ca. 0.055–0.09 m. Inner mortise widths are all about 0.08–0.085 m, thicknesses some 0.014 m, depths 0.065–0.08 m.

Information is more limited for the exterior planking mortises and tenons. Center-to-center spacing of tenon pegs is about 0.148 m in one instance, and the pegs are 0.018–0.022 m from the planking seam. Two mortises measure approximately 0.055–0.063 m wide, 0.065–0.07 m deep and 0.0075 m thick (Santamaria 1973: 135).

*Titan* (middle or late first century B.C.E., L ca. ≤ 25 m): the overall thickness of the two layers at the outboard edge of the outer second strake was some 0.056 m. The outer garboard overlay most of the molded surface of the keel and much of the inner garboard. Of pentagonal section, it reached a maximum thickness of 0.058 m opposite the bearding line of the keel rabbet and decreased to 0.032 m at its outboard edge. The outer second strake was also 0.032 m where it joined the outer garboard, but was sculpted to approximately 0.018 m in thickness at its outboard edge. No information for the thickness of additional exterior planks is available. The inner garboard was fitted into the keel rabbet. Its thickness was ca. 0.068 m at the top of the keel, tapering to 0.038 m at the inboard edge of the third strake. It seems
reasonable that there was no further thinning of the inner planking beyond this point.

The few available details of the mortise-and-tenon joinery in the two layers are consistent with the greater spacing to be expected in the outer layer. In the outer garboard the outboard mortises were 0.008 m thick, 0.045–0.055 m deep, and 0.06–0.07 m wide. The tenon pegs were 0.008 m in diameter, set 0.015–0.023 m from the planking seams, and spaced 0.22–0.23 m apart center-to-center; mortises were thus about 0.158–0.163 m apart.

The inner garboard had mortises 0.009 m thick. Along the keel edge they measured ca. 0.095–0.115 m deep and 0.058–0.075 m wide. Tenon pegs of 0.016–0.017 m diameter were 0.023–0.035 m from the plank edge and spaced 0.107–0.115 m apart center-to-center, making the distance between the mortises some 0.035–0.048 m. The mortise-and-tenon joints binding second strake to the garboard were less robust. Mortises measured 0.06–0.072 m deep and 0.075 m wide, and were 0.033–0.046 m apart. Tenon pegs tapered from ca. 0.012 m to 0.009 m in diameter, were 0.019–0.038 m from the planking seams and 0.108–0.13 m apart center-to-center.

Probably more representative of the interior layer of the main body of the hull was the joinery found in the third strake from the keel. In this strake of 0.038 m thickness the unstaggered mortises were about 0.01 m thick and 0.072–0.08 m deep; widths ranged from 0.06 m to 0.07 m and averaged 0.064 m. They were an average of 0.04 m apart, measuring 0.01–0.077 m. The tenon pegs fastening the tenons within the mortises were 0.010–0.014 m in diameter, set 0.019–0.035 m from the planking seams. The center-to-center distance between them averaged about 0.105 m, with a range of 0.096–0.13 m (Tailliez 1961: 195, fig. 20; Benoît 1961: 139, pl. 26; Throckmorton 1972: 68, fig. 4, 70, fig. 7).

*Tre Senghe A* (25 B.C.E., L ca. 20–24 m): the planking is 0.04 m thick and the beam is estimated to have been about 5 m (Freschi 1982a: 93, 96). This length-to-breadth (L:B) ratio of between 4:1 and 5:1 must be based on the extent of the hull remains, yet judging from other ancient merchant ships (see below, Relationships Between Vessel Size and Plank Thickness, and Chapter XIII), one closer to 3:1 or 4:1 seems more likely. This would yield a length in the range of 15–20 m. Freschi’s estimated date of the second or first century B.C.E. is revised to 25 B.C.E. in Parker (1992a: 435) and used here.

*Diano Marina* (mid-first century, L ca. 22–25 m): the strakes of this vessel are 0.06 m thick and 0.25–0.32 m wide. Mortise-and-tenon joints are ca. 0.12 m apart
center-to-center, and the spacing between the rectangular mortises and tenons is 0.06–0.07 m in the examined portions of the hull. The joints are secured with pegs 0.012 m in diameter. Mortises are apparently 0.075–0.08 m wide (Pallarés 1985a: 642, fig. 3:A; 1985b: 590, 593, fig. 8; 1985d: 617). It is not specified if the mortises are staggered along the planking thickness, nor from which direction the tenon pegs are driven. A more recent report (Pallarés 1991: 172) provides tenon peg diameters of 0.008–0.010 m (surely misprinted as "8–10 cm." in the article), and spaces of some 0.03–0.04 m between plank mortises.

**Torre Sgarrata** (late second century, L ca. 24 m): staggered rectangular mortises in planks 0.072 m thick are 0.104 m to 0.145 m wide, average 0.083 m deep, and are 0.01–0.012 m thick; they range from 0.028 m to 0.087 m apart, averaging 0.035 m. Tenons average 0.011 m thick, 0.12 m wide, and 0.167 m in length. Tenon pegs averaging 0.014 m in diameter are positioned 0.016–0.025 m from the planking seams. They are 0.15 m to 0.20 m apart, center-to-center (Throckmorton 1972: 70, fig. 8; 1968, drawing 11; 1989: 264).5

**Bourse** (late second or early third century, L ca. 23 m): planks are 0.06 m thick, 0.18–0.23 m wide, and some 8 m long. Tenon pegs are 0.06 m long; some are cylindrical and some taper from 0.015 m to 0.008 m in diameter. Tenons measure 0.01 x 0.06 x 0.12–0.13 m, and are 0.20 m apart center-to-center (Gassend 1982: 78).

**Smaller Hulls of One Planking Layer**

Planking is thin in the hulls of this category and there is usually little or no staggering of mortises in the main body of the hull. Center-to-center distances between the mortise-and-tenon joints in smaller ships are similar to those found on large hulls, but the mortises and tenons in smaller ships are considerably smaller, thereby making the relative spacing between joints greater.

**Ma'agan Michael** (ca. 400 B.C.E., L ca. 13 m): planks are 0.15–0.30 m in width; thicknesses average 0.04 m, varying from 0.03 m to 0.05 m. Tenon pegs 0.007–0.011 m in diameter, typically spaced 0.125 m apart center-to-center, fasten tenons usually 0.035 m wide and averaging 0.007 m in thickness and 0.135 m in length (J.P. Rosloff, personal communication).

**Kyrenia** (late fourth century B.C.E., L ca. 14 m): hull planking averages ca. 0.036 m thick, and average mortises measure 0.006 m thick, 0.045 m wide, and 0.08 m deep. Starboard mortise-and-tenon joints are set an average of 0.12 m apart center-to-
center, while those on the port side average 0.115 m apart. Mortises are not staggered in the plank edges, though they are in the 0.08 m-thick wale scarf (Steffy 1985b: 79, table 1, 81, 82, table 3, 83, ill. 7).

**Chrétienn**e C (175–150 B.C.E., L ca. 15–16 m): planks are 0.029–0.036 m in thickness. Unstaggered mortises measure 0.006–0.007 m thick, 0.04–0.08 m deep, and 0.03–0.055 m wide at the plank edge. Tenon pegs 0.007–0.009 m in diameter are spaced an average of ca. 0.12 m apart center-to-center, and are ca. 0.013–0.028 from the planking seams (Joncheray 1975a: 58, 59, fig. 19, 68).

**Apollonia I** (mid-second to early first century B.C.E., L ca. 15 m): the garboard is 0.04 m thick and the third through seventh strakes (the limit of preservation) do not exceed 0.03 m in thickness. Garboard mortises are 0.085 m wide and 0.01 m thick. Mortises first were delimited with holes drilled at each extremity and then chiseled out. Their spacing is not reported. Most tenons measure 0.16 x 0.06 x 0.01 m, though those used in scarf tips are 0.21 m long. Average tenon pegs taper from 0.011 m to 0.008 m (Long 1992: 73–74).

**Cavalière** (late second or early first century B.C.E., L ca. 13 m): the garboard tapers from 0.04 m in thickness at the keel to 0.03 m at the outboard edge; the remainder of the planking is also 0.03 m thick. Tenons are 0.12–0.13 m long, 0.006 m thick and 0.06 m wide. They were secured in mortises 0.05 m from one another with pegs 0.009 m in diameter. Center-to-center distances for pegs is thus 0.11 m (Charlin, Gassend, and Lequement 1979: 67).

**Miladou** (end of the second to first half of the first century B.C.E., L ca. 15 m): the thickness of the garboard where it contacts the keel at frame 6 is 0.043 m, but 0.03 m at the center of the wreck. It thins to 0.024–0.026 m at its outboard edge and the remaining planks are consistently some 0.025 m thick. Breadths of preserved planks range from 0.122 m to 0.178 m. Mortises measure 0.06–0.07 m wide, 0.065–0.08 m deep, and 0.006–0.007 m thick. Distances of 0.088 m to 0.13 m separate them (Dumontier and Joncheray 1992: 131, 132, 134, 136–37). Judging from the drawings and photos, these distances can be either center-to-center or between adjacent edges.

**Ladispoli** (early first century, L ca. 18 m): the garboard is 0.15 m in breadth and pentagonal in section. Thickness at the keel measures 0.08 m, decreasing to 0.045 m at the outboard edge. At the seam between the fourth and fifth strakes the plank thickness is 0.04 m. Planking widths range from 0.15 m to 0.20 m. Mortises in the keel edge of the garboard are staggered across the plank thickness with spaces of
0.025–0.03 m between adjacent edges. A sectional drawing of the hull at its west extremity (Carre 1993: 14, fig. 5) indicates the tenons joining the garboard and keel are ca. 0.01 m thick, and tapered pegs driven from the interior of the hull secure these tenons. Mortises along the seam of strakes 4 and 5 exhibit spaces of 0.045–0.05 m between one another; tenons are not quite as wide as their mortises in order to facilitate the fitting of planks. The sectional drawing mentioned above shows a tapered tenon from the garboard/second strake seam that is ca 0.035 m in width at its widest point and 0.0075 m thick, but it is stated to measure ca. 0.015 m in thickness. Tenons are believed to fill the mortise thicknesses completely (Carre 1993: 9, 12, 14, 17, fig. 5, 9, 27–28).

*St.-Gervais 3* (mid-first century, L ca. 17 m): the garboard’s keel edge measures 0.075 m in thickness, which decreases to 0.065 m at the opposite edge. The adjacent strake is 0.06 m thick across its width, and all following strakes are 0.035–0.045 m thick. Mortises in the garboard are 0.07 m wide, 0.13 m deep, and 0.007 m thick; the tenons within them are just slightly smaller in all dimensions. The tenon pegs, driven from the interior, taper from 0.005 m or 0.006 m in diameter to 0.012 m. There are 0.12 m between each pair, so the center-to-center spacing is 0.132 m. Plank widths do not exceed 0.30 m (Liou and Gassend 1991: 232).

*Herculaneum* (A.D. 79, L ca. 9 m): the planking measures 0.017–0.02 m in thickness; tenon peg spacing is irregular, but for over 200 measurements it averages 0.13 m. The few accessible mortises average 0.051 m deep, 0.052 m wide, and 0.005 m thick. The tenon pegs were driven from inside, with exterior diameters of 0.006–0.01 m (Steffy 1985a: 520–21).

*Laurons 2* (late second century, L ca. 15 m): the planks are 0.025 m thick at the outboard edge of the second strake and thereafter; the garboard is 0.045 m thick at the keel. Tenons generally are 0.004 m thick, 0.12–0.13 m long and 0.06 m wide. Tenon pegs are 0.009 m in diameter and spaced about 0.12 m apart center-to-center (Gassend, Liou, and Ximénès 1985: 91).

*Pommègues* (A.D. 250–300, L undetermined): the wreck has garboards 0.045 m thick, while other planks are 0.037–0.04 m in thickness. Mortises are 0.007 m thick, 0.05–0.07 m wide, and 0.05 m deep. Tenon pegs are 0.14–0.15 m apart center-to-center and measure 0.011–0.012 m in diameter (Gassend 1979: 103).

*Cala del Lazzaretto* (after A.D. 315, L undetermined): the two plank fragments that were raised measure 0.10 and 0.12 m wide and 0.035 m in thickness. Mortises are
placed 0.09–0.14 m from one another, and the trapezoidal tenons are 0.07 m wide. Thus tenon pegs are spaced ca. 0.16–0.21 m apart, center-to-center. The tenons measure 0.008 m in thickness (Riccardi 1991: 11, 12, fig. 3).

_Golo_ (undated, L ca. 14 m): the planks were 0.033 m thick; the tenons binding them were 0.04 m wide and 0.216 m long, set perhaps 0.25 m apart center-to-center (Basch 1973: 331, fig. 2, 342, appendix 1).

**RELATIONSHIPS BETWEEN VESSEL SIZE AND PLANK THICKNESS**

It must be recognized that the hulls of some of the wrecks listed above have been much more carefully studied than others. Consequently the original dimensions of the former are more accurately estimated than those of the latter. In fact, given the number of incomplete excavations represented in the catalog, it seems quite possible that original hull dimensions are often estimated according to hull timber dimensions and site characteristics rather than careful study and reconstruction. Therefore a search for correlations between estimated original length and planking thickness in the main body of the hull (i.e., exclusive of garboards and associated strakes) must be based upon well documented hull remains.

Given this cautionary note, some strikingly orderly correlations are evident (Table 3). Indeed it seems quite logical that shipwrights would have employed general rules of thumb to govern, if only roughly, the relationship between the length (and therefore breadth and depth) of a ship and the thickness of its planking. The evidence at hand indicates that three sea-going ships of some 30 m or longer dating from early in the first century B.C.E. through perhaps the first century A.C., i.e., those at Antikythera, Giens, and Caesarea, were built with planking about 0.09–0.10 m thick in either one layer or two. The Lake Nemi ships, not sea-going craft, also were built to their prodigious dimensions with planking 0.10 m thick. The wreck at Punta Scaletta (150–140 B.C.E.), estimated to have been about 30 m long, is exceptional either because it is built of one layer about 0.065–0.07 m thick, or of two totalling some 0.135 m.

Five hulls measuring about 20 m to 25 m in length (at Grand Congloué, Dramont (A), Titan, Diano Marina, and Bourse) and dating from the late second or early first
<table>
<thead>
<tr>
<th>Site</th>
<th>Inner/Outer (cm)</th>
<th>Plank Thickness Total (cm)</th>
<th>Vessel Length (m)</th>
<th>Date (Century)</th>
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<tr>
<td>Punta Scaletta</td>
<td>6.5 / 7?</td>
<td>6.5–13.5?</td>
<td>30</td>
<td>2 B.C.E.</td>
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<tr>
<td>Spargi</td>
<td>/ 3.5?</td>
<td></td>
<td>30–35</td>
<td>2 B.C.E.</td>
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<tr>
<td>Albenga</td>
<td>/ 4?</td>
<td></td>
<td>40</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Antikythera</td>
<td>9</td>
<td></td>
<td>30</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Mahdia</td>
<td>5 / 3.6</td>
<td>8.6</td>
<td>30</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>M. de Giens</td>
<td>6 / 4</td>
<td>10</td>
<td>38</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Caesarea</td>
<td>9–9.4</td>
<td></td>
<td>40</td>
<td>1 A.C.</td>
</tr>
<tr>
<td>Gr. Congloué</td>
<td>4.5 / 2.2</td>
<td>6.7</td>
<td>23</td>
<td>2/1 B.C.E.</td>
</tr>
<tr>
<td>Dramont A</td>
<td>3–4 / 2.5–3</td>
<td>5.5–7</td>
<td>25</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Titan</td>
<td>3.8 / 1.8</td>
<td>5.6</td>
<td>≤25</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Diano Marina</td>
<td>6</td>
<td>22–25</td>
<td>1 A.C.</td>
<td></td>
</tr>
<tr>
<td>Bourse</td>
<td>6</td>
<td>23</td>
<td>2/3 A.C.</td>
<td></td>
</tr>
<tr>
<td>Ma’agan Michael</td>
<td>4</td>
<td>13</td>
<td>5/4 B.C.E.</td>
<td></td>
</tr>
<tr>
<td>Kyrenia</td>
<td>3.6</td>
<td>14</td>
<td>4 B.C.E.</td>
<td></td>
</tr>
<tr>
<td>Chréienne C</td>
<td>2.9–3.6</td>
<td>15–16</td>
<td>2 B.C.E.</td>
<td></td>
</tr>
<tr>
<td>Apollonia I</td>
<td>3</td>
<td>15</td>
<td>2–1 B.C.E.</td>
<td></td>
</tr>
<tr>
<td>Cavalière</td>
<td>3</td>
<td>13</td>
<td>2/1 B.C.E.</td>
<td></td>
</tr>
<tr>
<td>St.-Gervais 3</td>
<td>3.5–4.5</td>
<td>17</td>
<td>1 A.C.</td>
<td></td>
</tr>
<tr>
<td>Herculanum</td>
<td>1.7–2</td>
<td>9</td>
<td>1 A.C.</td>
<td></td>
</tr>
<tr>
<td>Laurons 2</td>
<td>2.5</td>
<td>15</td>
<td>2 A.C.</td>
<td></td>
</tr>
</tbody>
</table>
century B.C.E. through the late second or early third century A.C. display one or two layers of planks that range from ca. 0.055 m to 0.08 m in total thickness. Planking is preserved for only a short distance from the keel on the first three wrecks, which exhibit two layers of planking. Whether or not they were completely double-planked is discussed below.6

Eight smaller ships of the 13–16 m range and dating from the fifth or fourth century B.C.E. into the second century A.C., those that wrecked at Ma’agan Michael, Kyrenia, Chrétienne (C), Apollonia (1), Cavalière, Laurons (2), St.-Gervais (3), and Herculaneum were built with single layers of planking 0.025–0.045 m thick.

This rather orderly scheme strongly suggests that the large hulls at Spargi, Albenga, and Mahdia were completely double-planked, that the wreck at St. Jordi was a vessel of some 30 m or more, and that the wreck at Torre Sgarrata was a ship of perhaps 24 m in length, not 33 m (see note 5 above). Moreover, Rival’s proposal (1991: 40) that the outer fir planking on the Giens hull was intended primarily to protect the inner elm planks seems unlikely. Hull characteristics and estimated dimensions of the wrecks at Miladou and Ladispoli also fit the pattern, as do those of the Golo wreck (of unknown date) if the nineteenth-century documents describe the vessel accurately. The wreck at Tre Senghe is estimated to have been 20–24 m long, but the planking thickness is more consistent with a length no more than 17–18 m. The original beam is estimated to have been ca. 5 m, which also makes a shorter length more likely, perhaps ca. 15–16 m (see Chapter XIII regarding evidence for length-to-breadth ratios).

Regarding the somewhat smaller hulls at Grand Congléoué, Titan, and Cap Dramont (A), it is not known if the two planking layers extended from the keel to the sheer strake, or just some distance from the keel. The issue would be less confusing were they not of an intermediate size (ca. 20–25 m in length). As such, they occupy a less clear-cut position between smaller ships with thinner planking and big ships with thicker planking. Another source of uncertainty is the fact that two wrecks of somewhat smaller dimensions display doubled garboards. On the wreck at Cavalière (L ca. 13 m), an outer plank, triangular in section, was fitted to overlap completely the molded face of the keel and most of the garboard. There is no doubt, however, that the remainder of this hull consisted of a single layer of planking (Charlin, Gassend, and Lequément 1979: 64, fig. 39, 66, fig. 42, 69, 70, fig. 47, 72, 73, fig. 49). This outer garboard must have improved the longitudinal strength of the ship in addition to
bolstering the keel/garboard joint. Similarly, a plank triangular in section overlaps the
keel and garboard on Wreck 2 at Laurons (L ca. 15 m) for a distance of 4 m forward
of the keel/sternpost scarf (Gassend, Liou, and Ximénès 1985: 95, fig. 17:d, 97). It is
therefore not surprising that slightly larger ships needed similar but more extensive
support near the keel. However, because the known planking thicknesses of moderate-
sized, double-layered vessels fit nicely between those found on larger and smaller
ships, it is more likely that the ships that wrecked at Grand Congloué, Titan, and Cap
Dramont (A) were completely double-planked.

RELATIONSHIPS BETWEEN VESSEL SIZE AND WOOD TYPE

It may be asked if structural considerations were responsible for the utilization of
hardwood planking. Maximum shell strength would have been imperative in large
ships built in mortise-and-tenon fashion, with their greater tendency to hog and sag in
the absence of a well developed spine and skeletal framework. In merchant hulls of
comparable size, form, and construction, one built with planks of hardwood (with finer
and tighter grain) would most likely manifest more structural integrity than one
comprising more coarse- and open-grained softwoods. This is suggested by the
materials found in the wrecks at Grand Congloué, Dramont (A), Titan, La Madrague
de Giens, and Mahdia. In the first three hulls, which are all double-planked and about
20–25 m long, the planking on each is identified as pine or possibly pine. These
identifications do not distinguish between inner and outer layers, but if in fact both
layers are softwoods on these three ships, a very interesting pattern might be in
evidence. In the Giens hull (ca. 38 m long) the outer layer is fir and the inner is elm,
while both layers of the Mahdia ship (ca. 30 m long) appear to be elm. Although this
is the best information regarding big two-layered hulls, the possible difference in
material usage in large and moderate-sized double-layered hulls suggests that the
physical properties of hardwood planks were, or were regarded as, beneficial to large
ships. Indeed, one scholar concludes this is the reason the inner planking layer of the
Giens hull is elm, as only hardwoods imparted enough strength to serve adequately in
large ships (Rival 1991: 298). This preference accords with evidence from the wrecks
of most large Roman merchant ships. Among Mediterranean seagoing merchant ships
of the Graeco-Roman period, hardwood planking is found only on those of some 30 m
or more in length, i.e., at Punta Scaletta, Antikythera, Mahdia, Giens, and possibly Punta Scifo (Table 4). In contrast, the wreck at Caesarea is the only vessel of such dimensions that was built with softwood planking.

More generally, Rival (1991: 28, 89, 298) proposes that the specific applications of deciduous and coniferous timbers were a function of their morphological characteristics. Therefore Aleppo pine, for example, was commonly employed because it was easy to obtain and was found in a variety of useful shapes (Steffy 1985b: 92). Similarly, this usage is consistent with the proposal that fitting a single layer of hardwood planks of the thicknesses required for big ships simply required an undesirable amount of time and effort. Indeed, hardwood planking does not exceed ca. 0.06 m in thickness in the wrecks known to date, with the exception of the single-layered Antikythera hull. Such planks certainly would have been heavier and harder to work than those of softwoods. So, when hardwood planks were to be used, perhaps the shipwrights fitted two layers of thinner planks that created greater hull strength and were easier to work with and repair as well.

Finally, this general pattern suggests that the big wrecks at Spargi and Albenga may have had thinner outer layers of softwoods and thicker inner layers of hardwoods. Similarly, perhaps the big ship that sank at Punta Scaletta will reveal an outer planking layer of softwood.

**RELATIONSHIPS BETWEEN PLANK THICKNESS AND MORTISE-AND-TEPON JOINERY**

It is tempting to engage in an extensive analysis of the joinery details cataloged, but the information, with few exceptions, is far too incomplete. Some general comments are in order, however, as several characteristics common to the mortise-and-tenon joinery in the wrecks reviewed above hold the promise of an eventual understanding of some basic relationships between planking and mortise-and-tenon joints. First, the joints were most likely a relatively homogeneous constant in the hulls, because the tenons and tenon pegs found in virtually all of them were fashioned from some type of oak or other strong and resilient hardwood (Table 2). Moreover, fitting tenons tightly in their mortises appears to have been generally standard practice prior to commencement of the shift from shell-first to frame-first construction techniques.
<table>
<thead>
<tr>
<th>Site</th>
<th>Plank Thick.</th>
<th>Wood Type</th>
<th>Vessel Length</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inner/Outer</td>
<td>Inner/Outer</td>
<td>(m)</td>
<td>(Century)</td>
</tr>
<tr>
<td>Punta Scaletta</td>
<td>6.5 – 13.5</td>
<td>oak / oak? or oak / softwood?</td>
<td>30</td>
<td>2 B.C.E.</td>
</tr>
<tr>
<td>Spargi**</td>
<td>? / 3.5</td>
<td>? / pine</td>
<td>30–35</td>
<td>2 B.C.E.</td>
</tr>
<tr>
<td>Albenga**</td>
<td>? / 4</td>
<td>? / fir</td>
<td>40</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Antikythera</td>
<td>9 / 3.6</td>
<td>elm / elm</td>
<td>30</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Mahdia</td>
<td>5 / 3.6</td>
<td>elm / fir</td>
<td>30</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>M. de Giens</td>
<td>6 / 4</td>
<td>elm / fir</td>
<td>38</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Punta Scifo</td>
<td></td>
<td>oak</td>
<td>*</td>
<td>2/3 A.C.</td>
</tr>
</tbody>
</table>

* Marble wreck site measuring 50 x 50 m.
** It is proposed that the planking fragments represent an outer planking layer that lay atop an inner layer of hardwood planks.
Thus tenons acted as both lateral and longitudinal stiffeners, like thousands of little internal frames (Steffy 1985b: 90). Hull stiffness and integrity were therefore to a large degree functions both of planking thickness and of tenon volume within the planking. It seems likely that the ancient shipwrights had some means of relating these different factors to one another in order to determine the appropriate size and spacing of joints in planks of a specific thickness and width. Unfortunately, analysis of the information gathered here has not yet yielded any convincing evidence of concepts or relationships, with one straightforward exception. Double-planked hulls in the catalog, which are always reconstructed or estimated to have been at least 20 m long, exhibit advantages beyond those inherent in "lamination" alone. Specifically, more tenon volume per unit of hull plank length is achieved by the employment of two layers of planks. A comparison of tenon area per meter of planking, as measured along the plank edge, reveals that the double-planked Giens hull displays some 160–190% of the tenon area of the Caesarea hull.

SCARFS

Aspects of Scarf Tips

Mortises cut completely through the tips of scarfed planks are common on Graeco-Roman hulls and in evidence at Caesarea, but there is a difference in where the tenons in such mortises are pegged. The scarf tips in the Kyrenia hull have mortises cut completely through them and a peg always fastens the tenon within the scarf tip itself. The second peg is located either in the adjoining plank of the strake or in a plank of the strake above or below, but not both (Steffy 1985b: 78, fig. 5, 81, 90–91, 91, fig. 15). This method is also in evidence on the small Kinneret boat of the first century B.C.E. or A.C. (Steffy 1987: 326, fig. 2).

In contrast, on the sea-going Roman hulls cataloged above, if scarf tip tenons are pegged, it is only in addition to being pegged in one or both of the planks adjacent to the scarf tip. Often the tenon is pegged only in the planks adjacent to the scarf tip, not in the tip, as is evident on the exterior planking layer of the wreck at Giens (Pomey 1978a: 79, fig. 11:3). This seems to be true for the Chrétienne C wreck (Joncheray 1975a: 60, beneath fig. 21), and the Nemi ships (Ucelli 1950: 153, fig. 153). It is distinctly evident on Wreck 3 at St.-Gervais, though in this hull are also scarf tip
tenons pegged in all three planks (Liou and Gassend 1991: 240, fig. 104). The technique was also used on the Bourse hull (Gassend 1982: 34, fig. 15, 78), on the ship that sank near Torre Sgarrata (Throckmorton 1972: 70, fig. 8), and apparently on Wreck 2 at Laurons in the first three strakes (Gassend, Liou, and Ximénès 1985: 96, fig. 18). Wreck 1 at Apollonia (mid-second to early first century B.C.E.) is specifically reported to display scarf tip tenons pegged in all three associated planks (Long 1992: 74).

The wreck of the Punic ship at Marsala yielded a tenon with three holes in it that is said to have fastened a scarf, though it was not found in situ (Frost 1981b: 90, fig. 41). One hole is nearly at the center of the tenon and has a diameter of ca. 0.01 m. The other two holes are confined to a final third of the length and the largest, of a diameter matching the one centrally located, is placed so close to the tenon edge that the edge was broken away. The third hole, ca. 0.01 m from the edge hole and some 0.03 m from the central one, measures only about 0.007 m in diameter. This disparity in hole sizes is conspicuous, as is the proximity of the two holes near one end. That this tenon was part of a scarf tip is possible, but if so, holes more uniformly spaced along the tenon’s length might be expected. Further, the tip of an intact S scarf has its tenon pegged only in the adjacent planks (Johnstone 1981: opposite p. 224, fig. 138), and the same technique is illustrated in a schematic of diagonal scarfs on the wreck (Frost 1981b: 128, fig. 64:A).

The evidence from Apollonia aside, an examination of these data may tend to suggest a developmental pattern in the pegging of scarf tip tenons on seagoing Graeco-Roman ships. Given the paucity of detailed information, such a conclusion would be premature and tenuous at best.

If, however, a suggestion regarding the issue of date had to be made based upon the available evidence, the characteristics of the Caesarea plank fragment are consistent with the scarf tips of seven other hulls (counting both Nemi ships) dating from the mid-third century B.C.E. to the early third century A.C. Six date earlier than the second century A.C. The median of the time span is the turn of the millennium, which therefore might be considered the most conservative date for the fragment from Caesarea. Finally, if the Caesarea fragment could represent part of a hooding end, stealer, as well as a scarf, it is possible that the joinery techniques reviewed here were not necessarily confined only to scarf tips.
Aspects of Nailed Scarf Tips

On the Caesarea hull nails are driven into the edge of the plank beneath half-frame 10 at its outboard extremity. The apparent absence of a scarf seam associated with the nails creates some doubt as to whether or not this is a nailed scarf tip. Perhaps the nails were driven down through the plank into the adjacent one, as was done on the Nemi ships (Ucelli 1950: 153, fig. 153); more likely, however, is the prospect that this is simply the repair of a split in the plank, given the size of the nail heads and the number of nails in evidence (J.R. Steffy, personal communication). Yet, because nailed scarf tips are typical of Graeco-Roman shipbuilding practices of the fourth century B.C.E. into the seventh century A.C., a review of their occurrence might help provide clues to the reason for the edge-nailed plank at Caesarea. Rival (1991: 279) reasonably suggests scarf tips were nailed to help keep them aligned with the outer surface of the planking.

Kyrenia (late fourth century B.C.E.): at least two upper scarf tips and two lower ones were nailed down. Copper nails 0.085 m long, with shaft diameters of 0.005 m and head diameters of about 0.015 m were used. Adjacent plank edges were hollowed out to receive the nail heads to ensure tight planking seams (Steffy 1985b: 78, 81).

Marsala (mid-third century B.C.E.): planks sometimes had a single nail driven through an upper scarf tip, while one or two fastened the lower tips (Frost 1981b: 128, fig. 64:A).

La Madrague de Giens (60–40 B.C.E.): upper scarf tips were nailed on the outer planking layer of the ship (Pomey 1978a: 79, fig. 11:3). In the figure, the nail nearest the scarf tip is ca. 0.12 m long, while a shorter one some 0.11 m away barely penetrates the lower plank of the scarf.

Lake Nemi (mid-first century): a schematic drawing of the planking indicates that two copper nails ca. 0.22–0.25 m long, with heads approximately 0.04 m in diameter, secured both upper and lower scarf tips. But instead of hollowing out the adjacent plank edges to avoid poor seams, as did their Greek predecessors when building the Kyrenia ship, the Roman shipwrights countersank the nails (Ucelli 1950: 153, fig. 153).

At least some scarf tips are nailed on Wreck C at Chrétienne (Joncheray 1975a: 59, fig. 19), Wreck 1 at St. Jordi (Colls 1987: 24), the Kinneret boat (Steffy 1987: 325, 326, fig. 2), Wreck 2 at Laurons (Gassend, Liou, and Ximénès 1985: 96, fig. 18), Torre Sgarrata (Throckmorton 1972: 70, fig. 8), the Bourse wreck (Gassend 1982: ...)
34, fig. 15), the wreck off Pommègues island near Marseille (Gassend 1979: 103), and Wreck 1 at Port-Vendres (Liou 1974: 422). Scarf "feather noses" are fastened with iron nails on the County Hall ship (Marsden 1974: 58, fig. 3, 59, 61, fig. 6:B, C) and the fourth-century wreck at Yassi Ada (van Doorninck 1976: 121). On the seventh-century wreck at Yassi Ada, iron nails were found in two scarf tips (van Doorninck 1982: 59; Steffy 1982a: opposite p. 74, re-assembly drawing 2).

All of these Graeco-Roman parallels for the practice of nailing scarf tips would make it difficult to suggest another explanation for the nails in the planking edge of the Caesarea hull, were it not for the matter of missing evidence for a scarf seam. That this is the repair of a split plank remains the best explanation, in view of the number of nails used.

**Diagonal and S Scarfs**

I have found only five wrecks upon which S scarfs are evident in the surviving portions of the hulls, and three of these display diagonal scarfs as well. Those with both include the small wreck found at Ma'agan Michael, although the difference between the two types is often slight (J.P. Rosloff, personal communication), the Punic wreck at Marsala (Frost 1981b: opposite p. 32, fig. 9, 128, fig. 64, 245-46; Johnstone 1981: 196, fig. 113, opposite p. 224, fig. 138), the second Nemi vessel (Ucelli 1950: pl. 8), and the Pantano Longarini hull (Throckmorton and Throckmorton 1973: 250, fig. 9). Only Wreck C at Chrétienne (Joncheray 1975a: 60, fig. 21) and the fourth-century wreck at Yassi Ada (van Doorninck 1976: opposite p. 116, fig. 1) appear to display exclusively S scarfs. Perhaps these scarfs were not worth the extra time and effort that must have been required; clearly diagonal scarfs were most often used.

Although it is not known how the scarf joints were fastened on the Caesarea ship, it is interesting to note that the wrecks at Marsala (Frost 1981b: 128, fig. 64:A), Chrétienne (C) (Joncheray 1975a: 60, beneath fig. 21), La Madrague de Giens (Poméy 1978a: 79, fig. 11:3), Lake Nemi (Ucelli 1950: 153, fig. 153), and Torre Sgarrata (Throckmorton 1972: 70, fig. 8), seem to share a common method of fastening scarfs: the tenons are set perpendicular to the scarf seam. This seems also to be the case on Wreck 2 at Laurons, but because no details are available (Gassend, Liou, and Ximénès 1985: 96, fig. 18), this and other examples illustrate well the need for caution when studying and recording the mortise-and-tenon joints of scarfs. For example, on the Kyrenia hull scarf mortises are cut perpendicular to the planking seams rather than the
scarf seams (Steffy 1985b: 91, ill. 15). In the illustration, however, the axes of some of the pairs of tenon pegs on the scarf seam are perpendicular to the seam, or nearly so, which gives the impression that the tenons are set at right angles to the seam. Therefore, without actually examining the mortises of a scarf, their precise orientation to the scarf seam will remain unknown, as will the quality of the fit of the scarf tenons within the plank mortises. Without this knowledge it is possible to indicate erroneously, or indeed to overlook the actual presence of, an interesting aspect of the shell-first mortise-and-tenon shipbuilding process: the pre-assembly of pairs of planks, or even entire strakes.

Mortise-and-tenon joinery prohibits the fitting of a plank to hull tenons and scarf tenons simultaneously unless the scarf tenons, like the hull tenons, are set perpendicular to the planking seams, or unless the scarf mortises of the plank being fitted are cut large enough to accommodate scarf tenons set perpendicular to the scarf seam. Therefore the only way scarf tenons perpendicular to the scarf seam can fit snugly in their mortises is if the two planks are scarfed prior to being fitted to the hull. This in fact was done on Starboard Strake 4 and Port Strake 7 of the Kyrenia ship (J.R. Steffy, personal communication). Furthermore, the lower scarf tips were edge-nailed upward from the bottom of the planks, and this too could only have been done before the assembly was joined to the hull. Such pre-assembly was also required in one instance during the construction of the Kyrenia replica (J.R. Steffy, personal communication). What appears to be another example of pre-assembly is found on the Chrétienne C wreck. The lower tip of a curved plank is nailed from below, and the tenons fastening this plank to the one above it are perpendicular to the curvature of the plank (Joncheray 1975a: 59, fig. 19). In addition, it is clear that in a pair of planks with scarf tenons at right angles to the scarf seam, and therefore pre-assembled, it is impossible to edge-nail both the upper and lower scarf tips from the same direction. Consequently, drawings representing both upper and lower tips nailed from the same direction on the same planking scarf, with scarf tenons perpendicular to the scarf seam, are suspect (see Ucelli 1950: 153, fig. 153; Frost 1981b: 128, fig. 64A).
Notes

1. Based on the Roman pes that measured 0.296 m and comprised 16 fingers, or digiti (F.N. Pryce and M. Lang in OCD², s.v. “measures”).

2. Planking widths are not exceptionally well documented in the archaeological literature, but most often seem to range from ca. 0.15 m to 0.35 m. The oak planks on the two largest Fiumicino vessels (third to fifth centuries) reach 0.40 m in width (Testaguzza 1970: 130–31). Pine planks on the St. Jordi 1 wreck planks measure up to 0.60 m wide (Colls 1987: 24). Regarding attainable planking lengths, Meiggs (1982: 241) states that mountain pines were preferred for ships because they grew stronger and taller than coastal varieties, sometimes exceeding 60 feet (ca. 18.3 m) in height. Fir trees occasionally provided straight lengths of 100 feet (ca. 30 m) or more.

3. Identification of this vessel as a warship has been questioned (Ascani and Penso 1988). Based strictly on the data in Table 3, a reconstructed length of 35 m for this ship seems a bit doubtful.

4. A similarly unique mortise-and-tenon technique is found on a wreck at Cala Binisafuller, dated to the early second century B.C.E. It appears that two pegs were driven through each plank to affix the tenons in their mortises (Parker 1992a: 74).

5. It should be noted that in 1969 Throckmorton estimated the length of the ship to be some 24 m, but later (1989: 266), suggested an overall length of 33 m, perhaps 23–24 m at the waterline, if reconstructed “along the lines of the Europa.” He also noted that the estimated 180 tons of cargo capacity derived from these new dimensions agrees well with the 160 tons estimated for the actual cargo. He does state that reconstruction along the lines of the Europa is very tentative, and indeed there appears to be no published evidence requiring or suggesting that shape. A waterline length of about 23 or 24 m could accommodate hull shapes less capacious than that of the Europa. In any case, the patterns discussed below under Relationships Between Vessel Size and Plank Thickness make somewhat unlikely the possibility that a lightly framed marble carrier of the late second century, with planking 0.072 m thick, would have been a viable seagoing vessel. Therefore the wreck is included in this smaller size category, even though Throckmorton’s calculations may well be correct.

6. Wreck 1 at Fos, dated ca. 50–25 B.C.E. (Pomey et al. 1988: 11, fig. 12), appears to have been double planked, but only the garboards are shown in the drawing. Measurements taken from the drawing indicate the thickness of the inner left garboard at its outboard edge is ca. 0.045 m, and the outer garboard at that point is 0.03 m, for an overall thickness of 0.075 m. On the right side of the keel, the outer garboard
measures the same as its left-side counterpart, but the inner plank at its outboard edge is only ca. 0.038 m thick, yielding an overall thickness of some 0.068 m. This wreck is not included in the catalog due to lack of details, but based only on the information available, and on the succeeding discussion in the text below, the planking of this ship may well have been similar to that of the ships that wrecked at Grand Congloué, Dramont (A), and Titan.

7. Such relationships might include, among others, that between tenon thickness and planking thickness, tenon spacing and tenon width or plank thickness, and tenon width and plank thickness or tenon spacing.

8. The percentage varies with the alignment of the mortises in the inner and outer layers along the length of the Giens hull. The proposition that greater tenon volume is indicated by greater tenon area at the plank edge is founded upon the notion that generally consistent proportions relating tenon dimensions to one another are a requirement of the joinery method if the joints are to function effectively.
CHAPTER VI

FRAMES IN LARGE GRAECO-ROMAN MERCHANT SHIPS
OF THE MEDITERRANEAN

In this chapter the framing details of the Caesarea hull are compared with those of other large Graeco-Roman vessels. Although not seagoing vessels, the Lake Nemi ships are included because they contribute to an overall picture of framing in large Graeco-Roman ships.

DIMENSIONS, SPACING, AND DISPOSITION

Only the framing characteristics of the wreck at La Madrague de Giens are well documented. This material and the scanty information we have from several other wrecks, however, indicate the frames of the Caesarea wreck are larger and more closely spaced than those found on any other seagoing ship of the Roman period I am aware of, save those of Caligula's obelisk freighter (see Chapter XIII). The frames of the latter aside, the Caesarea frames are exceeded in size only by the Nemi ship frames and those were spaced more widely than are the frames at Caesarea.

Punta Scaletta (150–140 B.C.E., L ca. 30 m): the preserved oak frames are from above the turn of the bilge, molded ca. 0.06 m and sided ca. 0.09 m, with two measuring 0.15 m. Average center-to-center spacing in some areas is a relatively consistent 0.24 m, but ranges from about 0.21 m to 0.56 m in others. Too little of the hull is preserved to gain an accurate idea of how floor timbers, futtocks, and half frames were employed in the hull (Lamboglia 1964: opposite p. 240, pls. 2, 3, 242, fig. 12). If spacing originally was consistent, it would appear that not all frame positions were noted, and that average center-to-center spacing is some 0.21–0.24 m.

Spargi (ca. 120–100 B.C.E., L ca. 30–35 m): an early report states oak frames of unknown disposition are 0.12 m square and set 0.22 m from one to the other (Lamboglia 1961a: 156). Wreck plans in subsequent publications (Pallarés 1983f:
223, fig. 1; 1986b: 92, fig. 5) indicate Lamboglia was working near the central portion of the hull, where frames are sided ca. 0.10–0.13 m and separated by the same distance. Hence center-to-center distances range from 0.20 m to 0.26 m. The same plans, however, show that at the northeast end of the site, near one extremity of the hull, the frames are separated by some 0.16–0.20 m.

Portions of seven floor timbers display worked surfaces that permitted good contact with the keel. Moreover, they exhibit the remains of nails or bolts about 0.60 m long—of unspecified metal—that joined them to the keel and “keelson” (Pallarés 1983b: 10, 12, 38; 1983f: 222). A report of an actual keelson affixed to the keel and frames should be regarded with caution. Such a timber is not evident in the published wreck plans, nor is one described further in the report (Pallarés 1983f: 222). It is even more important to note that no firm evidence yet exists for a true keelson this early in the history of Greek and Roman shipbuilding.

Albenga (early first century B.C.E., L ca. 40 m): two curvilinear pieces of oak recovered from the wreck are suggested to be frame components from near the turn of the bilge of one tapered extremity of the ship. One timber is 1.65 m long, apparently molded ca. 0.08 m and sided about 0.085 m. The other is 0.60 m in length and measures approximately 0.075 m square (Lamboglia 1953: 203, fig. 57). Casson (1986: 214) gives dimensions of 0.10 m molded by 0.10–0.12 m sided, but these appear to be the dimensions of rectilinear timbers thought by the excavator to be “sleepers” upon which beams rested (Lamboglia 1953: 205–6). Nails within the plug–treenails that fastened the frames to the planking are 0.22 m apart, approximately, and must correspond to the center–to–center distance between frames. If the frames have been correctly identified, and if their dimensions are representative, the space between frames is about 0.14 m. At this time the frame spacing must remain a question: because of the uncertain provenance and function of the timbers. The disposition of frames within the hull is unknown as well (Lamboglia 1953: 206).

Antikythera (early first century B.C.E., L ca. 30 m): one and possibly two pine timbers that appear to be frames are tentatively associated with the wreck material. We have no evidence of how the hull was framed. The best–preserved frame consists of a floor timber with one complete arm and part of the other. It is ca. 1.43 m long and reconstructed to ca. 2 m in length. The timber is molded ca. 0.153 m at its center and thins to ca. 0.085 m at its extremities. Part of a futtock is joined to the fully preserved arm by means of a shallow hook scarf. This futtock fragment is also molded 0.085 m,
and both components are sided ca. 0.085 m over their lengths. The scarf is ca. 0.50 m long and appears to be secured with a treenail ca. 0.015 m in diameter at each side of the hook (Throckmorton 1965: 46, fig. 17, 47).

*Chrétiennette A* (early first century B.C.E., L ca. 24–32 m): floor timbers and half-frames are molded some 0.10 m and sided about 0.08–0.10 m. Frames seem to be arranged in alternating pairs, first 0.0675 m apart and then 0.175 m apart (Dumas 1964: 120, fig. 12, 126, fig. 15:A, 127, fig. 15:B; Casson 1986: 215). On this wreck is a frame extremity that is tapered in its molded dimension and pierced by a treenail. This is interpreted as an indication of a frame scarf like those used on the Nemi ships (see below), wherein frame components were joined together with wedge-shaped chocks fitted to the tapered extremities of the timbers (Dumas 1964: 111; Frost 1963: 266, fig. 52, 267).³

*Mahdia* (early first century B.C.E., L ca. 30 m): the frames are about 0.60 m apart (whether this is average spacing between centers or distance between frames is not stated). One large membrure is “environ 0 m 20 de hauteur à la varangue” (about 0.20 m high at the floor timber) (Benoit 1961: 144). The meaning of this is unclear. It appears that membrure is used in the sense of arm or timber by Benoît, who distinguishes between two types of varangue. One type is the thickened central portion of what is today termed a floor timber, while the other is the chock he reports as fastened to and joining two half-frames over the keel on the wreck at Grand Congloué (Benoit 1961: 132). If the chocks on that wreck were in fact fastened to the under surfaces of the floor timbers (see Grand Congloué entry in Chapter IV), then we are left with two interpretations of Benoît’s report. Either a floor timber (in current terminology) is molded 0.20 m over the keel or after it has thinned to a uniform dimension a short distance from the keel, or a half-frame is molded 0.20 m at its inboard extremity. If, on the other hand, neither of these interpretations is correct, then the meaning remains entirely uncertain.

*La Madrague de Giens* (60–40 B.C.E., L ca. 38 m): frames vary from 0.09 m to 0.19 m in the sided dimension, averaging 0.13 m to 0.14 m, and are spaced an average of 0.10–0.11 m apart, ranging from 0.07 m to 0.14 m. Average center-to-center distance is therefore ca. 0.23–0.25 m. Floor timbers reach heights of 0.57 to 0.60 m over the keel, thinning to their normal molded dimensions of 0.12–0.15 m at a point only about 1 m from the keel centerline. The half-frames are of the same dimensions except where they curve down toward the keel. There they are molded only 0.06 m to
0.10 m. The floor timbers and futtocks are set a few centimeters apart, never fastened to one another. Overall lengths of floor timbers vary from 4.6 m to 5.1 m, and futtocks begin at between 2 m and 2.5 m from the keel axis. The half frames extend 3–4 m from the keel before futtocks are installed. Thus joints between the futtocks of floor timbers and of half-frames are staggered along the length of the hull. The extremities of one arm of a floor timber and its futtock are cut such that they could have been joined with a chock like those on the Nemi and Chrétienne A frames, but no chocks have been found, nor is there any evidence of fastenings in the timbers (Pomey 1978a: 80–81, 81, n. 16, and pl. 36).

Lake Nemi (mid-first century, L ca. 71 m and 73 m): the frames of these flat-bottomed hulls measured about 0.20 m in the sided dimension, with molded dimensions of approximately 0.35 m over the keel and 0.30 m elsewhere. At the foot of the stem, however, they were molded about 0.40 m. Other than at the foot of the stem, there seems to have been little or no thinning in the molded dimension from the keel to the turn of the bilge. Center-to-center spacing ranged from about 0.65 m to 0.70 m in most areas, but closed to approximately 0.45 m where the hulls narrowed, for example at the foot of the stem. The frames were simply nailed to the keel; further details are unavailable. According to the drawings, floor timbers were simply butted against their futtocks or joined by means of triangular chocks that were fitted into the tapered extremities of the floor timbers and futtocks. The means of fastening the chocks to the frame timbers is not specified. Scarfs and joints were staggered so as not to occur along the same strake, and there was at least one “passing frame” between frame scarfs near the same strake (Ucelli 1950: 153, fig. 153, 157, figs. 158, 159, 379, 382).

ANALYSIS

The general dearth of evidence for how large ships were framed prohibits more than preliminary observations. Although the specific effects on hull strength of features like decks, through-beams, stanchions and the like surely were significant and intimately related to framing, they are omitted here due to the paucity of archaeological evidence. To my knowledge, the only deck remains from the Graeco-Roman period that have been extensively published were found on Wreck 2 at Laurons
(Gassend, Liou, and Ximénès 1985).

The most striking aspect of these hull components is their diminutive size. The Caesarea framing is clearly the heaviest, with average dimensions of 0.1375 m molded and 0.18 m sided, and an average room and space 0.25 m. If the Caesarea frames are omitted from the group, molded dimensions other than near the keel range from 0.06 m to a maximum of 0.15 m. The average is approximately 0.0935 m. Sided dimensions average 0.108 m, ranging from 0.075 m to 0.15 m. Center-to-center spacing varies from 0.21 m to 0.56 m and averages almost 0.23 m. For this group, then, excluding the Caesarea hull, the distance between frames averages 0.116 m, just slightly more than the average sided dimension.

Further, the wrecks at Spargi (in the more central portion of the hull), Giens, and Caesarea exhibit frames set more closely together than their sided dimensions. This characteristic is not found on smaller Graeco-Roman ships for which we have information. For example, the extant Kyrenia ship frames average 0.09 m square along Strake 6, and are positioned an average of 0.25 m apart center-to-center. Spaces between frames thereby average 0.16 m, nearly twice the average sided dimension.

Judging from the information at hand, most big ships were built with relatively small frames, so the planking shell was probably more important to hull strength than were the frames, as it was in smaller ships. But it is clear that frames were positioned relatively much closer to one another in some larger vessels, which must represent a recognition or perception of the need to provide comparatively more strength to the planking shells of big ships. Therefore it appears that frames played a more important structural role in larger seagoing hulls than they did in smaller ones, but the extent to which this was true may be demonstrated only through calculations of the physics involved.

More support for the notion consists of some evidence for the fastening of futtocks to floor timbers and half-frames. A floor timber and futtock attributed to the Antikythera wreck are reported to be joined by a treenailed hook scarf; the Chrétienne A wreck displays two frame components that might be joined by a wedge-shaped chock. With the exception of the relatively early wrecks at Bon Porté and Ma‘agan Michael, this concept is not in evidence on small Graeco-Roman seagoing ships until the second half of the fourth century or later, at Yassi Ada and Port-Vendres (van Doorninck 1976: opposite p. 116, fig. 1, 124; Liou 1974: 423; Rival 1991: 285, 287, pl. 105, 288, pl. 106, 289, pl. 107). Although lake vessels, the frame components
joined with wedge-shaped chocks in the Nemi ships are the best examples of scarfed frame components.

So, sparse as it is, these large Graeco-Roman craft exhibit evidence of concepts fundamental to more supportive framing systems. Some frame components are rudimentarily scarfed to one another, and sometimes frames are set much closer to one another than the extent of their sided dimensions.

**ALIGNED WATERCOURSES AND LIMBER HOLES**

Cuttings in the undersides of frames to help bilge water pass freely along the hull's length are common in Graeco-Roman ship frames. When located above or near the keel they are termed limber holes, while those found farther from the keel, nearer the turn of the bilge, are here regarded as watercourses (J.R. Steffy, personal communication). They occur in rectangular, circular, semi-circular, or triangular forms.⁴

Possibly because of poor preservation on sites, I have found only two instances, aside from that at Caesarea, of rope within either watercourses or limber holes: Wreck 3 at St.-Gervais, dated to the mid-first century (Liou and Gassend 1991: 229, 233, fig. 95), and the Port-Vendres 1 wreck of the late fourth or early fifth century (Liou 1974: 423).⁵ At St.-Gervais, the rope measures 0.015 m in diameter and comprises three strands laid left, as does the one at Caesarea. Although ropes to keep limber holes or watercourses clear surely made working in the bilge less repulsive than it could have been, literary references confirm a natural expectation that it was a punishing and unpleasant experience (Oleson 1984: 65–67; Casson 1986, 176, n. 40; Torr 1964: 61, n. 139). Yet few ships in the corpus of evidence could have been fitted with such a convenience, except at the keels, since the alignment of watercourses is reported only infrequently in the archaeological literature. The Kyrenia ship had watercourses aligned over the seams of strakes 2/3 and 5/6 (Steffy 1985b: 85, 86, table 4). The wreck at Diano Marina exhibits watercourses of 0.02 m diameter every 0.07–0.10 m along the frames outboard from the keel, but their disposition down the length of the hull is not described (Pallarés 1985a: 642; 1985c: 601). I have found no other wrecks with watercourses that might have been aligned in every frame component down the length of the vessel, but it seems to have been approached on the
early-first century dolia wreck at Ladispoli (Carre 1993: 19). Watercourses 0.07 m long and 0.04 m high are found consistently 0.80–0.90 m from the keel. Carre attributes this arrangement to the drainage requirements of such a flat-bottomed hull, and this would be valid for the St.-Gervais 3 (see Liou and Gassend 1991: 226, fig. 86.3), Port-Vendres (Liou 1974: 431), and Caesarea wrecks (see Chapter XIII).

STRINGERS

In large Roman ships stringers typically alternate regularly with thinner removable ceiling planks to form a floor, or part of one, in the hold (cf. Gianfratta and Pomey 1981: 53–56). On the wreck at La Madrague de Giens these longitudinal stiffeners fixed with copper nails driven from inside the hull are 0.20–0.30 m wide and 0.06–0.10 m thick. At the turn of the bilge one preserved stringer is about 0.125 m in thickness. The removable ceiling planks between the stringers are 0.15 m to 0.25 m wide and only 0.025–0.04 m thick (Pomey 1978a: 84, and pl. 36). A similar scheme was used on the ships found in Lake Nemi, but their purpose and grand dimensions seem to have required additional structural provisions. Both holds were floored with alternating thick (ca. 0.075 m) and thin (ca. 0.0375 m) planks, and each hull included deck stanchions resting on central and lateral stringers notched to receive the frames. On the first ship the central stringer measured some 0.24 m thick, the lateral ones ca. 0.16–0.25 m; some of the lateral stringers were mounted atop the thick ceiling planks, and all were roughly 0.26 m wide. On the second vessel, the central stringer was about 0.26 m thick, while those to the sides ranged from approximately 0.155 m to 0.22 m in thickness and rested only on frames. They were ca. 0.31 m wide. All stringers on both ships took their places as thick timbers in the alternating thick-thin-thick-thin scheme (Ucelli 1950: 155, fig. 155, 157, fig. 158, 172, fig. 184, 379–80, and especially pls. 2, 6, 8).

Among hulls smaller than those at Caesarea, Giens, and Lake Nemi, the dimensions of stringers tend to decrease accordingly. What may have served as a stringer or clamp was found extending across six frames on the wreck at Capistello. It is ca. 0.30 m wide and 0.06 m thick; the ship is tentatively reconstructed to 20 m or more (Frey, Hentschel, and Keith 1978: 293, 294, fig. 18, 295, 298). On Wreck A at Cap Dramont (ca. 25 m long) are stationary planks 0.04 m thick and 0.25 m in width
that alternate with movable planks 0.025–0.03 m thick (Liou 1975: 600). Wreck 1 at Port-Vendres, also reconstructed to over 20 m in length, displays stringers 0.04–0.06 m thick and 0.12–0.20 m in width. Between the stringers are ceiling planks 0.015–0.03 m in thickness and 0.12 m to 0.28 m wide (Chevalier and Santamaria 1971: 17, fig. 13; Liou 1974: 423; Rival 1991: 273). Stringers on Wreck 3 at St.-Gervais (mid-first century, L ca. 17 m) are 0.08 m thick and 0.20 m wide, with average lengths of 4.50 m. Movable ceiling planks were placed between them (Liou and Gassend 1991: 258).

With regard to more elaborate ways of fitting stringers and ceiling planks, it is reported that two longitudinal *serrettoni di rinforzo* (thick ceiling planks of reinforcement) are carefully notched and nailed atop the frames of the wreck at Spargi (Pallarés 1983f: 222). More interesting is the wreck plan (Pallarés 1986b: 92, fig. 5) that shows that virtually all of the preserved ceiling planks are fastened to all the frames they traverse. One ceiling timber of notable width exhibits a shallow hook scarf as well. Whether these features were the product of a simple desire to immobilize the planks, or to impart some longitudinal stiffness to a ship some 30–35 m in length, they would have achieved the latter to some degree. Similarly, the hull remains at Diano Marina (of a *dolja* carrier ca. 22–25 m long) include ceiling planks 0.03 m thick fastened to the frames with treenails 0.02 m in diameter (Pallarés 1991: 172). The Bourse hull, originally ca. 23 m long, exhibits stringers 0.18–0.20 m wide and 0.08 m thick that are notched to receive the frames and are nailed to them. Smaller longitudinal timbers are notched and affixed along the axis of the hull in the same fashion. Removable ceiling planks, also notched to receive the frames, are 0.025 m thick and alternate with the stringers across the breadth of the hold (Gassend 1982: 82; Rival 1991: 250, 252). Parker (1992a: 345) reports that the wreck dated to perhaps A.D. 250 at Punta Ala exhibits one substantial stringer set into the frames just outboard of the centerline of the hull. A drawing in Lamboglia and Pallarés (1983a: 175, fig. 6), however, shows a substantial stringer set at either side of the keel. It seems likely that both were set into the frames, either through notches on the undersides of the stringers, on the tops of some of the frames, or a combination of the two.

As described above (figs. 33–39, 41, 42), remnants of six large copper or bronze fastenings have been discovered in the frames of the Caesarea hull, other than at the keel edge. One (*Cu10*) protruded ca. 0.08 m above the top of half-frame 12 at a point
0.93 m from the frame's inboard extremity. The others had been broken off prior to the 1986 excavations, though one was preserved for a few centimeters above half-frame 22 near its outboard extremity. Two copper or bronze washers (Cu14 and Cu15) were also found (fig. 40) and exhibit hole diameters that match perfectly those of the upper extremities of the fastenings. Because we have yet to discover and plot all such fastenings we can only speculate about their function in the Caesarea hull, but it is possible that they helped secure stringers to the frames. As shown above, a dimension of 0.08 m is certainly suggestive of stringers in a large ship. If these fastenings (whether bolts or nails) did bind stringers to both the frames and planks, the fastening method would be only the second example among Graeco-Roman ships (see Bolts and Washers in Chapter VII). Bolts did, however, pass through the wales, frames, and ceiling planks of the smaller (ca. 20 m) and much later seventh-century ship that wrecked at Yassi Ada (van Doorninck 1982: 42–43, figs. 3-17, 3-18, 3-19, 3-20, 45–46).

SHIMS

Although seemingly a natural part of the shell-first construction process, there are few published examples of shims or shimmed frames. Filling the gaps between ill-fitting frames and planking in shell-first hulls might be regarded as the counterpart to the dubbing of frames to receive properly the planks of frame-first hulls.

A piece of wood thought to be a shim was found on a wreck site near Porticello, Italy. It is 0.07 m long, 0.054 m wide, and 0.021 m thick. One face is flat and the other curves smoothly in the shape of a wedge (Eiseman 1979: 24, 30, 49, figs. 2.6, 2.7; Eiseman and Ridgeway 1987: 10, 16). Half-frames were frequently shimmed on the Kyrenia ship, the floor timbers less often (Steffy 1985b: 93). It is suggested that one use of the putty found on the Punic ship was to fill gaps between frames and planks (Frost 1973b: 44; 1981b: 250). A gap between a frame and plank of the wreck at Palamós was apparently filled with pieces of fabric and then tarred (Foerster Laures 1983b: 224). Two pieces of wood identified as elm and deciduous oak found on the wreck at La Madrague de Giens might be wedges or shims (Couvert 1978: 111). On the second-century wreck at Torre Sgarrata, brushwood sticks of tamarisk or ilex (sic) were found packed between frames and planks (Throckmorton 1969: 300; 1972: 70;

**HULL INSCRIPTIONS**

Most of the few examples of letters found carved or painted on ancient hull timbers seem to be related to the construction of the vessels. On the funerary ship of Cheops at Giza no fewer than 1,131 small hieratic and hieroglyphic marks were both incised and painted in black on 305 ship timbers. These signs appear to fall into three categories, the broadest of which consists of four signs that denote to which quarter of the hull a timber belonged. The largest category comprises a number of signs used to match battens with their positions in the hull. The third category is represented by one symbol occurring numerous times along the centerline of the hull. Lipke proposes that they might be reference points used during construction to ensure that the hull was built symmetrically (Lipke 1984: 12, 13, fig. 7, 82, 86, figs. 54, 55, 87, fig. 56; Jenkins 1980: 87, fig. 62, 88, fig. 63; Nour et al. 1960: 8, fig. 3). Punic letters painted at various places on the hull of the Punic wreck at Marsala are argued convincingly to be shipwright’s marks associated with the sequence of the hull’s construction (Johnstone 1981).

The Roman numerals X and XIV were discovered incised on two starboard stern ceiling planks of a river vessel that sank at Comacchio late in the first century B.C.E. It was suggested in early reports (Bonino 1985: 93; Berti 1986: 26, 30, fig. 23) that they might have been linked with the installation of the ceiling. With excavations now completed, Bonino rejects this notion, as well as the possibility that they were random and pointless markings. From port to starboard, nine planks, only the central of which was fastened to the frames, bear the respective numerals III, IV, V, VI, VII, IIX, IX, X, XI. Bonino submits there were originally, or originally intended to be, planks numbered from I to XX, and that they were so-marked to ensure proper reinstallation after removal for cleaning or repair operations (Berti 1990b: 32; Bonino 1990: 36, fig. 2, 37; cf. Berti 1992: 222, 224).

Graffiti in the form of Greek capital letters were found on some ceiling planks of the Kyrenia ship, but the material has yet to be published (Steffy 1985b: 86). On a more personal level, it seems a shipwright or carpenter with the *praenomen* Quintus carved his initials in a place that won him a bit of immortality. On Wreck 3 at St.-
Gervais (mid-first century), the letters Q·M·F (Quintus Marci filius) appear four times on the bottom of floor timber 150 (Liou and Gassend 1991: 229, 232, 234, fig. 96).\textsuperscript{7}

NOTCHES

The purpose of the horizontal notch on Caesarea floor timber 39 is unknown. It is not paralleled by the installation of stringers or by any other features found on other Graeco-Roman hulls. The frames of the wrecks at Giens and Lake Nemi were not notched for stringers, and only two wrecks display evidence of the practice. On the small wreck at Monaco, notches are cut completely across the frame widths at some distance from the keel. Others were cut above the keel for a central longitudinal timber (Mouchot 1970a: 163, figs. 1:1, 1:2, 177, fig. 6:3; 1978: 80). A large stringer on the Musée des Docks wreck was fitted into notches let into the top edges of the frames a short distance from a central longitudinal timber analogous to the one at Monaco (Varoqueaux 1970: opposite p. 30, fig. 4, 32, fig. 5:5).\textsuperscript{8} It seems that, despite the certainty that stringers were required on a ship the size of the one that wrecked at Caesarea, the notch on the Caesarea frame had another purpose. Examples of frames notched for stringers are few, they occur on smaller, later wrecks, and some are configured differently. Moreover, we do not yet know if there are other similar notches elsewhere on the Caesarea wreck. This curious feature must await further study.

The function of the crudely cut vertical notch on floor timber 35 of the Caesarea wreck is also unknown. The frame directly opposite the notch might have provided more clues to its nature, but regrettably it is lost. The notch is immediately adjacent to what appears to be a frame shim, but seems not to be associated with it because the shim is too narrow (0.16–0.185 m) to have protruded beyond the width of the missing frame (ca. 0.19 m). The notch could have received a vertical timber, but placing such a timber directly upon the hull planking would have been poor practice. The fact that the notch is larger at the top of the frame than at its bottom raises the possibility that it accommodated a temporary stanchion or one added after hull construction, one that did not necessarily rest upon the hull planking. Stringers or ceiling planks with mortises cut into them, as well as mast steps and keelsons, are commonly believed to have supported permanent stanchions. Such mortises are found on wrecks at Lake
Nemi (Ucelli 1950: 157, fig. 158, and pls. 2, 8), St. Gervais (3) (Liou and Gassend 1991: 223, fig. 85, 237, 240, 243, fig. 108, 244, figs. 110, 111), Bourse (Gassend 1982: 86), County Hall (Marsden 1974: 56, fig. 1, 59, fig. 4, 61, fig. 6), Port-Vendres (1) (Liou 1974: 424, fig. 8, 427, 430–31, fig. 12; Rival 1991: 270, pl. 92, 274, pl. 95, 276), Fiumicino (2) (Testaguzza 1970: 131, 138), Laurons (3) (Ximénès and Moerman 1987: 176), and possibly Marsala (Frost 1981b: 252, fig. 158, 253, fig. 159).
Notes

1. See Bolts and Washers in Chapter VII for an examination of wrecks exhibiting frames fastened firmly to the keel.

2. See Geanette 1983 for an examination of the development of the mast step and keelson.

3. A chock is any piece of wood inserted between two timbers or used to compensate for some deficiency in a timber.

4. A rare method of allowing water to flow to the ship’s pump is in evidence on Wreck 1 at Apollonia (mid-second to early first century B.C.E.). A groove with an average depth of 0.04 m was cut into the top surface of the keel over almost all of its length. The groove deepens to 0.06 m near one extremity, which is therefore suggested to be the stern, where excess water would have collected at the bilge pump (Long 1992: 72–73). A similar channel was found in the wreck of a Roman naval vessel found at Mainz. On Wreck 9 a groove was observed in the top of the keel. Further aided by limber holes in the floor timbers, the bilge water could thus be bailed from a single place (Höckmann 1988: 25, 26, fig. 2:2b, c).

5. It is interesting to note that the same technique was being employed in Europe in the last quarter of the eighteenth century. On French 74-gun ships, limber holes 0.054 m deep and 0.081 m wide were cut into the frames to accommodate limber chains, which were pulled back and forth to maintain the clear flow of bilge water (Boudriot 1986: 144).

6. C.W. Haldane (personal communication) suggests these two types of marks were intended to facilitate a subsequent re-assembly of the boat, i.e., that the boat was indeed built prior to interment. Therefore it was likely a functional craft, its components not merely fashioned and buried for the pharaoh.

7. See Liou and Gassend (1991: 245, 251–52, figs. 122–24) for other hull inscriptions whose purposes are either unknown or apparently not associated with the construction of the ship.

8. In two instances frames are notched to take keel stringers associated with mast steps or keelsons: Wreck B at Pointe de la Luque (late third or early fourth century) appears to have notches 0.02 m deep over the full width of the frames at one side of the keel, while the same frames are notched only at their upper edges for the corresponding stringer on the other side of the keel. These stringers support the mast step and measure 0.12 x 0.075 m in section (Clerc and Negrel 1973: 63, fig. 1, 65–66,
69, photos 1, 3, 70, photo 5; Liou 1973: 583). The late-fourth or early-fifth century wreck at Port-Vendres also has central stringers that provide a saddle for the mast step. Notched slightly themselves, they are fitted over frames notched to receive them, but whether or not the notches extend across the entire width of the frames is unclear (Liou 1974: 423, 430–31, fig. 12; Chevalier and Santamaria 1971: 17, fig. 13, 28, fig. 23, 30).
CHAPTER VII

PRIMARY HULL FASTENINGS IN GRAECO-ROMAN
MEDITERRANEAN SHIPS

INTRODUCTION

Few fastenings were recovered from the Caesarea wreck: treenails, evidence for plug-treenails pierced by nails, some copper, bronze, and iron nails of various sizes, and remnants of copper or bronze fastenings of partly unknown configuration in some planks and frames. The apparent use of these latter fastenings to bind some stringers and frames to the planks is the most significant aspect of the Caesarea fastenings. If confirmed, such employment would be only the second instance in the archaeological literature and would have significant implications for the demands made upon the planking shell of a large ship. The evidence for plug-treenails pierced by nails has implications for dating the time of hull construction, while the nails found on the site contribute to an overview of material usage and morphological characteristics of nails used in Graeco-Roman ships.

In Greek and Roman Mediterranean ships, the most common method of securing frames to the hull planking was by means of treenails. In some instances metal nails were driven through treenails called plug-treenails, which also joined planking and frames. Not infrequently, the nails were driven through planks and frames and protruded above the frame tops, where they were clenched either once or twice. When clenched just once, the shafts were bent at a right angle, usually toward the keel, and pounded into the frame tops. Nails clenched twice had first their tips and then their shafts bent at right angles, such that the nail was locked into place as the tip was driven back into the frame top. Wreck 3 at Laurons and possibly the wreck at Punta Ala constitute the only reported instances of bolts binding frames to planking (see Bolts and Washers below). Bolts most often were used to fasten floor timbers to the keel in classical Mediterranean ships, although the Athlit ram was secured to the timbers it encased with bronze bolts.
In rare instances, cordage was one of the materials employed in the fastening of frames to planking. On a wreck at Cap Béar (first century B.C.E.), beginning with the garboard, every other strake is bound to the frames with a length of plait that passes up and around the frame and then down through holes in the planks. The plait, of an unidentified plant material, is accommodated by grooves or notches in the frame tops and in the exterior plank surfaces and secured with treenails. The intervening strakes exhibit only treenails driven into the frames (Pomey et al. 1988: 2–3). A river vessel discovered at Comacchio, of the late first century B.C.E., displays a similar utilization of cordage, but on a more extensive scale (see Comacchio entry in Chapter XI).

Iron fastenings have received relatively little attention in the archaeological literature; this neglect must stem in part from their rather rare employment as major hull fastenings in pre-Byzantine hulls. For this reason it is not known precisely under what conditions and in what capacity they were utilized on ships before Byzantine times. A greater body of information exists about copper and bronze fastenings. These were the predominant metals used in seagoing ships in the Graeco-Roman period because the resistance of copper and its alloys to corrosion was superior to that of iron. For this reason, too, copper-based fastenings have survived better than iron over the centuries.

The following sections of this chapter address respectively the use of treenails, plug-treenails pierced by nails, and nails to fasten together frames and planking in Graeco-Roman Mediterranean ships. The use of bolts in Roman and early Byzantine ships is surveyed in an attempt to understand better some fastenings in the Caesarea hull that could be bolt remnants.

**TREENAILS**

Treenails were driven through holes drilled through a plank and the entire molded dimension of the frame, then trimmed at the plank and frame surfaces. Sometimes, however, it seems the drill bits went awry, as treenails have been observed exiting from the molded faces of frames instead appearing at the upper surfaces. Usually two treenails are found per plank per frame. When planks are ca. 0.10–0.15 m wide only one might be in evidence, and three can be found on uncommonly wide planks. The shipwrights staggered the treenails along each frame to avoid splitting it. Diameters of
such treenails naturally varied according to the size of the vessel and its timbers, ranging from about 0.015 m to 0.035 m in diameter at the outer planking surface. Ships reconstructed to more than about 10–12 m long most often display treenails with diameters of 0.02–0.025 m. In double-layered hulls usually only the inner layer was treenailed to the frames; most often the outer layer was simply nailed to the inner planking and the frames. Only on the Dramont A wreck of the first half of the first century B.C.E. are both planking layers treenailed to the frames; the outer layer is also nailed to the inner layer and to the frames.

Most of the observed treenails on the Caesarea wreck are ca. 0.02–0.025 m in diameter at the outer planking surface and 0.018–0.02 at the frame tops. Some (the precise number is unknown) measure 0.015 m at the frame tops. On the Bourse wreck are treenails tapering from diameters of 0.015 m at the frame tops to 0.02 m at the outer planking faces, but no explanations are offered (Gassen 1982: 79). Tapered treenails were also found on the fourth-century Dramont F wreck, which is reconstructed to some 10–12 m in length (Joncheray 1975c: 123; 1977: 6). This seems an unlikely practice on a large vessel like the Caesarea ship, however. When wet and swollen and subjected to the much greater dynamic stresses in a big ship, tapered treenails in tapered holes would probably tend to work out of the timbers they were meant to bind together. On the fourth-century wreck at Yassi Ada, diameters of several treenails were found to be 0.016 m at the frame tops and 0.02 m at the outer planking faces. This change occurred only in the last two centimeters of length (van Doorminc 1976: 125–26). The issue must remain open for the Caesarea ship until an extensive examination can be made.

**PLUG-TREENAILS**

The practice of fastening frames to planking with treenails was sometimes modified by driving nails through softwood treenails. In such instances the nail became the primary fastening, though it has been suggested, in the cases of the Planier 3 and Musée des Docks wrecks, that such nails prevented the shearing of the softwood treenails they were driven through (Couvert 1978: 111, n. 3). First a pilot hole was drilled through the plank and frame, the treenail was inserted, then the nail was driven through it. This forced the treenail tightly against the surrounding wood with uniform
pressure. Because of this equalization of pressure and the forgiving softwood treenail, planks and frames were not split when the treenail became wet and swollen. Unlike hardwood, the softwood also provided a soft corridor for the nail to pass through, and improved the watertightness of the fastening by serving as a tight sheath around the nail. Finally, the softwood treenail acted to cushion the nail, which might otherwise tend to work loose (Steffy 1985b: 91 and personal communication).

The tightness inherent in such plug-treenail fastenings, partly a function of the size of nail used, must have made the employment of hardwood treenails difficult because the grains of most hardwoods are generally finer and tighter than those of softwoods. We do have reports of such usage, however.

**Archaeological Evidence for Plug-Treenail Fastenings**

The following chronological catalog presents the basic characteristics of plug-treenail fastenings used to bind frames to planking on Greek and Roman Mediterranean wrecks (Table 5). The plug-treenail fastenings in the fourth-century Yassi Ada hull and within the Athlit ram did not serve the same purpose, but are included for completeness.²

*Ma'agan Michael* (ca. 400 B.C.E., L ca. 13 m): iron nails were driven through treenails (species not yet identified) and clenched twice on the frame tops, toward the keel (Linder 1989: 6; 1992: 26, 33, 34; Rosloff 1990: 4 and personal communication 1993).

*Kyrenia* (late fourth century B.C.E., L ca. 14 m): every pine treenail had driven through it a round copper nail ca. 0.01 m in diameter that was clenched twice on the top of the frame, toward the keel, thus creating a herringbone pattern atop each frame (Steffy 1985b: 84, and pl. 21, fig. 3).

*Marsala* (mid-third century B.C.E., L ca. 35 m [?]): the Punic ship had square bronze nails and possibly some of iron driven through at least some of the oak treenails and clenched over the frame tops (Frost 1981b: opposite p. 32, fig. 9, 36, fig. 11, 37, fig. 12, 122, fig. 58:1, 126).

*Jeanne-Garde B* (late third or early second century B.C.E., L undetermined): iron nails were driven through the oak treenails and clenched once toward the keel (Carrazé 1976a: 163; 1977: 302, fig. 6).
<table>
<thead>
<tr>
<th>Site</th>
<th>Nails Metal</th>
<th>Nails Shaft Shape</th>
<th>Nails Clenched</th>
<th>Treenails Wood Type</th>
<th>Vessel Length (m)</th>
<th>Date (Century)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ma'agan Michael</td>
<td>iron</td>
<td>square</td>
<td>x</td>
<td></td>
<td>13</td>
<td>5/4 B.C.E.</td>
</tr>
<tr>
<td>Kyrenia</td>
<td>copper</td>
<td>round</td>
<td>x</td>
<td>pine</td>
<td>14</td>
<td>4 B.C.E.</td>
</tr>
<tr>
<td>Marsala</td>
<td>iron &amp;/or</td>
<td>square</td>
<td>x</td>
<td>oak</td>
<td>35</td>
<td>3 B.C.E.</td>
</tr>
<tr>
<td></td>
<td>bronze</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jeaneu-Garde B</td>
<td>iron</td>
<td>round</td>
<td>x</td>
<td>oak</td>
<td>3</td>
<td>3/2 B.C.E.</td>
</tr>
<tr>
<td>Ashlit Ram</td>
<td>bronze</td>
<td>round</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gr. Congloué</td>
<td>copper</td>
<td>square</td>
<td>x</td>
<td>oak</td>
<td>23</td>
<td>2/1 B.C.E.</td>
</tr>
<tr>
<td>Pozzuno</td>
<td>copper</td>
<td></td>
<td>x</td>
<td>softwood</td>
<td>40</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Albenga</td>
<td>copper</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antikythera</td>
<td>bronze</td>
<td>round</td>
<td></td>
<td></td>
<td>30</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Chrétienne A</td>
<td>copper</td>
<td></td>
<td>x</td>
<td></td>
<td>24–32</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>St. Jordi 1</td>
<td>copper</td>
<td>square</td>
<td>x</td>
<td>pine</td>
<td>15–20</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Planier 3</td>
<td>bronze</td>
<td></td>
<td>x</td>
<td>fir</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Titan</td>
<td>copper</td>
<td></td>
<td></td>
<td></td>
<td>≤25</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Tre Senghe A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20–24</td>
<td>2–1 B.C.E.</td>
</tr>
<tr>
<td>Grand-Ribaud D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18</td>
<td>1 B.C.E.</td>
</tr>
<tr>
<td>Caesarea</td>
<td>bronze</td>
<td>square</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lake Nemi 1, 2</td>
<td>copper</td>
<td>square</td>
<td>x</td>
<td>pine, fir</td>
<td>71, 73</td>
<td>1 A.C.</td>
</tr>
<tr>
<td>Pommègues</td>
<td></td>
<td></td>
<td></td>
<td>cypress or olive or</td>
<td></td>
<td>3 A.C.</td>
</tr>
<tr>
<td>Musée des Docks</td>
<td>copper</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiumicino 1</td>
<td>iron</td>
<td>square</td>
<td></td>
<td>softwood</td>
<td>19</td>
<td>3–5 A.C.</td>
</tr>
<tr>
<td>Fiumicino 2</td>
<td>iron</td>
<td>square</td>
<td></td>
<td>softwood</td>
<td>17</td>
<td>3–5 A.C.</td>
</tr>
<tr>
<td>Yassi Ada*</td>
<td>iron</td>
<td></td>
<td>x</td>
<td>oak</td>
<td>20</td>
<td>4 A.C.</td>
</tr>
</tbody>
</table>

* Technique used only to fasten the wales to the frames; nails not always clenched.
Athlit Ram (204–167 B.C.E., L undetermined): bronze nails with heads 0.025–0.027 m in diameter and shafts of 0.01–0.013 m diameter were driven through plug treenails to fasten the wales to the ramming timber. Such fastenings are hypothesized to have bound frames to the planking as well (Steffy 1983: 238, 239, fig. 7; 1991: 21, 22–23, fig. 2–19, 25, fig. 2–21, 31, 35, fig. 2–26).

Grand Congloué (110–70 B.C.E., L ca. 23 m): the oak treenails joining the planks, half-frames, and chocks or floor timbers were pierced with copper nails clenchend once toward the keel on the molded surfaces of the chocks or floor timbers (see Grand Congloué entry in Chapter IV) (Benoît 1961: 135, pl. 23, 137, pl. 25:1, 2, 151, 189, 190, pl. 34:b, 191, figs. 102, 103).

Pozzino (late second or early first century B.C.E., L undetermined): at least the futtocks are fastened to the planking with treenails pierced by copper nails, which were driven from outside and clenchend on the interior futtock surfaces (Riccardi 1990).

Albenga (early first century B.C.E., L ca. 35–40 m): copper nails with heads 0.02 m in diameter were driven into treenails of “softwood” 0.014 m in diameter (Lamboglia 1953: 203–4, 206, fig. 59, 207).

Antikythera (early first century B.C.E., L ca. 30 m): bronze nails with head diameters of 0.03–0.035 m and shaft diameters of ca. 0.015–0.02 m apparently were driven into the treenails (Throckmorton 1965: 41, 45, fig. 15).

Chrétienne A (early first century B.C.E., L ca. 24–32 m): copper nails were driven into treenails that bind some floor timbers and other frame components to the planking (Dumas 1964: 142, 143, fig. 22, 144, and photos 4, 28, 35). Frost (1963: 266, fig. 52) indicates the copper nails were clenched over the frame tops, but not that they were driven through treenails.

St. Jordi 1 (100–80 B.C.E., L undetermined): copper nails with heads 0.02 m in diameter and shafts 0.01 m square were driven through the pine treenails and clenched over the frame tops. Most were clenched toward the keel, six in the opposite direction (Colls 1987: 24, 29–31, 35, 36, fig. 13).

Planier 3 (50–25 B.C.E., L ca. 15–20 m): fir treenails were pierced with bronze nails clenched over the frame tops (Liou 1973: 588, fig. 21; Couvert 1978: 111, n. 3).

Titan (middle or late first century B.C.E., L ≤ 25 m): the inner layer of planks was fastened to the frames with copper nails driven through treenails (Tailliez 1961: 195, figs. 19, 20; Benoît 1961: 139, pl. 26; Throckmorton 1965: 44, fig. 11, 45, fig. 14).
*Tre Senghe A* (25 B.C.E., L ca. 20–24 m): nails alternating with plug-treenail fastenings were used to bind frames to the planking (Freschi 1982a: 93). Parker (1992a: 435) adds that the nails used independently of the plug-treenails do not emerge from the frames.

*Grand-Ribaud D* (last decade of the first century B.C.E., L ca. 18 m): one of three treenails in frame fragment B.2 is pierced by a nail square in section. In frame fragment B.3 one treenail contains the remnant of a square-shafted nail. A second treenail bears no such evidence (Rival, Hesnard, and Carre 1988: 108, 121, pl. 41).

*Lake Nemi* (mid-first century, L ca. 71 and 73 m): frames of the ships were fastened to the planks usually with two treenails per plank per frame. A treenail of oak was driven only partly into the frame. A second treenail of pine or fir penetrated the entire molded dimension of the frame and was pierced with a copper nail clenched twice on the top of the frame in a direction parallel to the keel (Ucelli 1950: 152, 153, fig. 153, 154, fig. 154; Throckmorton 1965: 45, fig. 13).

*Chiessi* (A.D. 60–85?, L undetermined): treenails were found with copper nails driven through them, but apparently they were not *in situ* in the timbers they fastened. That this was a large ship is suggested by the size of the amphora mound at the time of discovery: 25 x 12 m (Parker 1992a: 140). The references Parker cites differ in their dating of the wreck, but Parker submits that a Flavian date, presented here, fits all the evidence best. (Because it is not certain that a frame was affixed by these nail and plug-treenail fastenings, this wreck is not included in Table 5).

*Punta Scijo* (early third century, L ca. 30–35 m): fragments of the ship’s oak planking and possibly a frame were fastened with treenails pierced with large iron nails (Parker 1992a: 361). (Because it is not certain that a frame was affixed by the nail and plug-treenail fastenings, this wreck is not included in Table 5).

*Pommègues* (second half of third century, L undetermined): frames are joined to the planking by treenails and nails, but a single treenail pierced by a nail was also noticed during the excavations. The genus of wood used is unknown. Eleven samples of *chevilles* (generally wooden pegs, therefore possibly tenon pegs and/or treenails) are identified as being of cypress, olive, and *Pinus leucodermis* Antoine. There is no distinction made, however, between treenails and tenon pegs, nor of the distribution among the three woods identified (Gassend 1979:103, n. 1).

*Musée des Docks* (late third century, L ca. 20–25 m): copper nails with hammered conical heads about 0.02 m. in diameter pierce the fir treenails (Varoqueaux
1970: 34, fig. 7, 37).

*Fiumicino 1* (third to fifth centuries, L ca. 19 m): iron nails with shafts 0.009 m square were driven through treenails made of “softwood” to fasten frames to planks. Chestnut treenails not pierced by nails were also used (Testaguzza 1970: 130, 145).

*Fiumicino 2* (third to fifth centuries, L ca. 17 m): iron nails were driven through the “softwood” treenails of this vessel as well. Shafts were just over 0.01 m square (Testaguzza 1970: 132; Scrinari 1979: 48, fig. 22).

*Yassi Ada* (second half of fourth century, L ca. 20 m): slender iron nails passed through treenails of the live oak group to fasten wales to frames. The nails were driven from inside the hull and when they protruded beyond the wales, they were clenched over the outer wale face (van Doorninck 1976: 118, fig. 3, 126).

**Analysis**

Several observations can be made with respect to the dating of wrecks that display nails driven through their treenails, the sizes and types of ships upon which they are found, nail morphology, and the types of treenails the nails are driven through, for the purpose of fastening frames to planks (Table 5).

Plug-treenail fastenings were used on seagoing Greek and Roman ships of all sizes dating from the fifth or fourth century B.C.E. (Ma’agan Michael) into the third century A.C. (Musée des Docks). The Lake Nemi ships also display the technique, as do two Fiumicino river vessels dated to the third to fifth centuries A.C. Given the broad temporal context in which plug-treenail fastenings are found, no firm dating of wrecks can be achieved based only upon such a feature. That the technique most often occurs on wrecks dated to the first century B.C.E. must be balanced with the knowledge that a large number of excavated wrecks date to this period (see Parker 1990a: 336, fig. 1; 1992a: figs. 3, 4). Yet it does appear significant that the hull in the Musée des Docks and perhaps the Punta Scifo wreck are the only seagoing hulls fastened this way and dated after the first century A.C. This seems to suggest the fastening method passed out of use to a large extent during the first century A.C.

Only 5 to 7 of the 23 wrecks displaying such fastenings (25 if the Chiessi and Punta Scifo wrecks are included) are reconstructed to lengths of less than 20 m. Of 10 wrecks of pre-Byzantine seagoing ships believed to have been 30 m or more in length (counting Chrétienne A and St. Jordi 1 [see above, pp. 119, cf. Table 3]), the method of fastening frames to planking is known for those at Marsala, Albenga, Antikythera,
Chrétienne (A), St. Jordi (1), Giens, and Caesarea. All but the one at Giens display some evidence of the use of plug-treenail fastenings (cf. Tables 1, 5). These facts might hint at the greater demands made by larger ships on their major hull timber fastenings, or that such demands were believed by the ancient shipwrights to be at work.

Wood types used for treenails have been identified for 36 wrecks (cf. Table 2). Of 21 exhibiting hardwood treenails, on only 5 did they serve as plug-treenails. In contrast, 15 wrecks with softwood treenails are in evidence and in 9 and possibly 10 wrecks they were used as plug treenails. Softwoods for plug-treenails appear to have been the preferred wood type, regardless of the wood types being employed for frames and planks.

In plug-treenails, copper or bronze nails are most often found; iron is reported in only two and maybe three of the cataloged hulls dating before the third century A.C. Shafts of nails within plug-treenails are square in 9 of 14 instances. This is surprising, as it seems that round shafts would provide better equalization of the pressures exerted on the treenails and surrounding timbers. A preference for square shafts perhaps developed because they were easier to manufacture.

NAILS

In addition to the employment of treenails and plug-treenails with nails driven through them to fasten frames to planks, unassisted nails were also used, but this is extremely rare in documented wrecks. Head profiles range from flat to rounded, often taking the form of hammered, or truncated, cones; heads are usually round as viewed from above. Shafts are more often square than round, and sometimes they are found clenched over the frame tops. In the Greek and Roman periods copper and bronze were the preferred metals for primary ship fastenings. With the notable exception of the first century A.C., iron was fairly consistently, if infrequently, employed in the same capacity and for repair work.

Nails of copper or bronze often seem to be identified as such on the basis of observation only, as there is a notable dearth of published metallurgical analyses. The work that has been done, however, indicates that copper of exceptional purity was used during the Roman period. Less is known about bronze, partly because of
difficulties associated with analysis of its corrosion products (see, e.g., Frost 1981b: 120–25).

**Catalog of Metallurgical Analyses of Copper and Bronze Nails**

The following chronological catalog reviews the metallurgical analyses of copper and bronze nails from Greek and Roman ships.³

*Kyrenia* (late fourth century B.C.E.): the amount of copper in four nails and one tack from the ship ranges from 88.22 percent to 91 percent. Traces of other elements are present, but in no case is there more than 0.05 percent tin (Steffy 1985b: 84, n. 5).

*Marsala* (mid-third century B.C.E.): one bronze nail from the ship is 80 percent copper, 12.3 percent lead, 7.1 percent tin (±0.5 percent), 0.6 percent zinc. Of two tacks from the “Sister ship,” one consists of 80.9 percent copper, 10.7 percent lead, 9.4 percent tin, 0.3 percent zinc, and less than 0.05 percent arsenic (equalling 101.35 percent). The other tack is 73.6 percent copper, 17.3 percent lead, 7.3 percent tin, 0.4 percent zinc, and less than 0.05 percent arsenic (equalling 98.65 percent). One nail from the “Sister ship” is composed of 84.7 percent copper, 7.3 percent lead, 7.7 percent tin, 0.2 percent zinc, and traces of iron, arsenic, magnesium, nickel, and antimony (Frost 1981b: 122–23).

*Athlit Ram* (204–167 B.C.E.): an alloy of 90 percent copper and 10 percent tin was selected by the makers of the ram (Eisenberg 1991: 40–43, 44, fig. 3–3; cf. Steffy 1983: 234).

*Grand Congloué* (110–70 B.C.E.): some of the copper nails are as much as 98.5–99 percent pure, with traces of tin (0.01 percent), zinc (0.3–0.4 percent), and iron (0.2 percent). Others nails have similar traces of tin (0.02–0.03 percent) and iron (0.01 percent), along with silver (0.1 percent), antimony (0.03–0.07 percent), lead (0.03 percent), arsenic (0.02 percent), and other traces (Benoît 1961: 193).

*Albenga* (early first century B.C.E.): inconclusive analyses of the internal bronze of two nails from the wreck showed one nail to be 56.48 percent copper, 4.76 percent tin, 2.40 percent lead, 4.70 percent zinc, 1 percent iron, with traces of sulphur (equalling 69.34 percent). In the second nail the amount of copper was 47.50 percent, tin 8.50 percent, lead 2.88 percent, zinc 6.50 percent, iron 3 percent, again with traces of sulphur (equalling 68.38 percent) (Lamboglia 1953: 207).

*Chrétiennne A* (early first century B.C.E.): some copper nails from the wreck had no tin and merely traces of silver and iron (Benoît 1961: 193).
**Mahdia** (early first century B.C.E.): some copper nails from the wreck were found to have no tin content and just traces of iron and silver (Benoît 1961: 193).

**Palamós** (100–50 B.C.E.): some qualitative analyses of copper and bronze nails were done (Foerster Laures 1983c).

**Titan** (middle or late first century B.C.E.): the wreck yielded some copper nails with a tin content of 5 percent (Benoît 1961: 193).

**Lake Nemi** (mid-first century): the luxuriously furnished barges were fastened with nails made of copper over 99 percent pure. Analysis of a large nail revealed it was composed of 99.64 percent copper, 0.05 percent lead, 0.22 percent iron, and traces of tin, nickel, zinc, and manganese. A small nail was found to consist of 99.71 percent copper, 0.03 percent lead, 0.18 percent iron, and traces of the same materials found in the large nail. A sheathing tack was 99.60 percent copper, 0.06 percent lead, 0.25 percent iron, again with trace amounts of tin, nickel, zinc, and manganese (Ucelli 1950: 272).

**Musée des Docks** (late third century): the tin content in some nails was found to be 8.5 percent (Benoît 1961: 193).

**Synopsis of the Use of Copper, Bronze, and Iron Nails**

Writing in the second century, Athenaeus (5.207b) relates the use of copper spikes on the great *Syracusia* built for Hiero II (305–215 B.C.E.), and Vegetius (4.34), a late-fourth century military writer, recommends bronze nails because they resist corrosion better than do nails of iron. Julius Caesar (*De Bello Gallico* 3.13) describes the ships of the Veneti as built with iron fastenings, and Tacitus (*Annales* 3.47) noted that *camarae*, boats used by barbarians in Pontus, were fastened together without spikes of bronze or iron. Procopius of Caesarea (born ca. A.D. 500) mentions iron nails binding planks to the frames of the ship of Aeneas (*De Bello Gothico* 8.22.7–16). Gianfrotta (1991: 85–88) places the vessel much later than the (Archaic) time of Aeneas, and Basch (1985) argues it to be of Byzantine date.

The archaeological record bears out the example of the *Syracusia*, as the great majority of nails fastening frames to planking on Graeco-Roman ships before the late Roman period are reported to be copper. Bronze appears to have been used less frequently, and perhaps passed out of general use some time in the third century. A wreck of the Severan period near the harbor of Giglio displays frames fastened to planking with nails of *lega di rame*, copper alloy (Rendini 1991: 158).
The passage in Tacitus seems to have clear implications for the use of iron fastenings in Roman ships of his time (late first and early second centuries). Iron must have been in common use at least in the upper works and interiors of Greek and Roman ships of much earlier date, however, because they or their concretions are frequently discovered on sites dated long before the Roman Imperial period, whereas iron fastenings joining planking and frames is primarily a later Roman and Byzantine phenomenon (cf. Procopius above).

Another application of iron nails appears to be that of repairs. On the St. Jordi 1 wreck of the early first century B.C.E., all observed nails binding frames to planks are copper, save four iron ones on a single frame. These are believed to be associated with hull repairs (Colls 1987: 35). A patched area of the hull below the waterline of the Torre Sgarrata ship (late second century) was secured with wrought iron nails, whereas the nails originally used to build the hull are copper (Throckmorton 1969: 300; 1989: 264–65). Carpenters aboard Graeco-Roman ships surely stocked iron as well as copper and bronze nails.

Five and possibly eight wrecks of seagoing ships dated prior to the later Roman period exhibit iron nails joining frames to planking. The Ma'agan Michael vessel of ca. 400 B.C.E. has its frames affixed to the planks with iron nails driven through trenails and clamped twice on the frame tops, toward the keel (Linder 1989: 6; 1992: 26, 33, 34, Rosloff 1990: 4 and personal communication; Kahanov 1991: 6). The wreck at La Secca di Capistello, of the late fourth or early third century B.C.E., yielded three iron nails, one of which is clenched twice and is of a length sufficient to have joined frames to planks. It was not found in situ, however (Frey, Hentschel, and Keith 1978: 295, fig. 19). In 1973 the Punic ship at Marsala, dated tentatively to the middle of the third century B.C.E., was reported to display iron nails driven through oak trenails and clenched over the tops of the floor timbers (Frost 1973b: 36, fig. 4, 45, fig. 13). In the final publication such nails are said to be bronze (Frost 1981b: opposite p. 32, fig. 9, 120, 122, fig. 58:1, 126). Frames are fastened to the planking of the Jeanne-Garde B wreck with trenails pierced by iron nails clenched once toward the keel. The wreck is dated to the late third or early second century B.C.E. (Carrazé 1976a: 163; 1977: 302, fig. 6). Wreck 1 at Apollonia, of the mid-second to early first century B.C.E., also has frames bound to the planks with iron nails clenched atop the frames (Long 1992: 74). On the Dramont A wreck (first half of the first century B.C.E.), the frames are fastened to the garboard and second strake only with iron nails.
Further, the false stempost of the ship was joined to the stempost with iron nails and bolts (Liou and Pomey 1985: 569, fig. 21, 572). The bottom and sides of the Grand-Ribaud D hull, dated ca. 10–1 B.C.E., were fastened with iron nails (Parker 1992a: 203).


**Clipped Nails**

The practice of clenching nails over the tops of frames is found in earlier Graeco-Roman ships (Table 5). With the exception of the Lake Nemi barges, the practice seems confined generally to wrecks before the middle of the first century B.C.E.

*Porticello* (415–385 B.C.E.): some of the square copper nails found on the site are clenched either once or twice, but none were discovered within planking or frames (Eiseman 1979: 25–27, 29, 54, fig. 2.13, 56, fig. 2.15, 57, fig. 2.16; Eiseman and Ridgeway 1987: 11, 13, 14, fig. 2.6, 15, fig. 2.7).

*Ma'agan Michael* (ca. 400 B.C.E.): frames are affixed to planks with iron nails 0.005 m square. They are driven through treenails (species not yet identified) and clenched twice on the frame tops, toward the keel (Linder 1989: 6; 1992: 26, 33, 34; Rosloff 1990: 4 and personal communication; Kahanov 1991: 6).

*Kyrenia* (late fourth century B.C.E.): round copper nails driven through pine treenails were clenched twice toward the keel (Steffy 1985b: 84, and pl. 21, fig. 3).

*Capitello* (late fourth or early third century B.C.E.): copper nails were reported to be clenched on the frame tops. One iron nail found loose on the site is double-clenched and the length of the straight portion of the shaft matches the combined measured thicknesses of the planking and frames (Frey, Hentschel, and Keith 1978, 293, 295, fig. 19).

*Marsala* (mid-third century B.C.E.): in 1973 iron nails were reported to be driven through oak treenails and clenched over the tops of the floor timbers (Frost 1973b: 36, fig. 4, 37, fig. 5). In the final publication such nails are reported to be bronze. One
bronze nail found loose on the site has its double-clenched shape preserved (Frost 1981b: opposite p. 32, fig. 9; 120, 122, fig. 58:1). In any case the nails were clenched.

Jeanne-Garde B (late third or early second century B.C.E.): iron nails driven through the oak treenails were clenched once toward the keel (Carrazé 1976a: 163; 1977: 302, fig. 6).

Apollonia I (mid-second to early first century B.C.E.): clenched iron nails fasten frames to planks. The hull remains are almost devoid of treenails serving this purpose (Long 1992: 74).

Grand Congloué (110–70 B.C.E.): the copper nails within the oak treenails joining the planking, half-frames, and chocks or floor timbers were clenched once toward the keel on the molded surfaces of the chocks or floor timbers (see Grand Congloué entry in Chapter IV) (Benoît 1961: 135, pl. 23, 137, pl. 25:1, 2, 151).

Pozzino (late second or early first century B.C.E.): copper nails are driven through treenails binding futtocks to planks and clenched on the inner futtock surfaces (Riccardi 1990).

Chrétiennne A (early first century B.C.E.): Frost (1963: 266, fig. 52) reports the nails binding frames to planking are clenched. Dumas does not mention this detail, but his photos show nails are indeed clenched on the frame tops in at least one instance (Dumas 1964: photo 28—the upper frame—and perhaps photo 32).

St. Jordi 1 (100–80 B.C.E.): square copper nails are driven through pine treenails and the great majority are clenched, all but six toward the keel; the others toward the turn of the bilge. Some appear to be clenched twice, most only once, and some take the form of an arc above the frame tops (Colls 1987: 24, 29–31, 35, 36, fig. 13).

Planier 3 (50–25 B.C.E., L ca. 15–20 m): fir treenails were pierced with bronze nails clenched over the frame tops (Liou 1973: 588, fig. 21; Couvert 1978: 111, n. 3).

Lake Nemi (mid-first century): the square copper nails driven through the pine and fir treenails were clenched twice in a direction parallel to the keel (Ucelli 1950: 152, 153, fig. 153, 154, fig. 154).

**Observations**

Table 6 summarizes the primary characteristics of nails found on major Mediterranean sites. It suggests the employment of bronze nails below the waterline peaked in the first centuries B.C.E. and A.C., though again, this might be due to the greater number of published sites dated to the period (Parker 1990a: 336, fig. 1; 1992a:...
<table>
<thead>
<tr>
<th>Site</th>
<th>Metal</th>
<th>Head Shape</th>
<th>Shaft Shape</th>
<th>Clenched</th>
<th>Date (Century)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porticello</td>
<td>copper</td>
<td>rounded</td>
<td>square</td>
<td>x</td>
<td>5–4 B.C.E.</td>
</tr>
<tr>
<td>Ma'agan Michael</td>
<td>iron</td>
<td></td>
<td>square</td>
<td>x</td>
<td>5/4 B.C.E.</td>
</tr>
<tr>
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<td>copper</td>
<td>rounded</td>
<td>round</td>
<td>x</td>
<td>4 B.C.E.</td>
</tr>
<tr>
<td>Capistello</td>
<td>copper</td>
<td></td>
<td></td>
<td>x</td>
<td>4/3 B.C.E.</td>
</tr>
<tr>
<td></td>
<td>iron</td>
<td>flattened</td>
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<tr>
<td>Donuzlav</td>
<td>bronze</td>
<td>rounded</td>
<td>round</td>
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<td>4/3 B.C.E.</td>
</tr>
<tr>
<td>Marsala</td>
<td>bronze</td>
<td>hmrd. cncl.</td>
<td>square</td>
<td>x</td>
<td>3 B.C.E</td>
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<td></td>
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<tr>
<td>Jeaune-Garde B</td>
<td>iron</td>
<td>rounded</td>
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<td>x</td>
<td>3/2 B.C.E.</td>
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<tr>
<td>Apollonia 1</td>
<td>iron</td>
<td></td>
<td></td>
<td>x</td>
<td>2–1 B.C.E.</td>
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<tr>
<td>Gr. Congloué</td>
<td>copper</td>
<td>rounded</td>
<td>round</td>
<td>x</td>
<td>2/1 B.C.E.</td>
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<td></td>
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<td>flattened</td>
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<tr>
<td>Pozzino</td>
<td>copper</td>
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<td>2/1 B.C.E.</td>
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<tr>
<td>Albenga</td>
<td>copper</td>
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<td>x</td>
<td>1 B.C.E.</td>
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<tr>
<td>Antikythera</td>
<td>bronze</td>
<td>rounded</td>
<td>round</td>
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<td>1 B.C.E.</td>
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<tr>
<td>Chrétienne A</td>
<td>copper</td>
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<td>x</td>
<td>1 B.C.E.</td>
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<td>Mahdia</td>
<td>copper</td>
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<td>1 B.C.E.</td>
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<tr>
<td>St. Jordi 1</td>
<td>copper</td>
<td>hmrd. cncl.</td>
<td>square</td>
<td>x</td>
<td>1 B.C.E.</td>
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<td></td>
<td>iron repair</td>
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<td>Dramont A</td>
<td>copper</td>
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<td>1 B.C.E.</td>
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<td>Sa Nau Perduda</td>
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<td>square</td>
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<td>1 B.C.E.</td>
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<td>Palamós</td>
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<td>rounded</td>
<td>square</td>
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<td>bronze</td>
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<tr>
<td>Titan</td>
<td>copper</td>
<td>rounded</td>
<td>round</td>
<td>x</td>
<td>1 B.C.E.</td>
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<td>Planier 3</td>
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<td>1 B.C.E.</td>
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<tr>
<td>Grand-Ribaud D</td>
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<td></td>
<td>square</td>
<td></td>
<td>1 B.C.E.</td>
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<tr>
<td>Cap del Vol</td>
<td>iron</td>
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<td>1 B.C.E.</td>
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<td>Site</td>
<td>Metal</td>
<td>Head Shape</td>
<td>Shaft Shape</td>
<td>Clenched</td>
<td>Date (Century)</td>
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<tr>
<td>Kinneret</td>
<td>iron</td>
<td>flat</td>
<td>round</td>
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<td>1 B.C.E.–1 A.C.</td>
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<tr>
<td>Caesarea</td>
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<td>rounded</td>
<td>square</td>
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<td>1 A.C.</td>
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<td>copper</td>
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<td>octagonal</td>
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<td>Giglio Harbor</td>
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<td>round</td>
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<td>1–3 A.C.</td>
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<tr>
<td>Mateille B</td>
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<td></td>
<td>square</td>
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<td>1 A.C.</td>
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<tr>
<td>Diano Marina</td>
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<td>rounded</td>
<td>square</td>
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<td>1 A.C.</td>
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<tr>
<td>Dramont D</td>
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<td>flattened</td>
<td>square</td>
<td></td>
<td>1 A.C.</td>
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<tr>
<td></td>
<td>bronze</td>
<td>various</td>
<td>square</td>
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<td>Lake Nemi 1, 2</td>
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<td>hmrds. cncl.</td>
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<td>x</td>
<td>1 A.C.</td>
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<td></td>
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<td>flattened</td>
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<tr>
<td>Herculanium</td>
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<td>square</td>
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<td>1 A.C.</td>
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<tr>
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<td>2 A.C.</td>
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<tr>
<td>Laurone 2</td>
<td>copper or</td>
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<td>2 A.C.</td>
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<td></td>
<td>bronze</td>
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<tr>
<td>Torre Sgarrata</td>
<td>copper</td>
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<td>square</td>
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<td>2 A.C.</td>
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<td></td>
<td>iron repair</td>
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<tr>
<td>Marzamemi 1</td>
<td>copper</td>
<td>rounded</td>
<td>square</td>
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<td>3 A.C.</td>
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<tr>
<td>Musée des Docks</td>
<td>copper</td>
<td>hmrds. cncl.</td>
<td>square</td>
<td></td>
<td>3 A.C.</td>
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<tr>
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<td>square</td>
<td></td>
<td>3–5 A.C.</td>
</tr>
<tr>
<td>Fiumicino 2</td>
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<td></td>
<td>square</td>
<td></td>
<td>3–5 A.C.</td>
</tr>
<tr>
<td>P. de la Luque B</td>
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<td></td>
<td></td>
<td></td>
<td>3/4 A.C.</td>
</tr>
<tr>
<td>Grand-Bassin D</td>
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<td>hmrds. cncl.</td>
<td>square</td>
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<td>4 A.C.</td>
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<tr>
<td>Lazzaretto</td>
<td>hmrds. cncl.</td>
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<td>Yassi Ada</td>
<td>iron</td>
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<td>4 A.C.</td>
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</table>
The alloy appears rarely before and after this time. On seagoing ships, nails of copper are those found most often, from the fifth or fourth century B.C.E. into the fourth century A.C. Iron nails as primary fastenings on seagoing Mediterranean ships appear rather early (ca. 400 B.C.E.), and are fairly consistently in evidence through the first century B.C.E. They are associated with hull repairs (Torre Sgarrata) or river vessels (Fiumicino) after that time, until the later fourth century. Thereafter they were utilized more and more frequently.

In the table, copper and bronze nails with square shafts are found over twice as often as those with round ones through the first century A.C. (13 vs. 6), after which only square shafts are in evidence. Iron nails display only square shafts. Ease and economy of manufacture may be one explanation for this eventual prevalence. Rounded and flattened heads are found in all periods, the former being more common. Hammered conical heads in this body of data appear for the first time in the mid-third century B.C.E. and thereafter occur only occasionally. It is interesting to note that hammered conical heads are found only on nails with square shafts.

Clenched nails, whether associated with plug-treenails or not, are not in evidence on seagoing Graeco-Roman Mediterranean ships after the mid-first century B.C.E.

BOLTS AND WASHERS

Bolts of either the peined or forelock type seem to have been unknown in ancient Mediterranean hull construction before the Roman period. They most commonly fastened floor timbers and sometimes mast steps or keelsons to the keel. The wreck at Punta Ala (A.D. 250?) and Wreck 3 at Laurons (third century), however, display frames fastened to planking and stringers, or just to planking, with iron bolts or with clenched iron nails that evidently served as rivets or bolts.

The primary function of at least six fastenings on the Caesarea hull that might be bolts is unknown, but it was not (at least exclusively) to fasten frames to the planking. The most ready explanation, whether as bolts or just nails, is that they secured stringers to the planking and frames. If this is indeed the case, it constitutes one of the most important aspects of the Caesarea hull: extraordinary measures were taken to maximize longitudinal integrity. This method of fastening together planks, frames, and stringers would be only the second known example among Graeco-Roman
Mediterranean wrecks, and the earliest by perhaps 150–200 years, if the dating of the Punta Ala wreck is in fact near A.D. 250, and if the date of the Caesarea hull is valid (see Chapter XIV).

To gain better insight into this feature of the Caesarea hull, and into the employment of bolts (and some large nails) to fasten keels to other structural timbers, the following chronological catalog reviews the evidence from Roman and Byzantine wrecks through the fifth century.

_Athlit Ram_ (204–167 B.C.E., L undetermined): 12 bronze bolts fastened the rarn to the timbers within it. One surviving bolt exhibits a shaft 0.015 m in diameter, with a head of 0.025 m diameter that is rounded and 0.012 m thick at its center (Steffy 1983: 232, fig. 2, 233, fig. 3, 235; 1991: 12–13, and figs. 2–7, 2–9).

_Sparagi_ (ca. 120–100 B.C.E., L 30–35 m): portions of seven floor timbers display evidence that their bottom surfaces were worked in order to permit good contact with the keel. They exhibit the remains of nails or bolts about 0.60 m long—of unspecified metal—that had affixed them to the keel and to the _paramezzale_ (keelson), according to Pallarés. As noted in Chapter VI, note 2, no keelson is yet in evidence on this site, but perhaps these fastenings were associated with some element of the mast step assembly. They display _ribattitura all’esterno_ (Pallarés 1983b: 10, 12, 38; 1983f: 222). If this phrase is translated as “external rivetting” or “rivetting at/to/on the outside,” the meaning is ambiguous. Outside would seem to denote that the bottom surface of the keel was where the rivet plate or washer was located. But on the upper (hence interior) surface of one of the floor timber fragments, there appears to be a rectangular object that might be a metal plate over which the fastening could be peined. This would mean the bolts had been driven up through the keel, as was apparently the normal practice (see below). This may not be the case, however, judging from the wreck plans (Pallarés 1983f: 223, fig. 1; 1986b: 92, fig. 5). Between about two and four meters southwest of the southernmost floor timber remnant still attached to the keel are what appear to be two other central portions of floor timbers, each resting on one of their molded surfaces. On what was the upper surface of the southwest-most floor timber is drawn a rounded object that appears to be the head of a nail or bolt, which therefore would have been driven downward through the keel.

In any case, this wreck appears to constitute the earliest evidence from published Graeco-Roman hulls of floor timbers firmly fastened to the keel (see Chapters XVI and XVII).
Dramont A (first half of first century B.C.E., L ca. 25 m): the outer (false) sternpost was fastened to the sternpost with iron bolts ca. 0.025 m in diameter (Liou and Pomey 1985: 569, fig. 21, 572).

Capo Testa (75–50 B.C.E., L undetermined): a large bronze nail with a hammered conical head protrudes some 0.38–0.40 m above the seabed. It is taken to indicate the position of the keel, which is still buried, and to suggest the fastening of the keel to a paramezzale centrale (central longitudinal timber). Frames are not mentioned (Gandolfi 1983: 45–46; 1985: 315; 1986a: 84–85; Parker 1992a: 125–26).

La Madrague de Giens (60–40 B.C.E., L ca. 38 m): bolts probably of bronze fasten floor timbers of oak to the keel at frames 90, 94, 98, 104, 110, 114, 120, 128, and 134. Thus the interval of occurrence is 4-4-6-6-4-6-8-6. The forward-most bolt (at frame 134) is placed at the forward extremity of the mast step and marks the commencement of the rise of the keel to the sternpost. This fastening pierces the keel scarf and the small timber that overlies it. Bolts are ca. 0.03 m in diameter and washers over which they are peined on the frame tops measure 0.05–0.06 m on a side and ca. 0.01 m thick. The metal from which the washers were made is not specified (Pomey 1978a: 77, fig. 10, 82–83; 1982: 143, fig. 7; Liou and Pomey 1985: 564, fig. 15, 565; Rival 1991: 203).

Porto Badisco (60–40 B.C.E., L undetermined): only the keel of the hull has survived, protected by amphoras, mill stones, and anchors. At least one floor timber was fastened to the keel with a metal “rivet,” but no detailed drawings have been published (Parker 1992a: 335).

L’isola di Mal di Ventre (mid-first century B.C.E., L ca. 36 m): 11 iron nails stand vertically on the seabed, preserved to a height of ca. 0.40 m (loss from oxidation and concretion aside) and disposed longitudinally along the wreck at fairly regular intervals. It is merely suggested that they could constitute a means of reinforcement between the keel and the paramezzale (keelson), because the keel has yet to be exposed and neither keelson nor frames are described (Salvi 1991: 150, 152). What Salvi proposes to be a keelson might well have been a component of the mast step assembly. In any case, if these fastenings were used in such a capacity, they performed a task reserved for bolts in almost all other known Graeco-Roman vessels. They are included here for this reason.

Fos 1 (50–25 B.C.E., L undetermined): toward the stem, two floor timbers are bolted to the keel (Pomey et al. 1988: 11–12).
Terrasini (first century, L undetermined): a copper bolt 0.018 m in diameter and 0.20 m in preserved length was found within a wood fragment of unknown function (Giustolisi 1975: 31, and pl. 15).

St.-Gervais 3 (mid-first century, L ca. 17 m): three floor timbers are fastened to the keel. A copper or bronze bolt passes through each of the two “Thunderbolt of Jupiter” keel scarfs. A third was installed at the sixth frame aft of the keel/sternpost scarf, for reasons unknown. Measurements taken from the drawings indicate bolt shaft diameters of ca. 0.013–0.014 m and head diameters of ca. 0.06 m. The extremities are peined on washers ca. 0.04 m square atop the frames (Pomey et. al. 1988: 13; Liou and Gassend 1991: 223, fig. 85, 229, 230, fig. 89, 233, fig. 94, 235, fig. 97).

Tiboulen de Maïre 1 (first to second century, L undetermined): a copper broche d’assemblage (assembly bolt) has been discovered on the site (Pomey et al. 1988: 15).

Grand-Bassin C (A.D. 120, L undetermined): two floor timbers reveal evidence of bronze bolts. Part of a bolt and the square washer over which it was peined on the frame top were found in one timber. In the second timber remnants of a bolt were merely evident (Chevalier 1982: 86, 87, fig. 36:1, 2; Parker 1992a: 199). The dating of these timbers is suspect, however, because the lamps and mortaria fragments, which suggest a date of about A.D. 130, were found some 200 m from the hull remains. Parker states, evidently erroneously, that the bolt is of copper.

Cap Taormina (Hadrianic or late second century? L undetermined): found loose on the site was a copper bolt 0.71 m long and 0.023–0.026 m in diameter. It is peined at the end opposite the head and a plate over which the peining could have been done is still on the bolt. The plate is 0.01 m thick and 0.085 m square. Clearly, this assembly could have fastened major hull timbers (Kapitan 1961: 306, 308, 309, fig. 4; van Doorninck 1972: 138).

Laurons 2 (late second century, L ca. 15 m): all four preserved scarfs in the spine of the ship exhibit nails (of an unspecified metal) driven up through them and the frames above; they are clenched twice on the frame tops (Gassend, Liou, and Ximénes 1985: 91, 92, fig. 17a, 93, fig. 17b, 95, fig. 17d, opposite p. 96, fig. 19). The function of these nails seems clearly related to securing the scarfs in the keel components and posts and to the fastening of floor timbers to the keel—an assignment given to bolts in almost all other known Graeco-Roman vessels. They are therefore included here.
**Bourse** (late second or early third century, L ca. 23 m): eight copper bolts, one about every eighth to tenth frame, extend through the keel and floor timbers 109, 119, 127, 135, 143, 155, 163 and 170. Those at frames 109 and 155 secure the scarfs joining the keel to the stem and sternpost, respectively. The bolts are 0.02 m in diameter with rounded heads of 0.05 m diameter. On the frame tops they were peined over plates or washers 0.05 m square and 0.02 m thick (Gassend 1975; 1982: 80–81; Gassend and Cuomo 1985: 345, 348–49, fig. 8).

**Monaco** (late second or early third century, L ca. 12–15 m): a single floor timber is fastened to the keel with a large copper bolt approximately 0.027 m in diameter, with a head diameter of about 0.055 m. The washer over which it apparently was peined on the frame top measures roughly 0.05 m square and 0.02 m thick. This is probably the only instance of a frame bolted to the keel of this ship, and it might have passed through a keel scarf (Benoît 1961: 146, fig. 79:7; Mouchot 1970a: 181, 201, pl. 15; Mouchot 1978: 80).

**Punta Ala** (A.D. 250 ?, L. ca. 25 m): stringers, frames, and planking were fastened with square iron “rivets” driven from the outside, where the heads were apparently sealed with tallow. The rivets were clenched on the inside and sealed with lead (Parker 1992a: 345). From Parker’s summary it is unclear if only the stringers and frames and planks were fastened with bolts, or if only frames and planks were bound in this way elsewhere on the hull. Use of the term “rivet” by Parker and of “bolt” in another reference to this wreck (Parker 1992a: 25) implies that washers were involved, unlike the term “clenched.” The fact that no washers are mentioned by Parker suggests he is repeating the terms used by the authors of the reports he summarizes. These terms are the basis for inclusion in this section on bolts and not that on clenched nails above.

**Pointe de la Luque B** (late third or early fourth century, L ca. 20 m): four bolts of iron ca. 0.025 m in diameter pierce the keel and one post of the wreck. Two are definitely forelock bolts, one of which extends through the keel/post scarf, floor timber 24, and a separate timber of uncertain nature resting on top of the frames. Its washer and key are intact; the washer is made of cast lead. Another bolt with its key and washer (0.06 m outer diameter) fastens floor timber 8 to the keel, and a third binds the mast step to the keel and to floor timber 14, though how it was secured is unknown. Evidence for the fourth bolt remains only within the post (Clerc and Negrel 1973: 63, fig. 1, 66, 68; Negrel 1973: 61, fig. 5, 62, 63, 65; Liou 1975: 578, 580, fig. 10, 581,
fig. 11; Gianfrotta and Pomey 1981: 248). Clerc and Negrel (1973: 66) report that the stringers supporting the mast step are rivetted (therefore peined?) to the frames, but this is not mentioned by Liou (1975), and so seems curious, given the later date of Liou’s report. If true, it would constitute the only example of the practice, to my knowledge.

_Laurons 3_ (third century, L undetermined): three floor timbers apparently were bolted to the planking (Ximénes and Moerman 1987: 176).

_Dramont F_ (middle or late fourth century, L ca. 10–12 m): iron nails or bolts 0.01–0.015 m in diameter extend through the keel and some floor timber. The excavator suggests they may also have fastened a keelson to the frames and keel, even though no evidence for a keelson exists (Joncheray 1975c: 122, 125, 126; 1977: 4, fig. 2, 6). The iron nails used to affix the ceiling planking extend through the frames and hull planking. When their tips protrude, they are clenched (Parker 1992a: 169).

_Yassi Ada_ (second half of fourth century, L ca. 20 m): floor timbers A-5, B-4, B-11, and B-17 were bolted to the keel and floor timbers B-23, B-27, and B-29 were bolted to the sternpost. These bolts of iron had heads 0.037–0.045 m in diameter and shafts 0.02–0.026 m in diameter. How they were secured on the frame tops is uncertain, though one recovered shaft end had a slot in it, suggesting these were forelock bolts. No bolt fastened the scarf joining the keel and sternpost, but one might have bound the ends of Wale 3 to the sternpost (van Doorninck 1976: 118, fig. 4, 120, 121, 124; Gianfrotta and Pomey 1981: 238, fig. b).

_Port-Vendres 1_ (late fourth or early fifth century, L ca. >20 m): iron forelock bolts ca. 0.02 m in diameter fastened floor timbers 2 and 8 to the stem and keel, thus bracketing the stem/keel scarf, and also fixed floor timber 22 to the keel. In the stem as well, the keel/sternpost scarf was bracketed by bolts that bound _le massif_ to the spine through floor timbers 40 and 44. Another bolt extended diagonally up through the keel from the position of frame 41 and emerged at the upper surface of the sternpost between floor timbers 42 and 43. At the aft extremity of the preserved sternpost another bolt is in evidence, but the absence of associated timbers above it renders its function unknown (Liou 1974: 416, fig. 2, 417, 419–20, 421, fig. 6, 424, fig. 8; Rival 1991: 268, 270, pl. 92, 272, pl. 94).

_Fiumicino 1_ (third to fifth centuries, L ca. 19 m): almost every floor timber is fixed to the keel with _perni di ferro_ (iron pins) 0.018 m in diameter. One passes through the keel/stem scarf into the frame above it (Testaguzza 1970: 130, 136, 145).
The word for pin is used for these round fastenings; presumably they would be termed nails if their shafts were square or rectangular. This suggests they are bolts whose upper extremities have disappeared, which prevents ascertainment of how they were secured on the frame tops. It is of course possible that they are the remnants of large nails with round shafts but this seems unlikely.

EVALUATION OF THE CAESAREA FASTENINGS AND GENERAL PATTERNS OF USE

If the Caesarea fastenings that may have been associated with the joining of stringers to the frames and planks were in fact bolts (and they may have been nails, in view of their taper), their diameters of ca. 0.0175 m at the head and 0.012 m at the opposite end would make them among the smallest bolts discovered so far on Roman and early Byzantine ships. Those in the Dramont F wreck, a vessel originally some 10–12 m long, had diameters of 0.01–0.015 m, while those within the keel and frames of the St.-Gervais 3 ship, reconstructed to about 17 m in length, are no larger, measuring 0.013–0.014 m in diameter. Most other bolts range in diameter from 0.018 m to 0.028 m, while those at La Madrague de Giens are the largest: 0.03 m. The small size of the Caesarea fastenings along the inboard edge of the hull make it unlikely that they bound the keel to floor timbers and/or a central longitudinal timber—the primary function of bolts on almost all Roman wrecks.

Bolts employed in other capacities in Roman and early Byzantine hulls are quite scarce. Their presence on Wreck 3 at Laurons and on the wreck at Punta Ala is the only evidence suggesting usage to bind frames to planking. Iron bolts fasten the outer sternpost to the sternpost of the Dramont A wreck. The fourth-century wreck at Yassi Ada displays an iron bolt that probably fastened one pair of wales to the sternpost. On the Pointe de la Luque B wreck are two bolts that bind the mast step to the frames and keel (and bolts may possibly fasten the mast step stringers to frames). The utilization of bolts on the Punta Ala and Pointe de la Luque B hulls most closely approximates what is proposed for the Caesarea nails or bolts: planks, frames, and stringers all bound together with a single fastening.

The Caesarea washers, whose inner diameters match perfectly the diameters of the nails or bolts at their upper extremities, are thin (0.0045–0.009 m) compared to the
few washers found on other wrecks. The square and rectangular plates over which bolts were peined on the wrecks at Giens and Monaco and the square plate on the bolt from Cap Taormina are ca. 0.01–0.02 m thick. I have found no information about the cast lead washer found on the Pointe de la Luque B wreck. The Caesarea washers could have served equally well with peined or forelock bolts, but they exhibit no signs of wear indicative of use beneath a forelock key. Lastly, Steffy points out (personal communication 1989) that the upper extremities of the nails or bolts, with such diminutive diameters, do not seem large enough to accommodate safely a forelock key. Therefore, if the washers were used with bolts, it is more likely the bolts were of the peined type.

Another consideration regarding the identification and function of the Caesarea fastenings is the fact that they are driven from outside the hull. Normally, when timbers of differing thickness are to be bound together, the fastening passes first through the thinner component and then into the thicker one. For this reason it might be expected that the Caesarea stringers were fastened from above, i.e. from the inside, as is most commonly found on Graeco-Roman ships. On the other hand, all bolts in the wrecks of the Roman and early Byzantine periods cataloged here, except perhaps at Spargi, were driven from the outside. This cannot confirm that the Caesarea fastenings are either nails or bolts, but the preference for installing bolts from below is clear.

The Caesarea fastenings were probably capable of binding together adequately planks, frames, and stringers. If this was indeed their function, this is only the second example of the common fastening of such hull members in Graeco-Roman ships. The use of copper or bronze suggests a date for the ship’s construction prior to the late second century.

With respect to the general employment of bolts in Roman and Byzantine Mediterranean ships, the incidence of copper, bronze, and iron appears to echo the basic trend toward iron for metal fastenings during the late Roman and Byzantine periods. Bronze is reported only at Capo Testa (probably 75–50 B.C.E.), Giens (60–40 B.C.E.), perhaps St.-Gervais (3) (mid-first century), and at Grand-Bassin (C) (A.D. 120). The wrecks at Cap Taormina, Monaco, and Bourse all date to the second century or early in the third, and represent the latest use of copper bolts. The wreck at Spargi (ca. 120–100 B.C.E.) may exhibit the earliest employment of iron bolts, followed by Wreck A at Cap Dramont (first half of first century B.C.E.).
The earliest bolts in Graeco-Roman ships cataloged here occur in the hull remains at Cap Dramont (A), at Giens, and possibly at Spargi. At Giens and probably at Spargi they are peined; the nature of those at Dramont is unknown. The forelock design is unattested until the late third or early fourth century, on the Pointe de la Luque B wreck, and then appears on the later fourth and the late-fourth or early-fifth century wrecks at Yassi Ada and Port-Vendres. If the mechanical demands of the forelock slot-and-key-upon-washer arrangement taxed the capabilities of a relatively soft metal like copper or even bronze, perhaps the appearance of this type of bolt in ships is at least partly related to iron’s greater strength and hardness.8

The benefits to hull integrity of fastenings passing through the scarfs in the keel and posts appear to have been widely appreciated at least by the third century. Bolts piercing floor timbers or other members pass through scarfs joining keel components or keels and posts on wrecks at St.-Gervais (3), Bourse, Monaco, Pointe de la Luque (B), and Fiumicino (1). In at least three instances on the Laurons 2 wreck, clenched nails were used for this purpose (Gassend, Liou, and Ximénès 1985: opposite p. 96, fig. 19). Moreover, the keel scarf in the Monaco vessel was secured with three treenails (Mouchot 1970a: 181, 201, pl. 15). The undated Golo wreck displayed a keel scarf fastened with two square treenails (Basch 1973: 331, fig. 2). The seventh-century wreck at Yassi Ada exhibits a bolt passing through the keel/stempost hook scarf (van Doorninck 1982: 38, fig. 3-11, 50, fig. 3-26, 58, 58, figs. 3-33, 3-34) and this might also be true of the contemporaneous St.-Gervais 2 wreck. In fact it is striking that, of the wrecks cataloged above that display bolts (or clenched nails) associated with scarfs in the spine of the hull, in all but one wreck the fastenings pass through the scarfs.

Wreck 1 at Port-Vendres is the exception. The keel/post scarfs are instead bracketed by an iron bolt through frames fore and aft. Rival (1991: 268) proposes that in the bow of this ship, two frames instead of the usual one were bolted to the spine to combat better the battering of the waves on this inherently weaker region of the hull. Thus it does seem clear that the additional strength gained by affixing framing members to a ship’s spine was the essential concept, and that the Port-Vendres configuration may be indicative of new approaches to keel/post assembly techniques.

It appears significant that both primary applications of bolts in the keels of Graeco-Roman ships, i.e., fastening frames to the keel and strengthening keel or keel/post scarfs, occurred first in large ships: those that wrecked at Giens and
probably Spargi (see Chapters XVI and XVII). Finally, bolts may have helped maximize the benefits of the Caesarea ship's heavy framing to its longitudinal strength by fastening stringers to frames and planks.
Notes

1. In the hull at Diano Marina they were also used to fasten ceiling planks to the frames (Pallarés 1991: 172). This would seem to have been a most sensible method of securing ceiling, but in fact it is rare on Graeco-Roman ships.

2. As noted on pp. 122–23 above, early drawings of the Dramont A hull show only plug-teenails pierced with nails joining frames to planking (Benoit 1961: 143, pl. 28:1; Throckmorton 1972: 68, fig. 1). These among other construction details are wrong, according to Santamaria (1975: 191–94).

3. While not pertinent to Greek and Roman copper processing, nor to the use of copper fastenings on such ships, it is interesting to note the copper of high purity found on the Royal Ship of Cheops (ca. 2500 B.C.E.). Staples used in this funerary barge are 94.5 percent copper, 1.4 percent arsenic, 0.8 percent iron, while zinc and oxygen make up the remaining 3.3 percent (Nour et al. 1960: 49–54).


5. Nails in the third-century wreck at County Hall in London are iron (Marsden 1974: 57, 59–60). Although this ship was built in mortise-and-tenon Mediterranean fashion, the presence of iron nails might reflect local practice or tradition rather than a move from copper-based to iron fastenings.

6. Coastal/river vessels 1 and 2 at Fiumicino (third to fifth centuries) were also built with iron fastenings (Testaguzza 1970: 130–31, 145).

7. Bronze nails large enough to be associated with the fastening of frames to planking have been discovered out of context at Laurons on Wrecks 1 (third to fourth century), 3 (third century), and 4. On Wreck 4, tentatively dated to early in the fourth century, a bronze nail was also found driven through a mast step stringer and into a frame (Ximénès and Moerman 1987: 174, 177, 178).

8. In the literature I have found peined bolts on only one site dated later than the fourth century: Wreck 2 at St.-Gervais, dated to the early seventh century. On this vessel of ca. 15–18 m in length, peined iron bolts about 0.015 m in diameter fastened all preserved frames, save one floor timber and five half-frames, to the keel. They also affixed the aft portion of the keelson to the keel and frames at floor timbers 91, 93, 95, 97, and 98 (Jézégou 1985: 353, figs. 3, 4, 354, 355). The bolt at frame 97 passes through an enlarged portion of the keel that could be the scarf joining the keel and sternpost, but the area is not labelled a scarf (Jézégou 1985: 353, fig. 3).
CHAPTER VIII

LEAD SHEATHING ON GRAECO-ROMAN MEDITERRANEAN SHIPS

INTRODUCTION

Lead sheathing was fitted to Greek and Roman hulls primarily to enhance watertightness, but also for protection against wood borers and as an anti-fouling measure. In the Roman Imperial period, this procedure might have been executed by ship workers known as *stuppatores*, or caulkers (Rougé 1966: 190–91). Because the practice appears to have passed out of general use early in the Roman Imperial period (Gianfrotta and Pomey 1981: 259), it constitutes a valuable means of dating the Caesarea wreck, given that the lead sheet fragments found on that site are in fact remnants of hull sheathing. As noted in Chapter III, tack hole patterns and lead sheet thicknesses at Caesarea match those on sheathing found on other hulls, as is demonstrated below. Nevertheless, it should be noted that lead patches were also commonly used on the inside and the outside of hulls to help stop leakage, and that at least some of the fragments found at Caesarea could be remnants of that practice.

To sheathe a hull, a layer of fabric or other material impregnated with pitch or a similar substance was first applied, presumably up to some distance above the waterline. Lead sheets were then fastened over this layer with closely-spaced, broad-headed tacks. The material sandwiched between the hull and the sheathing was hemp on the wreck at Grand Congloué (Benoît 1961: 152), wool on the wreck at La Madrague de Giens (Pomey 1978a: 85, n. 26) and on the Nemi barges (Ucelli 1950: 153). Agave leaves were used on the Kyrenia ship (Steffy 1985b: 84, 98). An unidentified woven fabric was noted on the Punic ship (Frost 1981b: 263) and on Wreck C at Grand Bassin (Parker 1992a: 199). Some type of plant fibers were employed on the St. Jordi 1 hull (Colls 1987: 36).

The lead sheets are most often found to be 0.001–0.002 m thick, and length and width dimensions seem to conform to rough standards. On the Kyrenia ship the sheets
were 1.05 m to 1.23 m wide and some were almost 2.0 m in length (Steffy 1985b: 83, 98); they seem to have been about 1.2 m wide on the Punic ship at Marsala. The lead sheaths covering the two Nemi ships comprised individual pieces 1.4–1.7 m high (i.e., long?) (Ucelli 1950: 153, 281), but those on the Grand Congloué hull were not over 1 m in length (Benoît 1961: 152). Wreck 1 at St. Jordi displays sheets only 0.35–0.50 m in length (Colls 1987: 28, fig. 9, 35).

Sheets were applied in a stern-to-stern direction on the Nemi ships, transversely from the keel to the first wale, to reduce drag over the hull (Ucelli 1950: 153). This was also done on the Kyrenia ship (Steffy 1985b: 99, fig. 19).

The tacks fastening the lead were usually driven in a diamond or quincunx pattern with a spacing of about 0.03–0.06 m, though they might have been some 0.08–0.10 m apart on the Punic ship. Sheathing from the wrecks at Kyrenia and Lake Nemi exhibits lines scored on the lead to guide such placement (Swiny and Katzev 1973: 349; Steffy 1985b: 84; Ucelli 1950: 153). Tacks are reported to be copper, with two exceptions. Those on the Punic ship at Marsala are leaded bronze (Tylecote 1977: 273), and one tack from the wreck at Punta Scaletta is identified as bronze (Firmati 1992: 83). Five sites have yielded tacks with shafts 0.003–0.005 m square at the head, while three others, including Caesarea, have round shafts of diameter 0.003–0.005 m at the head. Heads of published tacks are always round and 0.015–0.02 m in diameter except on the Nemi ships, where diameters measured 0.025 m to 0.03 m. Heads with protrusions on their undersides, in the form of bars and points in various patterns, were employed on the Punic ship and on four wrecks dated to the 150 years after ca. 110 B.C.E.: Grand Congloué, Albenga, and both Nemi ships. Such protrusions were also found on tack heads discovered in a wicker basket on the Dramont D wreck (Fiori and Joncheray 1973: 81, 82–83, pl. 3, 93, pl. C; Joncheray 1975b: 9, pl. 2, 10). It is dated to the middle of the first century and was not sheathed with lead. Similar tacks thought to be part of a carpenter’s store were found on a fourth-century site, Grand-Bassin D, which also lacks sheathing (Bouscaras 1982: 115, 116, fig. 50).
CATALOG OF WRECKS WITH LEAD SHEATHING

Specific Evidence for Sheathing

*Tyre G* (fifth century B.C.E.?): pieces of timber and lead sheathing are preserved on the wreck. A Hellenistic date is possible, but Parker (1992a: 438) uses the date suggested in the first published report of the site.

*Kyrenia* (late fourth century B.C.E.): a layer of agave leaves applied with pitch lay beneath the lead sheath. Scored diagonal lines used to regulate the placement of the copper tacks were observed on lead sheets measuring 1.05–1.23 m wide and almost 2 m long. They were 0.001 m thick, held in place by copper tacks with heads 0.02 m in diameter and shafts 0.005 m in diameter and 0.0115–0.025 m long (Swiny and Katzev 1973: 349; Steffy 1985b: 83–84, 95, 98, 99, fig. 19). Steffy supplies evidence that the lead was applied later in the life of the ship, not when it was built (see below).

*Fethiye* (late fourth century B.C.E.): fragments of lead sheathing are attached to what might be a wale (Pulak 1985: 2; Pulak and Townsend 1987: 35, n. 10).

*Donuzlav* (late fourth or early third century B.C.E.): nine fragments of lead sheathing were discovered, the largest measuring 0.5 m x 0.6 m. They are about 0.001 m thick with tack head impressions up to 0.016 m in diameter. The tack holes are 0.045–0.075 m apart, some in rows (Blavatsky and Peters 1973: 25, 28, fig. 4).

*Serçe Limanı* (280–275 B.C.E.): lead sheets 0.001–0.0015 m thick covered the hull. The copper tacks are 0.019 m long with shafts 0.003 m square at the heads, which are 0.015 m in diameter. The spacing between tack rows is 0.03 m; the distance between tacks in the same row is 0.08 m (Pulak and Townsend 1987: 35).

*Marsala* (mid-third century B.C.E.): lead sheathing had been fastened to the planking with leaded bronze “drawing-pin” tacks. On some planks they were set along the perimeter and in a diamond pattern about 0.08–0.10 m apart. On several planks lines of tacks pass vertically across the plank surfaces, while in a few instances the lines of tacks run horizontally. One tack has a protrusion on the underside of its head, suggesting the possibility of other protrusions on other tacks. The tack shafts are about 0.004 m square and 0.015–0.02 m long; heads measure 0.016–0.017 m in diameter. The lead itself was entire corroded and reduced to a bluish paste, but sheet widths seem to have been about 1.2 m. An unidentified woven fabric saturated with pitch was placed between the hull and the lead (Frost 1981b: 122, fig. 58:4, 5, 130; 262, 263; Tylecote 1977: 273).
*Porto Ercole B* (150–100 B.C.E.?): lead (and copper) sheathing "from the prow" were found on this wreck of a ship some 30–33 m long (Parker 1992a: 336–37).

*Punta Sottile B* (150–1 B.C.E.): lead sheathing on the hull is reported (Parker 1992a: 362).

*Punta Scaletta* (140–130 B.C.E.): the hull was lead sheathed. One fragment from the site is 0.16 x 0.15 x 0.002 m thick with three tack holes, one of which holds the head of a bronze tack (Firmati 1992: 83; Parker 1992a: 359).

*Ile Riou 3* (120–90 B.C.E.?): the hull was lead sheathed (Parker 1992a: 368).

*Spargi* (120–100 B.C.E.): copper tacks with shafts 0.015 m long spaced 0.03–0.055 m apart attached a fragment of lead sheathing to one plank (Lamboglia 1961a: 155, fig. 12:a, 156). Lamboglia says the sheathing was affixed with copper tacks 0.02 m long, with heads 0.015–0.02 m in diameter, in rows an average of 0.045 m apart. Du Plat Taylor (1965: 115) reports the tacks were coated with lead. Pallarés (1983b: 38) adds that the bronze nails securing the well preserved sheathing are 0.025 m long and placed in a diagonal pattern 0.04–0.06 m from one another. The dimensions and spacing of the tacks or nails are consistent with the earlier reports, but the bronze is not. Pallarés would have the most recent information, yet most descriptions of the metal would be reconciled if the tacks are in fact leaded bronze, as are those on the Marsala ship.

*San Ferreol* (110–80 B.C.E.?): only fragments of the hull have survived. They indicate the hull was sheathed in lead (Parker 1992a: 380).

*Grand Congloué* (110–70 B.C.E.): sheets of lead no longer than one meter and 0.001–0.0015 m thick cover a layer of pitch and hemp applied to the hull, and between the two layers of planks, it seems. The copper tacks holding the lead in place do not exceed 0.02 m in length, have slightly convex heads 0.015–0.02 m in diameter, and were driven in the typical diamond pattern 0.05–0.06 m apart (Benoît 1961: 152, 153, fig. 84, 171, pl. 29:1, 189). D.J. Blackman estimates the sheathing on this hull weighed about 20 tons (Swiny and Katzve 1973: 357).

*Pozzino* (late second or early first century B.C.E.): lead was observed covering the exterior planking and the keel, fastened with short, broad-headed copper nails (Riccardi 1990).

*Agde D* (first century B.C.E.): pieces of lead sheathing are among the hull elements that have survived (Parker 1992a: 44).
Albenga (early first century B.C.E.): sheathing was recovered with copper tacks still in place. The lead is approximately 0.001 m thick and the overall dimensions of the largest piece recovered are 0.18 x 0.46 m. Tack shafts are 0.002 m square and heads are 0.018 m diameter, spaced 0.05 m apart. The heads have on their undersides protrusions in the form of points and bars. The tacks were driven in the typical diamond pattern (Lamboglia 1953: 147, fig. 13, 206, fig. 59, 207–8, 209, figs. 62, 63).

Antikythera (early first century B.C.E.): plank fragments had remnants of copper tacks that secured the lead sheathing, none of which was preserved on the planks. Tacks were set in the standard diamond pattern and spaced about 0.033–0.048 m apart (Throckmorton 1965: 42, fig. 5, 43, 44, fig. 12).

Punta de Algas (100–50 B.C.E.): a sheet of lead 0.12 x 0.11 m displays holes for tacks, and is believed to be a portion of the lead sheathing from a hull estimated to have measured 30 m in length (Mas 1971: 408; Parker 1992a: 347–48).

St. Jordi I (100–80 B.C.E.): the hull was covered in lead sheets about 0.002 m thick and 0.35–0.50 m long. Copper tacks square and rectangular in section and 0.025 m long are spaced 0.09–0.15 m apart in the usual quincunx pattern. Tack heads are reportedly 0.045 m in diameter. Between the strakes and the lead is a layer composed of pitch or resin and a textile made from a vegetal material (Cerdá Juan 1980: 95, and fig. 157; Colls 1987: 28, fig. 9, 35–36).

St. Marguerite (100–50 B.C.E.?): the remains of a large ship display lead sheathing (Parker 1992a: 376–77).

Capo Testa (75–50 B.C.E.): large sheets of lead have been discovered (Gandolfi 1983: 45; 1985: 315; 1986a: 84–85; Parker 1992a: 125–26).

La Madrague de Giens (60–40 B.C.E.): the lead sheets are 0.002 m thick, and the tacks are regularly spaced 0.055 m apart in a diamond pattern. Much of this lead, like that found on the Marsala ship, was extremely degraded. Wool and resin or wax were used between the two planking layers and between the outer planking and the sheath of lead (Pomey 1978a: 85, 86, fig. 12, and pl. 34:1, 2).

Capo Rasocolmo A (36 B.C.E.): on this wreck of a ship that had been burnt, the lead sheathing was found to have melted and re-solidified on the seabed (Parker 1992a: 121–22).

Tre Senghe A (25 B.C.E.): lead was fastened to the planking and the sides of the keel with copper nails square in section with large round heads (Freschi 1982a: 93; Parker 1992a: 435).
Plavac A (late first century B.C.E.–early first century A.D.): lead sheathing is reported on this wreck of a ship that probably measured 25–30 m in length (Parker 1992a: 318).

Terrasini (first century): a fragment of lead with tack holes (inv. no. 41) is thought to have been used to help cover the hull (Giustolisi 1975: 30, and pl. 16).

Cala Rossano (A.D. 1–50?): this wreck is said to have covered an area of 40 x 15 m. Lead sheathing covered the hull (Parker 1992a: 90–91).

Perduto (A.D. 15–25): lead sheathing is present on this hull (Parker 1992a: 307).

Port-Vendres 2 (A.D. 42–48): this apparently large ship was sheathed in lead (Parker 1992a: 331).

Lake Nemi (mid-first century): flat tack heads measured 0.025–0.03 m in diameter and had protrusions on their undersides in at least four different patterns. Shafts were 0.004–0.005 m square at the heads and 0.043–0.053 m long. The tacks were driven in typical quincunx pattern and center-to-center distances appear to have been ca. 0.08–0.10 m. Score lines used to guide tack placement were still visible on the lead. Lead sheets 0.001 m thick and 1.5 m wide, which were fastened atop a layer of wool and pitch, were applied from the keel to the first wale in a transverse direction from the stern toward the bow, to reduce drag (Ucelli 1950: 70, fig. 70, 75, fig. 78, 79, fig. 82, 153, 158, 159, fig. 162, 265–68).

Mezzapraia (mid-first century): lead sheathing is mentioned among the items found on the site (Purpura 1986: 146).

Porto Cristo A (A.D. 50–70): no details regarding this well preserved hull of some 20–30 m are available, except that it was sheathed in lead (Parker 1992a: 335–36).

Ses Salines (A.D. 70–80): the hull is represented by some lead-sheathed wood, among other artifacts (Parker 1992a: 379).

Marritza (A.D. 75–125): a large quantity of contorted lead sheathing fragments and remnants of copper tacks were found on this dispersed site. The tacks seem to be arranged in a diagonal pattern on the sheets, at intervals of about 0.07–0.08 m. Negative impressions of tack heads observed on the reef rock measure ca. 0.02 m in diameter (Gandolfi 1986b: 70, 72, fig. 5; Pallarés 1986a: 75–76, 76, figs. 4, 5; Parker 1992a: 262).

Ben-Afeli (A.D. 85–95): lead sheathing was found on the wreck (Parker 1992a: 71).
**St.-Gervais 4** (first or second century): traces of sheathing are evident on all strakes, but no specific details are available. The important point is that the site yielded Dressel 20 and Beltran 2B amphoras that can date to the first and second centuries. But due to the presence of lead sheathing, which is believed to have fallen out of use near the end of the first century, the excavators prefer a date no later than that century (Pomey et al. 1988: 13).

**Grand-Bassin C** (A.D. 120): the planking was covered with lead sheathing, applied over a layer of fabric and pitch. In one place, where the sheathing had come away from the wood, a hole left by a lost tack had been filled with a small treenail and a replacement tack had been driven next to it (Parker 1992a: 199).

**Procchio** (A.D. 160–200): this ship, more than 18 m long, was sheathed in lead (Parker 1992a: 343).

**Grado** (A.D. 200?): this ship is estimated to have measured 18 x 5 m and was sheathed in lead (Parker 1992a: 197).

**Plemmirio B** (A.D. 200): small pieces of lead sheathing are preserved on the site (Parker 1992a: 319).

**Ayia Galini** (A.D. 276–290): no wood was found on the site, but “a piece of lead, apparently hull sheathing, appears to confirm that the site is a shipwreck” (Parker 1992a: 62). Given the rarity of sheathing on sites dated after the first century, this identification is certainly possible, but may be regarded with caution.

**Sobra** (A.D. 320–340?): a ship 25 m long is suggested by the dimensions of timbers exposed during excavation. “The ship was definitely sheathed in lead, one of the latest known examples” (Parker 1992a: 408). The date in Parker’s catalog is followed by a question mark, duplicated here, but not explained. As with the Ayia Galini wreck, such a late occurrence of sheathing is surprising.

**Other Evidence for Sheathing**

delle Correnti (Kapitän 1961: 288).

ANALYSIS OF PURPOSE AND USE

The material at hand reveals no developmental patterns in sheathing details on hulls of any size or date. Fastening techniques and the thickness of sheeting are essentially consistent, although tacks with square shafts seem to have been preferred to those with round ones (Table 7).

With regard to the table, an absolute maximum of 15 percent (8 of 53) and probably only 11 percent (6 of 53) of the wrecks cataloged above date after the first century A.C. and exhibit evidence for lead sheathing. Its latest documented use on the hulls listed above occurs on a single wreck dated to the fourth century. Two wreck sites of the late second or early third centuries, Plemmirio B and Ayia Galini, have yielded only dubious testimony to its employment. Possibly five wrecks dated to the second century and perhaps only one from the third century exhibit evidence of the practice. Otherwise, 49–51 percent of the wrecks are heavily concentrated in the two centuries B.C.E. (26–27 of 53), with 17–22 percent (9–12 of 53) dating to the first century B.C. If the Caesarea hull was in fact covered with lead, a date for the service life of the ship of no later than the first century A.C., and more likely the first century B.C.E., is consistent with the frequency of occurrence of lead sheathing.

The archaeological evidence confirms one reference in the ancient literature to the use of lead sheathing and material soaked in tar or pitch. Athenaeus (ca. A.D. 200) describes the construction of the *Syracusia*, to which lead sheathing is applied over a layer of tarred fabric after the hull is complete (Athenaeus 5.207a–b).²

There is much more testimony regarding hulls covered with pitch or resin only, however. Vergil (*Aeneid* 4.398) writes of Aeneas' pitch-covered ships (*uncta carina*), though it is uncertain if this can be taken as representative of contemporary practices (late first century B.C.E.) or of those some seven centuries earlier. In the first century, Plutarch (*Moralia* 6/76A) stated that no hull was seaworthy without a coat of pine pitch or resin. These two passages do not necessarily exclude of course the use of lead sheathing in addition to the pitch and resin. In a fourth-century discussion of incendiary warfare at sea, Vegetius (4.44) describes the tactic of shooting flaming arrows into enemy hulls covered with pitch and resin. It should be noted, however,
Table 7. Greek and Roman Wreck Sites with Evidence of Lead Sheathing.

<table>
<thead>
<tr>
<th>Site</th>
<th>Lead Thick. (mm)</th>
<th>Tack Metal</th>
<th>Tack Spacing (cm)</th>
<th>Head Diameter (cm)</th>
<th>Shaft Dim. at Head (mm)</th>
<th>Material Beneath Lead</th>
<th>Date (Century)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tyre G</td>
<td>ND</td>
<td>ND</td>
<td>1</td>
<td>4.5–7.5</td>
<td>1.6</td>
<td>agave leaves</td>
<td>5 B.C.E.?</td>
</tr>
<tr>
<td>Kyrenia*</td>
<td>1</td>
<td>copper</td>
<td>2</td>
<td>5 D</td>
<td>3</td>
<td>textile</td>
<td>4 B.C.E.</td>
</tr>
<tr>
<td>Fedhiye</td>
<td>ND</td>
<td>ND</td>
<td>4.5–7.5</td>
<td>1.6</td>
<td>3</td>
<td>textile</td>
<td>4 B.C.E.</td>
</tr>
<tr>
<td>El Sec</td>
<td>ND</td>
<td>ND</td>
<td>4.5–7.5</td>
<td>1.6</td>
<td>3</td>
<td>textile</td>
<td>4 B.C.E.</td>
</tr>
<tr>
<td>Donuzlavl</td>
<td>ND</td>
<td>ND</td>
<td>4.5–7.5</td>
<td>1.6</td>
<td>3</td>
<td>textile</td>
<td>4/3 B.C.E.</td>
</tr>
<tr>
<td>Filicudi F</td>
<td>ND</td>
<td>ND</td>
<td>4.5–7.5</td>
<td>1.6</td>
<td>3</td>
<td>textile</td>
<td>4/3 B.C.E.</td>
</tr>
<tr>
<td>Sea of Marmara</td>
<td>ND</td>
<td>ND</td>
<td>4.5–7.5</td>
<td>1.6</td>
<td>3</td>
<td>textile</td>
<td>4/3 B.C.E.</td>
</tr>
<tr>
<td>Serçe Limani</td>
<td>1–1.5</td>
<td>copper</td>
<td>1.5</td>
<td>3</td>
<td>4</td>
<td>textile</td>
<td>3 B.C.E.</td>
</tr>
<tr>
<td>Marsala**</td>
<td>1–1.5</td>
<td>bronze</td>
<td>2</td>
<td>8–10</td>
<td>1.6–1.7</td>
<td>textile</td>
<td>3 B.C.E.</td>
</tr>
<tr>
<td>Jenaune-Garde B</td>
<td>ND</td>
<td>ND</td>
<td>1.5</td>
<td>3</td>
<td>4</td>
<td>textile</td>
<td>2 B.C.E.</td>
</tr>
<tr>
<td>Porto Ercole B</td>
<td>ND</td>
<td>ND</td>
<td>1.5</td>
<td>3</td>
<td>4</td>
<td>textile</td>
<td>2 B.C.E.</td>
</tr>
<tr>
<td>Punta Sottile B</td>
<td>ND</td>
<td>ND</td>
<td>1.5</td>
<td>3</td>
<td>4</td>
<td>textile</td>
<td>2 B.C.E.</td>
</tr>
<tr>
<td>St. Cat. di Nardo</td>
<td>ND</td>
<td>ND</td>
<td>1.5</td>
<td>3</td>
<td>4</td>
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<td>2 B.C.E.</td>
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<tr>
<td>Punta Scaletta</td>
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<td>2 B.C.E.</td>
</tr>
<tr>
<td>Bagaud 2</td>
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<td>ND</td>
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<td>4</td>
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<tr>
<td>Spargi</td>
<td>ND</td>
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<td>1.5</td>
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<td>4</td>
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<tr>
<td>Île Riu 3</td>
<td>ND</td>
<td>ND</td>
<td>1.5</td>
<td>3</td>
<td>4</td>
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<td>2 B.C.E.</td>
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<tr>
<td>San Ferreol</td>
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<td>ND</td>
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<td>Gr. Congloué</td>
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<td>1.5–5</td>
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<td>2</td>
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<td>2–1 B.C.E.</td>
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<tr>
<td>Carry-le-Rouet</td>
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<td>ND</td>
<td>1.5–2</td>
<td>2</td>
<td>2</td>
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<td>2 B.C.E.</td>
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<tr>
<td>Pozzino</td>
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<td>ND</td>
<td>1.5–2</td>
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<tr>
<td>Agde D</td>
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<td>ND</td>
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<td>ND</td>
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<td>1 B.C.E.</td>
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<td>Mahdia</td>
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<td>ND</td>
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<td>St. Jordi 1</td>
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<td>copper</td>
<td>1.5–2</td>
<td>2</td>
<td>2</td>
<td>textile</td>
<td>1 B.C.E.</td>
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190
<table>
<thead>
<tr>
<th>Site</th>
<th>Lead Thick. (mm)</th>
<th>Tack Metal</th>
<th>Tack Spacing (cm)</th>
<th>Head Diameter (cm)</th>
<th>Shaft Dim. at Head (mm)</th>
<th>Material Beneath Lead</th>
<th>Date</th>
<th>Date</th>
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<tr>
<td>St. Marguerite</td>
<td>ND</td>
<td>ND</td>
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<td>Capo Testa</td>
<td>ND</td>
<td>ND</td>
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<td>5.5</td>
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<td>Planier 3</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>square</td>
<td>2–1 B.C.E.</td>
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<td>La Tradelire</td>
<td>ND</td>
<td></td>
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<td></td>
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<td>1 B.C.E.</td>
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<td>Plavac A</td>
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<td></td>
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<td>wool</td>
<td>1 B.C.E./</td>
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<tr>
<td>Caesarea</td>
<td>0.9–1.8</td>
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<td>5.5–6.5</td>
<td>1.5–1.7</td>
<td>5 D</td>
<td>wool</td>
<td>1 B.C.E.</td>
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<td>Terrasini</td>
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<td>wool</td>
<td>1 A.C.</td>
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<td>Cala Rossano</td>
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<td>wool</td>
<td>1 A.C.</td>
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<tr>
<td>Perduto</td>
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<td>wool</td>
<td>1 A.C.</td>
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<tr>
<td>Port-Vendres 2</td>
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<td></td>
<td></td>
<td>wool</td>
<td>1 A.C.</td>
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<tr>
<td>Lake Nemi**</td>
<td>1</td>
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<td>8–10</td>
<td>2.5–3</td>
<td>3.5²–5²</td>
<td>wool</td>
<td>1 A.C.</td>
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<td>Mezzapraia</td>
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<td></td>
<td></td>
<td>wool</td>
<td>1 A.C.</td>
<td></td>
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<tr>
<td>Porto Cristo A</td>
<td>ND</td>
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<td></td>
<td></td>
<td></td>
<td>wool</td>
<td>1 A.C.</td>
<td></td>
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<tr>
<td>Ses Salines</td>
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<td></td>
<td></td>
<td></td>
<td>wool</td>
<td>1 A.C.</td>
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<tr>
<td>Marritza</td>
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<td>copper</td>
<td>7–8</td>
<td>2</td>
<td></td>
<td>wool</td>
<td>1 A.C.</td>
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<tr>
<td>Ben Afel</td>
<td>ND</td>
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<td></td>
<td></td>
<td>wool</td>
<td>1 A.C.</td>
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<tr>
<td>St.-Gervais 4</td>
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<td></td>
<td></td>
<td>wool</td>
<td>1/2 A.C.</td>
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<td>Grand-Bassin C</td>
<td>ND</td>
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<td></td>
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<td>wool</td>
<td>2 A.C.</td>
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<td>Prochio</td>
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<td></td>
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<td>2 A.C.</td>
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<tr>
<td>Grado</td>
<td>ND</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>wool</td>
<td>2/3 A.C.?</td>
<td></td>
</tr>
<tr>
<td>Plemmirio B</td>
<td>ND</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>wool</td>
<td>2/3 A.C.</td>
<td></td>
</tr>
<tr>
<td>Ayia Galini</td>
<td>ND</td>
<td></td>
<td></td>
<td></td>
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<td>wool</td>
<td>3 A.C.</td>
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<tr>
<td>Sobra</td>
<td>ND</td>
<td></td>
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<td></td>
<td></td>
<td>wool</td>
<td>4 A.C.?</td>
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<tr>
<td>Isola delle Correnti</td>
<td>ND</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>wool</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>

* Score lines on lead for tack placement  
** Protrusions on undersides of tack heads
that Vegetius used materials from many previous periods to compile his handbook.\textsuperscript{3}

Wax also was used to protect and waterproof hulls, according to writers of the first century B.C.E. and later (Ovid, \textit{Metamorphoses} 11.514–15; Arrian, \textit{Periplus Maris Euxini} 5; Lucian, \textit{Dialogi Mortuorum} 4; Vegetius 4.37). Pliny (first century) mentions “live pitch,” which consists of pitch scraped off the bottoms of seagoing ships and mixed with wax. He says this produces a superior material for all the purposes pitches and resins serve (\textit{Nat.} 16.23.56; cf. Valerius Flaccus 1.478–80). Discussing wax further, Pliny (\textit{Nat.} 35.41.149) relates that it is melted and mixed with paint and then brushed on to decorate warships. Such a coating is not spoiled by sun, saltwater, or wind. Most pertinent to merchant ships is a passage in which he states that wax is stained with colors for encaustic painting, which is commonly done on naval vessels and also merchant ships, because even \textit{vehicula} are decorated with paintings (\textit{Nat.} 35.31.49). Protogenes, a contemporary of the famous painter Apelles of the later fourth century B.C.E., might have been just such a ship painter until he was about 50 years old. His status as a colleague of Apelles may have been achieved after turning his talents to other artistic pursuits later in life (see Pliny, \textit{Nat.} 35.36.101).

Benoit (1961: 153–54) takes the passages in Vergil and Pliny to mean that lead sheathing was replaced by wax and encaustic paint in the first century. Other scholars cite third-century mosaics from North Africa as evidence that lead sheathing was used on small fishing boats (Casson 1978) and big warships (Frost 1978; Dell’Orco 1979; Basch 1979; 1980; 1987: 477, 482). The catalog above supports the use of sheathing in the third century. Five and possibly seven cataloged shipwrecks dated to the second and third centuries, though not small fishing boats or large warships, do display evidence of the practice. In contrast, the tactic of shooting flaming arrows into the sides of enemy hulls covered with pitch, as described by Vegetius, suggests lead sheathing was not being used in his day (though this information may not have been contemporary), and references to wax mixed with pitch hint at the growing use of this material to protect and help waterproof hulls after the first century B.C.E. The evidence as a whole does not seriously contradict at least part of what Benoit’s statement implies, and what Pomey (1973a: 49–50) observed two decades ago: that lead sheathing passed out of general use in the course of the first century.

There appears to be no evidence in the ancient literature for the intentional use of lead as a barrier to ship worm, so its presence on the Lake Nemi ships makes best sense in the context of watertightness (as in Frost 1981b: 263; cf. Ucelli 1951: 153),
unless the ships were subject to some other kind of biological attack, because it was known in antiquity that η τερηδόν, the ship worm, is confined to the seas (Theophrastus, *HP* 5.4.4; Pliny, *Nat.* 16.80.220). Evidence that the lead sheathing of the Kyrenia ship was added later in its life and not when newly built might seem to contradict this notion, but in his study of that vessel’s wooden and lead sheathing, J.R. Steffy provides clues that the Greeks, and therefore probably the Romans, viewed lead sheathing primarily in the context of waterproofing. The Kyrenia ship’s wooden sheathing is believed to have bolstered the bow structure somewhat, and to have held some type of caulking material in place atop old and worm-eaten planking. That is, it was employed primarily to help seal a leaky hull. Rather shortly after this covering was nailed on, repairs to planking seams and the keel were executed, and then the entire hull was fitted with a lead sheath. Upon excavation, the wood used for the planking repairs looked fresh and new, while the wooden sheathing was darker, and therefore somewhat older, though still undamaged by bivalve mollusks (Steffy 1985b: 96–99). The relatively close temporal proximity of these two maintenance operations, and the fact that the wooden sheath was free of ship worm when the lead was applied, renders almost inescapable the conclusion that the primary purpose of the lead sheathing was to help restore watertightness.

The Nemi vessels provide a key to even more evidence for the use of lead sheathing primarily to combat leakage and not wood borers. As noted by F. Hocker (in press), it must have been difficult to effect watertightness in large mortise-and-tenon-built hulls. Achieving sufficient structural stiffness on such a scale, with an elastic material like wood and the technology of the day, was no mean feat. It would have been desirable to sheathe a big ship early in its working life, or when built, as was done for the *Syracusia* and presumably the Nemi barges as well. Moreover, putting ships of grand size into dry dock to be retro-fitted with lead sheathing would have been a major undertaking, and would also seem to have encouraged sheathing at the time of construction. It may therefore be no coincidence that 13 of the 14 wrecks cataloged in this study that are estimated to have been 30 m or more in length (the Punic and Caesarea ships included) exhibit evidence of lead sheathing (cf. Tables 1, 3, 5, 7). Rival’s suggestion (1991: 40) that lead sheathing was used on the hull at Giens to protect the outer layer of fir planks because fir does not fare well in high humidity or immersion in water, thus appears to reflect too narrow a view of the issues involved.
Other opportunities to maximize watertightness at the time of building were certainly exploited. Resin or wax and wool were placed between the inner and outer layers of planking, and between the lead and the outer planking layer, of the ship that sank at Giens. This measure was also taken on the double-planked ships that wrecked at Cap Dramont (A) (Santamaria 1973: 133; 1975: 192–94) and at Grand Congloué. These two vessels sank in the first century B.C.E. and were each ca. 20 m in length, but only the latter was covered with lead.

Hocker (in press) proposes that the disappearance of lead sheathing after about the first century was the result of heightened economic awareness and sophistication; hence efforts to develop easier and less costly methods of waterproofing ships. This seems quite consistent with the dynamic economic environment around the Mediterranean in the first century but it leaves to be explained the inconsistent use of sheathing before that time, as well as a somewhat curious absence of ancient references to the practice. Indeed, economic considerations might illuminate this matter equally well. Perhaps lead sheathing represented appreciable additional expense throughout its period of employment, and so was used only when the size or intended use of the ship dictated it, or when a leaky hull needed to be kept in service, or simply because sheathing a smaller ship at the time it was built was a procedure affordable by only the more financially established builder(s) or owner(s). Some support for this suggestion comes from the wreck of a ship some 13 m in length discovered at modern-day Kibbutz Ma’agan Michael, Israel. Dated to about 400 B.C.E., this vessel sank very soon after being built, judging from the color and pristine condition of the wooden hull components and dunnage, the wood chips in the bilge, and the absence of evidence of wear on the false keel and waterline wale. It had not been covered with lead, just thinly painted with a yellow substance (Rosloff 1990: 4 and personal communication 1993; Linder 1992: 28, 29, 31, 34.). Professor van Doorninck (personal communication 1994) points out that the practice of sheathing ships with lead and therefore also the discontinuation of its use must be related to its availability in Greek and Roman times. This is a promising avenue of more extensive research.

The positive evidence, admittedly quite scarce, argues against specific knowledge among the Greeks and Romans of the protection against ship worm offered by lead, and in favor of their simple recognition of its preservative effects on the tar or pitch and associated cloth, vegetal, or other materials applied to the exterior of the hull. It
therefore seems reasonable to suppose that watertightness was the sheathing's primary purpose, and that only incidentally did it provide additional benefits. It certainly would have been superior to exposed tar or pitch in keeping the submerged portion of the hull free of barnacles and other sessile marine life and debris (J.R. Steffy, personal communication 1989). Therefore, given that the lead sheathing on the Nemi ships was to promote watertightness, perhaps new materials and techniques shipwrights might have been experimenting with or developing in the first century were felt to be still too unproven for use on the emperor's colossal barges.
Notes

1. Similar tacks with protrusion patterns consisting of a single ring around the underside of the head, either close to the tack shaft or along the outer circumference of the head, have been found associated with footwear in Gallo-Roman tombs at Calade. The tombs are dated to the early Imperial period (Bérard 1961: 127, 128, pl. 15:84, 152, pl. 32:243, 153).


3. According to Watson in *OCD*², s.v. “Vegetius Renatus.”

4. I thank Dr. Hocker for allowing me to read and address points in his stimulating paper prior to publication. This discussion is consequently a more thorough examination of the issues.

5. Of interest is M.-B. Carre’s observation (1993: 25) that no lead sheathing has been discovered on the *dolia* wrecks excavated to date. Most of these hulls seem to have measured 18–25 m in length.
CHAPTER IX

BOXES AND PIPES OF LEAD ON GRAECO-ROMAN
MEDITERRANEAN SHIPS

INTRODUCTION

A number of lead boxes similar to the one found at Caesarea, though of no uniform size or configuration, have been recovered from shipwrecks of the Roman period. Some have pipes still attached, and all seem to have been fitted with pipes originally. Many Greek and Roman wreck sites have yielded pipes but no boxes as well. Only one function has been proposed for the boxes: that of catch basins for bilge pumps. A review of the development of the catch basin concept and of the boxes and pipes discovered to date casts doubt upon identification of the relatively small Caesarea box as such a basin.

References to the bilge abound in the ancient literature, but because no intact bilge pump apparatus has ever been found, presumably due in large part to salvage efforts in antiquity, and because no detailed pictorial representations have been discovered, we have only theories about how they worked.¹ Ucelli presents Tassan’s reconstruction of a wooden box and other objects found on the two Nemi ships as representative of the bilge pump equipment used on the vessels (Ucelli 1950: 181–84), but other scholars are critical of various aspects of Tassan’s interpretations (White 1962: 103–6; Carre and Jézégou 1985: 125–29; Oleson 1984: 230–31).

Lead pipes recovered from the wreck at Albenga are suggested to be remnants of the bilge pump apparatus (Lamboglia 1953: 198–200), as are those found on the wreck at Grand Congloué (Benoît 1961: 174–75), but in neither case is a specific scheme proposed. A general idea of how lead boxes and pipes could have helped empty a ship’s bilge was presented by excavators of the wreck at Palamós, where long lead pipes and the possible remains of a lead box were discovered. A reconstruction drawing depicts the pipes spanning the breadth of a ship and protruding from either side near deck level. The proposed lead box is joined to both pipes in the center of the
hull section, but no specific arrangement with respect to a bilge pump is ventured (Vidal and Pascual Guasch 1971: 124, fig. 5, 125–26). Dumas submitted the same idea to explain the function of two long pipes attached to a lead box found on a wreck at Cap des Mèdes (Tchemia 1969b: 478; Dumas 1972b: 199–219). The lead box would have caught bilge water raised to near deck level by the pump and the water would then drain via pipes exiting the box abreast and extending through the hull to port and starboard. This scheme is supported by the discovery of pipes lying parallel to the hull frames at La Madrague de Giens and La Tradelière and atop the top layer of amphorae of the Dramont A wreck. Perhaps the best evidence consists of pipes found approximately one meter above the hull planking of the wreck at Los Ullastres. They rest upon the necks of the cargo amphorae, run parallel to the frames, and one terminates almost precisely at the extremity of the frames at one edge of the hull remains. A similar situation was in evidence when a wreck at Miladou was excavated, but the two pipes were separated by 0.58 m, a space proposed to have been occupied by the water collection reservoir. Such an arrangement of pipes and a reservoir as served by a chain-pump is illustrated by Foerster Laures (1979: 174, fig. 3; 1985a), who has investigated the water-moving capabilities of this pump type by means of a working model (Foerster Laures 1983c; 1985c).

There has been disagreement about whether force pumps (see, e.g., Rouanet 1974), chain-pumps, or even Archimedean screws were used to eliminate water from the bilges of ancient ships. Oleson (1984) maintains that force pumps were employed, while Pulak (Pulak and Townsend 1987: 37–38) argues for the use of chain-pumps. Carre and Jézégou (1985) provide a good discussion of the state of knowledge at the time of publication. They support the idea of a chain-pump existing on at least one of the Lake Nemi vessels, and present from Wreck 2 at St.-Gervais the first indisputable remains of a chain-pump tube. Even more substantial remains of the bottom portions of two chain-pump tubes, and associated fittings, have been discovered on a wreck site at Cap Gros and on a dolia wreck at Île-Rousse (Joncheray 1989a: 68–78; Alfonsi and Gandolfo 1988).2 Unfortunately, upper elements of a chain-pump have yet to be found. Oleson (1984: 224), citing Drachmann (1973), notes that the crank in Foerster Laures’ scheme is probably anachronistic, which renders problematic the operation of chain-pumps and the reconstruction by Tassan in Ucelli (1950: 184, fig. 199). Tassan proposes a crank and flywheel assembly to drive a toothed gear and a chain of bailers, but White (1962: 103–6) points out that the provenances of the components makes
this proposition archaeological fantasy. Nevertheless, Drachmann accepts the idea of a crank with regard to the Nemi ships. A wooden wheel or disk 0.24 m in diameter was found on the Tre Senghe A wreck (25 B.C.E.). A central hole in the shape of a truncated pyramid does not extend through the disk, and two holes at the outer edge are set 180 degrees from one another. Based on provenance, the excavator suggests this object might be part of a bilge pump apparatus (Freschi 1982b).

A chain-pump apparatus can explain reasonably well the function of most lead boxes found with pipes on Roman wrecks, but not necessarily that of the numerous lead pipes found with no associated boxes (Table 8), nor the configuration and diminutive size of the Caesarea box. Perhaps even bilge pumps in general cannot satisfactorily account for all occurrences of these objects on wreck sites.

CATALOG OF WRECKS YIELDING LEAD BOXES AND PIPES

Wrecks Yielding Boxes

*Grand Congloué* (110–70 B.C.E.): a lead pipe about 1.5 m long was recovered in four pieces. All display one soldered lateral seam, and the thickness of the lead is about 0.003 m. A diameter of 0.06 m at one end swells to 0.08 m at the other, where a lip or flange was fashioned presumably to effect a joint with a reservoir. Benoît suggests that two fragments of lead sheets about 0.003 m thick found in the same area might be part of such a reservoir, as they are each pierced by a hole of 0.05 m diameter (Benoît 1961: 174, 175, fig. 93, 181, pl. 32:b:4).

*Cap des Mèdes* (first century B.C.E.?): this is one of the most notable wreck sites producing lead boxes with attached pipes. The box was found in the supposed shaft of the bilge pump. It is 0.60 m square and 0.32 m deep; the lead is 0.08–0.10 m thick. Two pipes 0.09 m in diameter exit the tank opposite one another and span the wreck site in its width (Tchernia 1969b: 477, figs. 23, 24). Corsi-Sciullano and Liou (1985: 60, 62, fig. 47) report dimensions for this box of 0.63 x 0.61 x 0.34 m and note that the pipes 3 m long and exit the tank at its bottom. Given the two sets of dimensions, the capacity of the box is 115.2–130.7 liters.

*Palamós* (100–50 B.C.E.): on this wreck were found two lead pipes, each about 2 m long and 0.05 m in diameter, with flanges at their extremities. Fragments of a supposed box estimated to have been about 0.40 m long were still attached to one
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<tr>
<th>Site</th>
<th>Lead Box</th>
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<th>Lead-Box Pipes</th>
<th>Other Pipes</th>
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end of one of the pipes. Although the function of this assembly is uncertain, it has been reconstructed as a collection basin and evacuation device for a bilge pump (Vidal and Pascual Guasch 1971: 124, fig. 5, 125–26).

*Tre Senghe A* (25 B.C.E.): a lead pipe of oval section with a soldered seam was discovered, along with a copper box, in a port quarter of the wreck. They are taken to indicate the location of the ship’s pump (Freschi 1982b; Parker 1992a: 435).

*La Tradelière* (late first century B.C.E.): a lead pipe 1.13 m long and a lead plate 0.30 x 0.50 m might be remains of a bilge pump apparatus. The pipe lead is 0.006 m thick, the pipe 0.05 m in diameter. Preserved for a length of 1.73 m, it lay perpendicular to the axis of the ship (Joncheray 1976a; Fiori 1976: opposite p. 60, wreck plan). Another piece of pipe was attached to a piece of copper that could be the remains of a reservoir (Carre and Jézégou 1985: 141).

*Plavac A* (late first century B.C.E.–early first century A.C.): a collecting tank and lead tubing were discovered on the wreck. The total length of the assembly is 8.32 m, suggesting the beam of the ship at the point of installation in the hull (Parker 1992a: 318).

*Cabrera D* (A.D. 1–15): a small lead reservoir was found (Parker 1992a: 82).

*Chrétiennne H* (early first century): a box some 0.45 x 0.35 x 0.16 m deep was found at deck level, attached to a wooden chassis. It was made of a single sheet of lead about 0.002 m thick, with no folds, cuts, or soldered seams. A pipe fashioned from a thicker sheet of lead exits the tank at one corner. On the same side of the box is a hole that suggests another pipe was fastened to the box (Santamaria 1985: 50). Capacity is 25.2 liters.

*Grand-Rouveau* (mid-first century): the remains of a lead tank with a length of lead pipe still attached is stated to be the remnants of a reservoir intended to receive water delivered by the bilge pump. The tank is reconstructed to ca. 0.315–0.32 x 0.25 m. A pipe 0.055 m in diameter was driven into a hole near one corner of the tank and beaten back over in a carefully made joint; the lead wall of the tank was formed around the pipe on the exterior. Two other pieces of pipe 0.44 m and 0.70 m long and 0.05 m in diameter are thought to be part of the same apparatus (Corsi-Scialiano and Liou 1985: 60, 61, figs. 45, 46).

*Lake Nemi* (mid-first century): numerous objects found on Ship 1 were reconstructed by Tassan as a bilge pump apparatus. One item was a shallow wooden box with a spout. The box itself measured about 0.55 m square and 0.11 m high. The
spout was some 0.185 m wide as it exited the box, tapering to a width of ca. 0.13 m over a preserved length of about 1.3 m. Numerous lead pipes with inscriptions on them were also found on the first ship. They were surely involved with the circulation of water on board, though they cannot necessarily or exclusively be associated with the bilge pump apparatus. Six were of 0.09 m diameter, 1.35–3.6 m long; three were 0.03 m in diameter and 0.50–0.60 m long (Ucelli 1950: 181–86, 187, fig. 203, 410–11).

Wrecks Yielding Lead Pipes

Serce Limami (280–275 B.C.E.): one length of lead pipe about 0.08 m in diameter is fitted over another one of ca. 0.06 m diameter. They are soldered together and measure approximately one meter in exposed length. The segment with the smaller diameter displays a seam over its visible extent (Pulak and Townsend 1987: 36–38).

Marsala (mid-third century B.C.E.): one short lead pipe was found on the north slope of the port ballast area. In its distorted shape it measures about 0.124 x 0.03 m, and estimated original dimensions are 0.09 x 0.055 m (Frost 1981b: 132).

Cala Scirocco (200–150 B.C.E.): pieces of lead pipes were found (Parker 1992a: 91).


Grand-Ribaud A (ca. 130 B.C.E.): a concreted bar was discovered but left on the site. The excavator suggests it could be a pipe associated with a bilge pump apparatus (Carrazé 1975: 26).

Île Riou 3 (120–90 B.C.E.): part of the "pump tubing" was found (Parker 1992a: 368).

La Ciotat (late second century B.C.E.): pipe fragments are 0.05 m in diameter. They could have been associated with the ship’s bilge pump apparatus, or with the terra cotta baignoire sabot (slipper bath) found on the wreck (Benoît 1958: 24–26).

Miladou (end of second to first half of first century B.C.E.): two long lead pipes were discovered resting on the shoulders of the cargo amphoras, and thus could have been mounted on a beam or beams at that level originally, or higher, even on deck, if there was one. Regarded as having remained in situ since the wrecking event, they were essentially aligned with one another and lay exactly perpendicular to the long axis of the wreck. The outboard ends lay 3.67 m apart, which may indicate the beam of the
ship at the level of the pipes (though not necessarily its maximum beam at that point in the vessel’s length). The inboard extremities were separated by a distance of 0.58 m, which could represent the breadth of a tank or reservoir that received the pumped water. This space was excavated completely in a search for pump elements, but only two small fragments of lead were found, the largest of which is a sheet measuring 0.100 x 0.120 x 0.001–0.003 m thick. It is acknowledged that the reservoir could have been wooden and simply lined with the lead sheets.

The pipes, egg-shaped in section, were oriented with their longitudinal soldered seams facing up, attesting to a lack of confidence in their watertightness, according to the excavators. The port pipe is 1.400 m long and seems broken or worn at the inboard end, which could explain the greater length of its counterpart. Its other extremity is preserved and consists of a collar or flange pierced by holes. The lead thickness varies, but averages ca. 0.004 m; sectional dimensions are 0.062 x 0.050 m. The pipe to starboard is a little flatter in section but preserved intact to 1.600 m with flanges or collars at each extremity. The inboard collar or flange is oriented 45 degrees to the axis of the tube. That it was fastened to a surface inclined at the same angle is proposed (Dumontier and Joncheray 1992: 110, 113, 116, 118, 121, 124–25, 130, 132, 137–38).

_Ustica A_ (first century B.C.E.?): lead tubing was discovered on the wreck (Parker 1992a: 441).

_Albenga_ (early first century B.C.E.): unspecified lengths of lead pipes were recovered with diameters of 0.06 m and 0.08 m. The excavator suggests use in connection with either a bilge pump, or with a apparatus for pumping wine to and from land (Lamboglia 1953: 198–200).

_Antikythera_ (early first century B.C.E.): a lead pipe 0.68 m long with a crude flange at one end was recovered. Average interior diameter is 0.065 m, and the thickness of the lead averages 0.006 m. It is suggested to be a scupper (Throckmorton 1965: 44).

_Dramont A_ (first half of first century B.C.E.): at the forward and aft thirds of the wreck two lead pipes of 0.06 m diameter were found on top of the top layer of amphorae; they followed the angle of the tumulus into the mud. That they were found atop the top layer of amphorae seems to prove, according to the excavators, that they were originally located on or immediately beneath the deck of the ship, if the site was not looted prior to excavation (Santamaria 1961: 173–74; 1975: 190; Liou 1973: 129).
Another pipe fragment slightly ovoid in section has a maximum outer diameter of ca. 0.07 m and a maximum inner diameter of ca. 0.06 m. It is 0.35 m long (Fiori and Joncheray 1973: 89, pl. 6:9, 90).

_Sa Nau Perduda_ (100–50 B.C.E.): three pipes were probably joined originally, as part of a bilge pump apparatus, according to the excavators. Their lengths are 0.45 m, 0.55 m, and 1 m, all with diameters of 0.05–0.055 m (Foerster and Pascual 1970: 278, 286–87).

_Cap Spartel_ (100 B.C.E.–A.D. 50): lead pipes of varying diameters were discovered (Parker 1992a: 107).

_Capo Testa_ (75–50 B.C.E.): three pieces of lead pipe with diameters of about 0.07 m were found slightly southeast of the hull. Measuring 0.31, 0.35, and 0.59 m long, they are suggested to be remnants of the bilge pump apparatus (Gandolfi 1983: 45, 51; 1985: 315–16; 1986a: 84, 88, fig. 16; Parker 1992a: 125–26).

_La Madrague de Giens_ (60–40 B.C.E.): two pipes were found near the shaft of the bilge pump on the upper level of the hull, and were arranged symmetrically across the breadth of the ship. Both are 0.50 m long, 0.06 m in diameter, and exhibit lateral soldered seams in lead 0.008 m thick. Each pipe has a flange at each end that is oval-shaped and shows traces of nailing around the perimeter. Such flanges could have served to fasten the pipes to an evacuation tank, among other things (Carre and Jézégou 1985: 141, fig. 19, and n. 77).

_Cap Carqueiranne_ (mid-first century B.C.E.): some fragments of lead pipes about 0.07 m in diameter were found and are believed to be remnants of a bilge pump apparatus (Carrazé 1976b: 156).

_Titan_ (middle or late first century B.C.E.): a pipe with diameter 0.05 m was found on the wreck (Benoît 1958: 10).

_Los Ullastres_ (50 B.C.E.–A.D. 25): the wreck displays about 5 m of lead pipes that run parallel to the frames of the wreck. One pipe terminates almost precisely above the preserved frame extremities. The pipes rest on the necks of cargo amphoras about 1 m above the hull planking and some 0.80 m above what are suggested to be the remains of a chain-pump (Foerster Laures 1978; 1979; Parker 1992a: 439).

_Île-Rousse_ (Augustan period or later): a pipe 0.37 m long and 0.06 m in diameter was found on the wreck. The standard bilge pump application should be kept in mind, but because this ship was carrying a cargo of _dolia_, an alternate explanation of the presence of the pipe has been suggested. It might represent part of a apparatus used
to deposit and remove liquids carried in the dolia (Brenni 1985: 254). Two more pipes, with outer diameters of 0.070 m and lengths of 1.195 m and 0.50 m, weigh 11 kg and 6 kg, respectively. Another measures 0.058 m in outer diameter and is 0.160 m long. A pipe of similar length, 0.170 m, has an outer diameter of 0.038 m; its lead thickness is 0.003 m (Alfonsi and Gandolfo 1988: 70, 71, fig. 1, 73, figs. 1, 3).

Grand-Ribaud D (last decade of the first century B.C.E.): four deformed fragments of lead pipe are semi-circular to triangular in section. Their cumulative length is ca. 2.9 m, each displaying a crushed extremity. One has a collar or flange at one end and no trace of assembly with another piece. Another rested vertically between fragments of two dolia, the primary cargo or cargo containers of the ship. The pipes were discovered in the forward third of the hull, if the cabin was located in the stern. This position is contrary to that of bilge pumps in other wrecks (Rival, Hesnard, and Carre 1988: 116–17, 126, pl. 46:1, 46:2; Pomey et al. 1988: 31) and may therefore lend credit to an association with the dolia.

Cabrera E (10 B.C.E.–A.D. 25?): three pieces of lead "drainpipes" were found (Parker 1992a: 82).

Chrétienné I (first century?): a pipe with a flange at one end was found (Pomey et al. 1988: 44).

Giglio Harbor (first to third century): a lead pipe 0.30–0.35 m in length was recovered, and is suggested to have been associated with the bilge pump. No diameter is reported, but a measurement taken from the photograph indicates an inner diameter near 0.06 m (Aroba et al. 1983: 126, fig. 6).

Cala Rossano (A.D. 1–50): lead tubing was discovered (Parker 1992a: 91).

Grand-Bassin B (first third of first century): a lead pipe fragment measuring about 0.30 m long and 0.05 m in diameter was recovered. The lead is 0.004 m thick (Solier 1982: 83).

Dramont D (mid-first century): a piece of a small pipe slightly oval in section and 0.23 m long has a maximum outer diameter of about 0.035 m and a maximum inner diameter of 0.03 m (Fiori and Joncheray 1973: 89, pl. 6:10, 90).

Petit-Congloué (mid-first century): a lead pipe was recovered from what is perhaps the stern area of the ship. It is 0.53 m long with an outer diameter of 0.07 m. The lead is 0.005 m thick (Corsi-Sciellano and Liou 1985: 26, 30, fig. 14). This too is a dolia wreck, and the function of the pipe could be associated with the dolia or a bilge pump (Brenni 1985: 252).
Tirapei Promontory (mid-first century): no details are available for a lead pipe discovered on this dolia wreck (Brenni 1985: 255).

La Garoupe (second half of first century): a large pipe of lead was found on this dolia wreck site (Fiori 1972: 35, 42).

Chiessi (A.D. 60–85): a lead pipe that is not very long and has flanges of different sizes at each end is associated with a sheet of lead decorated with a hunting scene. The sheet has a hole at one corner into which the pipe might have fit, but the pipe could be a scupper (Rossi 1982: 80, fig. 66, 81, figs. 67, 68; Parker 1992a: 140).

Culip 4 (A.D. 70–80): lead pipe fragments were found on this wreck of a vessel only 9–10 m long (Parker 1992a: 158).

Ben Afeli (A.D. 85–95): a section of lead pipe whose diameter tapers was found on the site (Parker 1992a: 71).

Torre Sgarrata (late second century): a lead pipe 0.68 m long was found on the site. Egg-shaped in section, its smaller inner diameter measured 0.065 m (P. Throckmorton sketch held in the Institute of Nautical Archaeology archives, Texas A&M University).

Ognina (second half of third century): some lead and earthenware pipes were found (Gargallo 1972: 445).

ANALYSIS

A number of characteristics are apparent with respect to lead boxes and pipes in general. The average thickness of box walls (ca. 0.0038 m) is somewhat thinner than that of pipe walls (0.0043 m). With regard to diameter, the cataloged pipes fall fairly neatly into three groups, though inner and outer diameters are not often specified. With the exception of the pipes from Cap des Mèdes, pipes found attached to boxes are 0.05–0.07 m in diameter. Virtually 75 percent of the pipes not associated with boxes also display diameters between 0.05 m and 0.07 m, while those with diameters between 0.025 and 0.038 m constitute about 17 percent. The remaining pipes measure 0.08–0.09 m in diameter.

Vitruvius (8.6.4) and Pliny (Nat. 31.31.58), both writing in the first century, give basic specifications governing the manufacture of lead pipes, or fistulae plumbeae. The weight in Roman pounds per 10 Roman feet is specified for each standard size of
pipe, and each size was designated according to the width of the lead sheet, expressed in ūūgītī (fingers) of ca. 0.0185 m each, before it was bent around a form and its seam closed. For example, the smallest standard pipe, a fistula quinaria, or "five," was therefore made from a lead sheet 5 digiti (0.0925 m) wide; it was to weigh 60 pounds (ca. 19.65 kg) over the 10-foot length (ca. 2.96 m). Similarly, a 10-foot length of a "twenty" was to weigh 240 pounds. Sextus Julius Frontinus, who was appointed curator aquarum (water commissioner) for the city of Rome in A.D. 97, had a different viewpoint, however. He included in his treatise on the aqueducts of Rome (De Aquis Urbis Romae) a much more detailed discussion of the sizing of lead pipes, and disagreed with Vitruvius and Pliny as to what the pipe size designations actually signified. He submitted (De Aquis Urbis Romae 1.25) that the most probable explanation was that the basic unit in the nomenclature was 1/4 of a digitus, so that a quinaria designated a pipe with a diameter of 5/4 of a digitus (= ca. 0.0231 m), and that pipe sizes were termed in this way up to the size of a "twenty," the diameter of which was therefore 20/4 = 5 digiti = ca. 0.0925 m. Following Frontinus, the diameters of the Caesarea pipes, ca. 0.03 m, would then correspond well to that of an "eight": 8/4 = 2 digititi = ca. 0.037 m; the diameters of the other sizes of pipes most often found on wreck sites (ca. 0.05–0.07 m), are then essentially "twelves" (12/4 = 3 digiti = 0.055 m), or "forties." The system Frontinus describes is presented in tabular form by Landels (1978: 55, table 2) and reproduced in Hodge (1992: 297), both of whom discuss the issues in depth (Landels 1978: 43, 44, table 1, 51, 55, table 2, 56–57; Hodge 1992: 296–97, 309–14 and esp. nn. 16–21).

The lead box and pipes from Caesarea are typical of those found on other sites in terms of construction, the thickness of the lead, and the diameter of the pipes. But with a volume of only about 9.5 liters, it is the smallest box yet recovered with a configuration suggestive of use in a bilge pump apparatus. Moreover, the arrangement of pipe holes in the box is not easily compatible with the concept of a chain-pump catch basin. The presence of a hole near the top of the box on one long side suggests a pipe was fitted there, which would have required that the bilge water, after having been raised to some level, flowed either from a chain-pump catch basin or other (presumably larger) reservoir through the pipe to the box. As such, it would have been a small secondary receptacle from which the water exited. This elaborate and cumbersome arrangement urges another explanation. If the box was indeed part of the bilge evacuation apparatus, perhaps the pipe on the long side near the top was
connected to a force pump that delivered water directly to the box. With two exit pipes of diameters equal to that of the input pipe, the box could have received and evacuated quantities of water delivered by all but the most efficient force pump. It must be acknowledged, however, that the box and pipe could have served a still unknown function on the ship.

Indeed, a lead box on a wreck site need not always be regarded as a remnant of the bilge pump apparatus. This seems especially likely in view of the large number of sites that have yielded lead pipes but not boxes. Such sites date from the third century B.C.E. through the first century A.D., with one each dating to the second and third centuries. Further, the lead pipe found on the wreck of a merchant vessel at La Ciotat could be associated with the operation of a terracotta *baignoire sabot* (slipper bath), a bath tub taking the form of a slipper or clog, also recovered from the site (Benfôt 1958: 24, fig. 28, 25–26; 1960: 43; 1961: 174–75; Gianfrotta and Pomey 1981: 182). Finally, it is conceivable that lead pipes discovered on *dolia* wrecks were employed in the filling and emptying of those large containers.

It is curious that all lead boxes recovered so far are from wrecks dated to the first centuries B.C.E. and A.D. If they are indeed indicative of bilge pump installations, does their conspicuous confinement to wrecks of this period mean that bilge water was handled differently in earlier and later periods? Or is this simply a reflection of our incomplete knowledge? Similarly, if theories concerning the role of lead pipes in bilge pumps are correct, does their general absence from wrecks after the first century A.D. suggest new designs eliminated the use of lead pipes?

In light of these and other questions, identification of the Caesarea box as part of a bilge pump apparatus is dubious, although its association with a force pump should not be discounted.
Notes

1. See Foerster Laures (1989) for an idea regarding the origins of bilge pumps. See Torr (1964: 61, n. 139), Casson (1986: 175–76), and Oleson (1984) for ancient references to matters of the bilge. There are no indisputable representations of bilge pump components on ships, but it has been suggested that certain vertical elements above deck aft of amidships on vessels in some North African mosaics could represent components of bilge pumps (Pomey 1982: 148–50). These representations can be seen in Foucher 1957: 10, fig. 3, 12, fig. 4, 14, fig. 5; 1967: 84, fig. 1, 85, fig. 2, 90, fig. 16, 91, fig. 20. Some of the same mosaics are pictured in Ericsson 1984: 35, pl. 13, 36, pl. 14, and Basch 1987: 484, fig. 1098, 485, fig. 1099, 485, fig. 1105, 487, figs. 1108–10. It has also been suggested that a similar feature visible in the stern of the Europa, as depicted in a graffito from Pompeii (Throckmorton 1972: 72, fig. 11), could be a bilge pump element (Carre and Jézégou 1985: 140, n. 69).

2. For more evidence of chain-pumps on ships see Gassend, Liou, and Ximénes 1985: opposite 96, fig. 19, opposite 98, fig. 21, 101–3; D’Atri 1986; D’Atri and Gianfrotta 1986; Arata 1988; Dumontier and Joncheray 1991: 110, 130, 132, 137–38; Parker 1992a: 91; Carre 1993: 25–26; Liou and Gassend 1991: 244, fig. 11, 252–58. Among the components of such chain-pumps were wooden disks threaded on to and secured to a rope, the assembly constituting the “chain.” Numerous disks have been recovered from the wrecks mentioned in the foregoing references, but I have found only one instance of wood identification. The sample taken from one disk found on the wreck at Ladispoli has been identified as Populus sp., poplar (Meucci 1993: 23, 40, fig. 24, 47–49, 49, fig. 35, 58, fig. 46).

3. Pliny (Nat. 34.48.160) notes that the compound used to solder pipes consists of two parts black lead (lead) and one part white lead (tin). Nriagu (1983: 242) provides descriptions of three ancient soldering techniques.

4. Based on the Roman libra or as of 327.45 grams and the Roman pes comprising 16 digitii and 0.296 m (F.N. Pryce and M. Lang in OCD², s.vv. “weights” and “measures”).

5. I thank Professor J.P. Oleson for referring me to Hodge’s discussion, without which the foregoing would have been incomplete and probably erroneous.
CHAPTER X
LEAD RINGS FROM UNDERWATER MEDITERRANEAN SITES

INTRODUCTION

The small lead rings recovered at Caesarea could have served as either brailing rings or line or net “trips.” The question of function is problematic, because no brailing rings have ever been discovered fastened to a sail, so it is not known which of the sundry types of rings found on wreck sites were used for brailing. Known rings are circular, semi-circular, or rectangular in section, with or without lugs, holes, or splits, and can exhibit any combination of these features. Moreover, when a number of rings are found in association or in close proximity, they usually vary in size or design, or both. It has also been noted that the use of lead for such rings would not have been very logical in view of the weight involved (Santamaria 1975: 190). The issue is clouded further by the well-known practice of modern as well as ancient seafarers of using rings to free objects as small as fish hooks and as large as anchors from the sea bottom. Such rings are often identical in design to smaller rings thought to be brailing rings. Consequently, it is essentially impossible to determine the precise function of any small lead ring found alone on the sea floor.

Line or Net Trips

When rings are used in this capacity, a line is tied through a hole in the ring or ring lug, or to the ring itself. The ring is slipped over the fouled line or net and allowed to slide down to where it is caught or hung up. By maneuvering the ring with the attached line, anything from a fishhook to an anchor can be freed and retrieved (Foerster Laures 1985b; Pulak and Townsend 1987: 39–40). Many rings of stone, lead, or iron have been recovered that are far too large to have been used for anything but the freeing of heavy lines and ropes. Such rings have been found at the following wreck sites: Serçe Limanı (Hellenistic) (Pulak and Townsend 1987: 39–41), Dramont A (Santamaria 1975: 190), Grand Congloué (Benoît 1961: 176, pl. 30:1, 178, fig. 94), Lavezzi 5 (Bebko 1971: 40, pl. 34:235), and possibly Giglio (Bound and Vallentine
1983: 114, fig. 3, 119–20) and Porticello (Eiseman 1979: 40–41, 80, figs. 2.53, 2.54; Eiseman and Ridgeway 1987: 23, 24, figs. 2–23, 2–24).  

Brailing Rings

In the Graeco-Roman period, sailors varied the shape of the sail and the amount of sail area exposed to the wind by means of brailing lines. These consisted of ropes probably fastened to the boltrope at the bottom of the sail that passed up through rings on the sail’s leeward face, then over the yard through fairleads or perhaps small blocks attached to the yard, and down to the deck aft. As conditions dictated, the sail area was decreased or increased by hauling in or paying out the brailing lines along the length of the sail (Casson 1986: fig. 188).

Greek and Roman pictorial evidence for brailing lines is plentiful (DeVries and Katzev 1972: 56–57, ills. 10, 11, 13; Casson 1986: figs. 33, 81, 82, 90, 91, 110, 117, 150, 151, and possibly figs. 88, 89; Throckmorton 1972: 72, fig. 11), but actual rings do not appear in the representations until the Roman period. Two vessels with brailing gear, including rings, are depicted in a mosaic of a Nile scene dated to the first century B.C.E. (Viereck 1975: photo 8). Brailing rings are also visible on a sail in a relief in the Lamourguier museum in Narbonne (Rougé 1966: pl. 4:b), on the Portus relief of ca. A.D. 200 (Casson 1986: figs. 144, 146; Throckmorton 1972: 86, ill. 16), and on a vessel in a mosaic from a third-century house in Rome (Casson 1986: fig. 154).

There are numerous literary references to brailing lines in Homer (Odyssey 5.260), Herodotus (2.36), and later writers (Casson 1986: 259, n. 3), but few to the actual rings themselves (Casson 1986: 257, n. 135, 258, n. 136).

CATALOG OF LEAD AND WOODEN RINGS FROM UNDERWATER MEDITERRANEAN SITES

Numerous sites throughout the Mediterranean have yielded lead rings similar to those found at Caesarea, but most are larger, and many display additional features. The following alphabetical catalog of sites yielding lead rings is not exhaustive, but it is probably representative of most such rings found to date. There is little or no practical difference between the rings, whether thought to be brailing rings or trips. Three sites that have yielded wooden rings that are suggested to be brailing rings are
included for completeness.

**Lead Rings**

*La Balise du Pretre* (second century B.C.E.): a lead ring is split on one side and has a lug pierced by one hole. Inner ring dimensions are ca. 0.085 \times 0.067 m, and outer dimensions, including the lug, are ca. 0.116 \times 0.098 m (Bebko 1971: 3, 12, pl. 5:26).

*Bruzzi Islands*: a lead ring ca. 0.12 m in outer diameter displaying a lug with a hole is termed a brailing ring (Bebko 1971: 53, pl. 48:326), but seems a bit large for the purpose.

*Cap d'Antibes*: a lead ring has an outer diameter of 0.085 m (Bound and Vallintine 1983: 120).

*Cap des Mèdes* (first century B.C.E.?): three lead rings were found beneath the lead tank that had fallen into the shaft of the bilge pump. They are described as "open" (Tchernia 1969b: 477).

*Giglio* (ca. 600 B.C.E.): four lead rings with diameters of 0.058–0.077 m are known to have come from the wreck. Two are flat on one surface and inner diameters are ca. 0.05 m; outer diameters are just under 0.07 m. There are no lugs, holes, or splits on either of these two rings (Bound 1985: 60, fig. 5.9, 61; 1991: 27, fig. 60).

*Grand Congloué* (110–70 B.C.E.): numerous lead rings of all sizes were recovered. Most (80) were only ca. 0.08 m in outer diameter, and as at Caesarea, occurred in three forms: flat on both faces, rounded on one face and flat on the other, and rounded on both faces (Benoît 1961: 176, pl. 30, 177, pl. 31, 178, fig. 94). Some rings of diameter 0.09–0.12 m have lugs pierced by one or two holes (Benoît 1961: 176, pl. 30:2–6). One thick ring of only 0.05 m diameter exhibits a hole through the ring itself (Benoît 1952: 274, fig. 37; 1961: 177, pl. 31:1). Some of the small rings 0.08–0.09 m in diameter and 0.01–0.03 m in section show signs of wear (Benoît 1952: 274). Some are stretched and distorted in the direction of the lugs, and others are folded over themselves. One ring with a lug is split on one side (Benoît 1961: 176, pl. 30:3), while splits also occur in other rings with no lugs (Benoît 1961: 176, pl. 30:7, 9).

*Guidaloca* (Republican period): rings of lead are on the site (Purpura 1986: 157).

*Kyrenia* (late fourth century B.C.E.): more than 100 flat lead rings thought to be brailing rings were discovered in the stern area of the ship (Swiny and Katzev 1973:
351). One photograph shows rings with no splits, lugs, or holes anywhere (Katzev 1970: 853, 854). Other rings do exhibit lugs with holes (J.R. Steffy, personal communication).

Lake Nemi (mid-first century): five lead rings were found, three of which were oblong and measured 0.05 x 0.10 m, 0.06 x 0.10 m, and 0.07 x 0.10 m. Two were 0.05 x 0.06 m and 0.055 x 0.06 m (Ucelli 1950: 412).

Lavozzi 5 (dispersed site): a small lead ring ca. 0.07 m in outer diameter was recovered (Bebko 1971: 41, pl. 35:240).

Mahdia (early first century B.C.E.): bronze rings a mere 0.02 m in diameter with lugs but no holes anywhere were identified as brailing rings (Benoit 1952: 275; 1961: 179).

Taranto (ca. 350 B.C.E.): a ring similar to those found at Grand Congloué was recovered (McCann 1972: 182).

Tre Senghe A (second or first century B.C.E.): two lead rings were found (Freschi 1982b).

Small lead rings thought to be line trips have also been found off Île Riou (Dumas 1972a: 111, 113, photo 2), and off the Sicilian coast (Gargallo 1962: 194, 195, fig. 5). Lead rings have been recovered from isolated spots along various mainland and island coastlines, with no archaeological context, and therefore could be modern or ancient (Benoit 1960: 43; Mouchot 1970b: 311, fig. 4, 312, fig. 5; Fiori and Joncheray 1973: 89, pl. 6:1–6). See also Parker (1992a: entry nos. 47, 347, 355, 424, 530, 593, 615, 746) for more reports of rings that could be net trips or brailing rings.

**Wooden Rings**

**Chrétienne C** (175–150 B.C.E.): a rounded piece of wood with one straight edge has one large hole in the center and two smaller ones along the straight edge. The wood is some 0.016 m thick and 0.055 x 0.053 m at the straight edge. The central hole is 0.03 m in diameter, the smaller ones about 0.008 m. No specific function is proposed for this object (Joncheray 1975a: 104, 105, fig. 50:3). Its configuration is consistent with service as a brailing ring, as it could have been attached to the sail by means of the two small holes along the straight edge. The weight advantage over lead is obvious, but reliability and longevity might be inferior. The diameter of the central hole seems only just sufficient for a brailing rope.
Ladispoli (early first century): an object nearly identical to the wooden ring recovered from Wreck C at Chrétienne was excavated (Carre 1993: 26, and n. 50). It measures 0.079 x 0.07 m, and exhibits a central hole 0.036 m in diameter, with two smaller holes along the straight edge. Carre has not seen the ring, but suggests that, given the similarity to those found at La Madrague de Giens (see below), it also has a groove or notch on its under surface. She favors the identification of these rings as brailing rings.

La Madrague de Giens (60–40 B.C.E.): some of the lead and wood rings found on the wreck are believed to have belonged to a sail (Liou and Pomey 1985: 565, 567, and n. 67). Carre (1993: 26, and n. 50) adds that three complete wooden rings and fragments of five others were found. They are of the same type as those found on Chrétienne C and the wreck at Ladispoli. They measure 0.078 m long and 0.069 m in breadth, with a central hole 0.037 m in diameter. The rings also display a notch or groove on their under surfaces.

CONCLUSION

This search for rings configured like those from Caesarea has revealed that approximately 11 of 34 illustrated rings from the sites cataloged above have no lugs, splits, or holes. But it seems likely that the vast majority of rings that have been found on the Mediterranean sea bed have not been published, so any statements regarding the relative frequency of occurrence of the various configurations and their use either as brailing rings or line trips is premature. The lead rings found on other shipwreck sites must have been used in both capacities, as both functions could have been served by almost any configuration.

Because the inner diameters of the Caesarea rings (0.018–0.037 m) are among the smallest that have been reported from the above sites, they could have served as fishing line trips or as brailing rings on a rather small sail, as the need arose.
Notes

1. See Mouchot (1970b: 312, 313, fig. 6) and Pulak and Townsend (1987: 40–41, nn. 39, 40, 46–49) for other examples of large rings thought to be line or net trips.
CHAPTER XI

CORDAGE USED ON GRAECO-ROMAN MEDITERRANEAN SHIPS

There is only sparse literary and pictorial evidence for the nature of ancient cordage, and its organic nature makes it relatively uncommon on both terrestrial and underwater sites. In Roman times rope makers were known as restiones (Suetonius, Augustus 2.6), but there seem to be no detailed descriptions of the actual making of rope in the Graeco-Roman literature.¹ Rougé (1966: 191, n. 3) theorizes that there were workers known as stuppatores restiones (rope caulkers) who applied tar or pitch to cordage to improve its durability at sea. His suggestion is inspired by a scene on a mosaic at Ostia in which the pair of letters SR appears, but he acknowledges that this is an almost unverifiable idea. With the exception of (at least) one piece of rope from the wreck at Ma’agan Michael, Israel, and the ropes used to help bind together the river vessel found at Comacchio, no pitch-like substances are reported on cordage described in the archaeological literature I have read. Restiones and stuppatores shared a stall in the Piazza delle Corporazioni in Ostia, however, and probably were closely associated (Hermansen 1982).

LITERARY REFERENCES TO ANCIENT NAUTICAL CORDAGE

Ancient writers mention ship’s ropes made of papyrus, flax, hemp, and esparto grass. In Homer (Odyssey 21.390–91) there is a reference to a ship’s cable made from βάτος, papyrus. Theophrastus writes of papyrus ropes made by the Egyptians, and that Antigonus had fashioned from Syrian papyrus the cables for his ships (HP 4.8.4; cf. Pliny, Nat. 13.22.73).² Herodotus (7.25.1, 7.34.1, 7.36.4) relates that Xerxes’ bridges across the Styx were built with papyrus ropes furnished by Egyptians and with flax ropes made by Phoenicians. In the Loeb edition of Herodotus (1922: 339, n. 1), it is noted that λευκόγαλινος, which is translated as flax in this passage, is apparently Spanish esparto grass imported by the Phoenicians. In Euripides’ Iphigenia Taurica (1043), a ship is moored with “flaxen bridles,” and Ovid (Fasti 3.587)³ tells of
a sail lowered by (presumably ropes of) "twisted flax." Palm fiber rope is mentioned in a fragmentary papyrus document (Casson 1986: 257, n. 135, 258), and Pliny (Nat. 16.37.89) says strong ropes of palm leaves are made in the east and are especially suited for use in water. According to Rougé (1981: 66–67), there are also references to the maritime use of linden bark and certain rushes. Pliny (Nat. 24.40.65) is certain that Spanish and African esparto was not common in Homer’s time. While speculating upon whether or not the word σπὶρα in a passage in Homer (Iliad 2.135) is a reference to the use of genista by the Greeks, he states that while ships were made with sewn seams in that time (presumably that of the Trojan war), they were sewn with flax, never esparto. Ropes made from hemp acquired from the Rhone valley and Spanish esparto grass are included in a description of the equipment used on Hiero’s Syracusa (Athenaeus 5.206f). In 217 B.C.E. Hasdrubal, the founder of Carthago Nuovo (Cartagena), acquired a great quantity of esparto grass for his navy (Livy 22.20.6). Pliny (Nat. 19.8.29) says that on dry land hemp ropes are preferred to those of esparto grass but Spanish esparto grass has unrivalled utility in water, at sea, and for the rigging of ships and other things (Nat. 19.7.26–19.8.30).

**VISUAL REPRESENTATIONS OF ANCIENT CORDAGE**

Detailed depictions of ropes on ships of the Greek and Roman period are relatively scarce, and they contribute little to our knowledge of what kinds of materials were used or how ropes were made. The oldest representation of rope-making appears in a Theban tomb painting dated about 1500 B.C.E. It shows one man with a tool for twisting the strands together walking backward away from a second man holding the strands taught. Finished ropes hang on the wall, while others lie on the floor (Gaitzsch 1985: 47, fig. 11). A relief on a sarcophagus of the Roman Imperial period found at Ostia depicts a shoemaker and a ropemaker. The latter is using a tool somewhat similar to the one in the painting at Thebes to twist some type of material together. As it would take more than one person to twist strands into a rope, this scene is interpreted as an illustration of yarns being twisted into strands (Gaitzsch 1985: 44, fig. 7, 49).

Ropes are shown as laid either right or left, but usually there are examples of both in the same representation. This occurs on the Portus relief (Casson 1986: figs. 144,
The sarcophagus found at Sidon (Casson 1986: fig. 156; Throckmorton 1972: 80, ill. 2), and on a sarcophagus from Beirut (Casson 1986: fig. 147). These reliefs all date to the second and third centuries. Similar problems are found in representations of cordage that is not nautical in nature. On the Monument of the Haterii, dated to ca. A.D. 100, the ropes on the right side of the crane are laid right while those on the left side are laid left, with one exception. One rope passing through the second block from the top of the crane on the left side is laid right as it comes off the top of the sheave, but laid left as it comes off the bottom of the same sheave (Shaw 1967: pl. 78a; White 1984: 15, fig. 3). Nautical ropes depicted on a portion of the triumphal arch at Orange (ca. A.D. 21–27), however, are all laid in one direction, to the right (Amy 1962: pl. 25; Oleson 1983: 160, fig. 5). This evidence demonstrates the futility of attempting to determine from representations if ropes of particular sizes and functions were characteristically laid left or right. The archaeological evidence is more helpful.

REMAINS OF ANCIENT NAUTICAL CORDAGE

Although perhaps not directly pertinent to a comparative assessment of the ropes from the Caesarea wreck, the cordage from the Royal ship of Cheops, Cape Gelidonya, Ezion Geber (Eilat), Nin, and Xanten Harbor is included below for completeness.6

Catalog of Ancient Nautical Cordage

Royal Ship of Cheops (ca. 2500 B.C.E.): the pit that held the dismantled vessel contained great quantities of rope made from the leaves and culms (stems) of halfa grass (Desmostachya bipinnata L.). They were of diameters 0.01, 0.015, and 0.025 m (Nour et al. 1960: 42–45, 49, 68, 69, and pls. 32:B, 38:B, 41:A, 63:A, 63:B, 64, 65). Some ropes still lashed timbers together (pl. 63:A), others were thrown between the layers of wood (pl. 63:B), and a large number were found beneath the wooden members (pl. 64). This arrangement of both "new" and used rope makes feasible the notion that at least some of it was nautical in nature, so that the boat could be properly assembled (or reassembled — see above, pp. 150, 153, n. 6) and operated in the afterworld (see also pl. 38:B). Lipke (1985: 21) reports diameters of 0.01, 0.015, and
0.02 m, but these dimensions are not adjusted for shrinkage (this might also be true for the dimensions in Nour et al. 1960, as well). Lipke also states that most of the cordage is of three stands laid right, but in the illustrations it is all laid left (see Lipke 1984: 14, 17, 19, 27, fig. 12, 24, 91, fig. 60; 1985: 24, figs. 3.4, 3.5, 27). This is because he describes the rope as it recedes from the viewer (P. Lipke, personal communication 1994; see above, p. 90, n. 5).

**Cape Gelidonya** (second half of thirteenth century B.C.E.): the wreck site yielded pieces of three different ropes. One small fragment of diameter 0.009–0.010 m consisted of two strands laid left. The strands each had diameters of 0.005–0.0057 m and comprised about seven stems loosely twisted right. Two lengths of rope of unspecified diameter were made from grass and palm fibers. The palm fibers belong to the genus *Hyphaene* and are possibly from the doum palm (*Hyphaene thebaica* Mart.). The grass was perhaps *Stipa tenacissima* L., esparto grass, but this could not be determined positively. Strands consisted of fibers twisted loosely to the right; two strands were then laid left to form the rope. The third piece was 1.5 m long and made from twisted grass stems possibly of *Phragmites communis* var. *isicus* (du Plat Taylor 1967: 160–61).

**Ezion-Geber** (eighth to fourth centuries B.C.E.): ropes perhaps from nautical contexts were found at this port of King Solomon’s merchant fleet (DeVries and Katz 1972: 38, fig. 1). The smallest piece of cordage pictured appears to be made of fibers twisted to the right, as is a larger single strand of coarser material. Similar in diameter to the latter are two pieces of rope that comprise three strands laid left. The largest fragment in the photo is laid left, but other details are unclear.

**Ma’agan Michael** (ca. 400 B.C.E.): numerous lengths of three-strand rope up to 0.04 m in diameter were found on the site. They are laid left, and at least one sample exhibits clear evidence of having been tared. Upon drying, the piece was hard; when broken, the sectional surface was found to be dark and shiny. Identification of the tarring material is in progress (Kahanov 1991: 6; J.P. Rosloff, personal communication 1993; Linder 1992: 32). This is the only example I have found of tared cordage from a Graeco-Roman nautical site in the Mediterranean.

**Marsala** (mid-third century B.C.E.): a variety of ship’s cordage was recovered from the Punic ship. All the rope, cord, plait, and string is of the *Stipa* genus, probably *Stipa tenacissima* L. Most of the rope is 0.03 m in diameter, with the heaviest measuring 0.055 m. The three strands of both sizes were laid left, unlike the
smaller cords of less than 0.01 m in diameter, which were laid right. The excavator states that the rope 0.055 m in diameter could have taken the weight of an anchor (Frost 1973b: 40, fig. 9; 1981b: 93–97, 100).

El Sec (360–340 B.C.E.): remains of rope were found (Parker 1992: 393).

Dead Sea (ca. 350–110 B.C.E.): three stone anchors were discovered on the exposed sea bed, two with ropes tied to them. Both ropes and the cord seizing the rope of Anchor A are identified as leaflets of the date palm, Phoenix dactylifera, a locally available material. The anchor A rope, 0.035–0.04 m in diameter, is of two strands laid left. Each strand measures 0.02 m in diameter and is twisted to the right. Strands are in turn made from yarns ca. 0.002 m in diameter, twisted left. The cord used as seizing consists of two strands laid right and is 0.0035–0.0038 m in diameter. The rope found tied to anchor C is 0.053–0.056 m in diameter, of three strands laid left, each 0.025–0.030 m in diameter and twisted right (Hadas 1992; Shimoni, Yucha, and Werker 1992).

Cap Gros (end of the second to first half of the first century B.C.E.): remnants of the rope that carried the wooden disks of a chain-pump were found within some of the disks. The rope is either Stipa tenacissima, Lygeum spartum (a halfa grass, and another source of esparto), or Ampelodesmos tenax (also known as Ampelodesmos mauritianca) (Joncheray 1989a: 75, photo, 76).

Cap Béar (first century B.C.E.): unidentified plaited vegetal cordage was used to aid the fastening of frames to the planking (see above, p. 156) (Pomey et al. 1988: 2–3).

La Madrague de Giens (60–40 B.C.E.): rope was found in a concretion (Parker 1992: 250).

Comacchio (last quarter of first century B.C.E.): both plaited and twisted cordage of Stipa tenacissima was used to help fasten the hull of this river vessel. Three-strand plaited cordage a maximum of 0.013 m wide and 0.008 m thick was employed to bind together the frames and hull planking. The strands at each end of the lengths of plait were left loose. The large ropes used to secure hull planks to one another are of esparto grass covered in woolen fabric and tarred or pitched, as is also the cordage made from linden bark (Tilia sp.) that was lashed in place over the interior plank seams. Portions of three ropes not used as hull fastenings are of three or four strands laid left and measure 0.04 m, 0.054 m, and 0.08 m in diameter. The one measuring 0.054 m consists of three strands, each 0.025 m in diameter; the smallest is made of
three strands, each 0.02 m diameter, and the largest comprises three strands, each 0.04 m in diameter. Generally, the individual strands consist of yarns twisted right, which in turn are made of fiber bundles twisted left. (Bonino 1985: 91–93; 1990: 35–37, 41, fig. 5; Berti 1986: 26, 28, figs. 19, 20, 31, fig. 24; Berti et al. 1990: 279 [catalog nos. 278, 279], 280, figs. 278, 279; and cf. her catalog nos. 280–283; Berti 1990a: 62, fig. 9; 1990b: 29, 30, figs. 2, 4, 31, fig. 10, 33, fig. 3; 1992: 220, figs. 1, 2, 224; Castelletti et al. 1990b; 1990c; Mello and Pizzigoni 1990).

*Nin* (first century): the planks of this sewn boat were bound to one another with pitch-soaked string probably of flax or yellow-barked willow. The string comprised three yarns twisted to the right that passed through holes 0.003–0.004 m in diameter (Brusic' and Domjan 1985: 71, 76, fig. 6:6, 77).

*Terrasini* (first century): two rope fragments laid left were recovered. Their diameters measure ca. 0.04 m and 0.028 m (Giustolisi 1975: pl. 16).

*Cala Rossano* (A.D. 1–50?): three meters of “cable” were discovered (Parker 1992a: 90).

*Lake Nemi* (mid-first century): the hawser was still attached to the large wooden anchor associated with the two barges found in the lake. It was made of pure esparto grass laid left and had a diameter of ca. 0.10 m. The small ropes to which the hawser was tied, and the smaller ropes that secured those to the anchor, were laid left or right. Other ropes of hemp and esparto grass were also found on the ships (Ucelli 1950: 243, fig. 275, 245, fig. 278, 268, 431, no. 440, 442, no. 589).

*St.-Gervais* 3 (mid-first century): a small rope 0.015 m in diameter, made of three strands laid left, was discovered within the timbers (Liou and Gassend 1991: 229, 233, fig. 95). In diameter and direction of twist it is identical to the rope found in the watercourses at Caesarea.

*Xanten Harbor* (A.D. 70–305): this Roman site on the upper Rhine known as Colonia Ulpia Traiana yielded four pieces of rope made from the rolled leaves of *Stipa tenacissima*. Not found in a nautical context but in a well, the fragments are 0.035 m in diameter and together measure 0.80 m in length. Each is made of two strands laid right; each strand is 0.02–0.025 m thick and consists of yarns 0.004–0.006 m in diameter. The yarn each comprised twisted fibers 0.0003–0.0007 m thick (Körber-Grohne 1979).

Fiumicino 1 (third to fifth centuries): segments of rope were found beneath the keel. They consist of three strands laid left and measure from ca. 0.012 m to 0.013 m in diameter. Each strand is composed of three yarns laid left (Scriniari 1979: 43, 45, fig. 20, pl. 32:2).

Port-Vendres 1 (late fourth century or early fifth century): cordage of various types and dimensions was found on the site (Liou 1974: 423, 427; 1975: 572), in addition to the rope found in the limber holes of the vessel.

St.-Gervais 2 (late sixth or early seventh century): rope was found within wooden discs associated with a chain-pump discovered on the wreck, and in other similar discs from other wreck sites (Carre and Jézégou 1985).

Golo (undated): several bits of rotten cable were found with this vessel. One fragment was 0.027 m in diameter, laid left. It appears to have been made of two strands, but this is uncertain (Basch 1973: 330, fig. 1, 342, appendix 1).

ANALYSIS

According to one study of the ancient literature and of evidence for the distribution of papyrus in antiquity through modern times (Lewis 1974: 3–20), the lower Nile valley, especially the Delta area, was in all probability the only commercial production center for papyrus and its products in classical antiquity. Lewis acknowledges its possible occurrence along the Niger river and on Grand Canary Island, but argues that it was introduced to the Tigris and Euphrates valley by the Seleucids between about 300 B.C.E and 150 B.C.E. It may have been found in India and Etruria, but Lewis maintains that if it did grow in Etruria, it would not have been used in the paper industry. He does accept that it grew near Lake Tiberias in Palestine and that Antigonus I Monophthalmus (ca. 382–301 B.C.E.) used it for his fleet’s cables (Theophrastus, HP 4.8.4; Pliny, Nat. 13.22.73).

Literary testimony to the use of palm fiber is borne out by the Cape Gelidonya excavation and by the Dead Sea anchor ropes. This is also true for the linden in evidence on the wreck at Comacchio. Rougé (1981: 66) observes that flax became
too valuable for such utilitarian purposes, presumably by virtue of its growing role in the manufacture of textiles (cf. Tacitus, *Germania* 17; Pliny, *Nat.* 19.1.1–19.6.26). The possible use of flax on the Liburnian sewn boat at Nin may not seriously compromise Rouge’s comment, as Brusic and Domjan (1985: 82–83) suggest a notably long Liburnian boatbuilding tradition. Perhaps such a tradition included the use of specific sewing materials. Further, if the string at Nin is flax, Pliny’s testament to the use of flax to sew Greek boats in the time of the Trojan war becomes more credible. This in turn casts a positive light on Williams’ argument for Nestor’s production of flax ropes for use in that same war. The presence of esparto grass on the hull at Comacchio tends to support an inference that may be drawn from the same passage in Pliny, i.e., that in his time esparto was used to assemble sewn boats.

Based on the available archaeological evidence, the material of choice for nautical cordage in the Roman period was esparto grass, prized for its exceptional resistance to rot. Including Caesarea, it has been found on probably five and possibly six of the nine cataloged nautical sites yielding nautical cordage that has been identified. This evidence supports Lewis’ deduction (1974: 26) that esparto grass was favored over papyrus for ship’s cables by the time of Pliny, who after repeating Theophrastus’ report (*HP* 4.8.4) of its use by Antigonus in Palestine (*Nat.* 13.22.73), adds the phrase “...*nondum sparto communicato...*,” literally “…esparto not yet being common....” This grass was not cultivated by the Romans, however, but grew only wild in southeastern Spain and northern Africa (Pliny, *Nat.* 19.7.26–27; Strabo 3.160), as it does today (Körber-Grohne 1979: 168, 171).

The manufacture of ancient nautical cordage, according to the evidence presented here, appears to have been characterized by consistent practices. Only cordage of diameter less than ca. 0.01 m is laid right; larger ropes are laid left, usually in three strands. This is perfectly logical, given that cordage was (and still is) composed of small units twisted in one direction to produce a larger component, a number of which were then twisted together in the opposite direction, and so on, until the desired diameter was reached. Working backwards from a substantial three-strand rope, then, it comprised three strands laid left that were themselves made of smaller yarns twisted to the right. Those yarns could also serve as smaller cordage of less than ca. 0.01 m diameter. They had been produced by twisting the fibers, stems, leaves, etc., to the left. Therefore, given that in all the adequately documented cordage cataloged here the strands are laid left to form the rope, then the fibers were usually first twisted left.
Notes

1. In *Odyssey* 10.165–68, Odysseus weaves together twigs and osiers (probably willow) to fashion a well-twisted rope with which he hauls a downed stag back to his hungry men. Xenophon (*Cynegieticus* 2.5, 10.2) specifies the number of yarns and strands to be used for the cords of different sizes and types of hunting nets. Pollux (5.27) provides similar information for particular kinds of rope (Gaitzsch 1985: 46-47). Gaitzsch (1985: 46, and n. 23) also notes that, although we have no detailed descriptions of rope manufacture in the literature, there are references from Classical Greek times to the devices used to twist the fibers. See Torr (1964: 97, n. 211) for more general references to rope.

2. Lewis (1974: 26, n. 10) cites documents of the Roman period that include papyrus ropes in lists of nautical gear.

3. The translations of both Euripides and Ovid are by Casson (1986: 231, n. 27). R. Williams (1986) argues plausibly for the availability of flax in the Pylos area during the later fifth century B.C.E., and even notes the plant was worked in the area in the 1950s. She proposes that in *Achilieid* 1.413–22, Statius is referring to Nestor’s contribution not of siege engines but of flaxen ropes to the war effort against Troy.


5. Morton (1986: 91) asserts that Pliny’s distinction (*Nat.* 19.7.26–19.8.30, 24.40.65) between two plants found in Spain, both bearing the name *spartum* and used for making rope, is one of two instances of Pliny’s original contributions to botanical knowledge.

6. Pompeii has yielded numerous types and sizes of carbonized cordage. Some fragments are hemp, of three strands laid left. Diameters range from 0.003 m to 0.025 m (Gaitzsch 1985: 41, 42, fig. 3).

7. The spun thread in woven cloth recovered from the wreck at Comacchio is twisted left (see Castelletti et al. 1990b: 157, 160, table 1). The question of in which direction fibers were first twisted during the manufacturing process has been a source of some disagreement. It could be a function of the natural twist a fiber exhibits when wet or, as suggested recently (Barber 1991: 65–68), it could be the product of the type of spindle used (high- or low-whorl) to do the spinning and with which hand the spinning was done.
CHAPTER XII

PINE CONES FOUND ON GRAECO-ROMAN MEDITERRANEAN SHIPWRECKS

A pine cone of the Italian stone pine (*Pinus pinea*) or umbrella pine discovered on the wreck at Caesarea could represent cargo, provisions for the passengers and crew, or it might be evidence of dunnage used in the hold.

RELATION TO FOOD AND DRINK

Columella, an agricultural writer of the first century, mentions the cultivation of *Pinus pinea* cones (*De Arboribus* 22.3), and Palladius, writing in the fourth century, provides instructions for the cultivation of the trees and cones (12.7.9, 12.7.12). A treatise by Apicius describes the culinary uses by Romans of *Pinus pinea* seeds (Kislev 1988: 77), and prices for cleaned pine seeds (probably *Pinus pinea*) were fixed by Diocletian's edict on maximum prices (6.54). From this evidence Kislev (1988: 74) concludes that the πεζκης...ημερον, or cultivated pine, mentioned by Theophrastus (HP 3.9.1) is a reference to *Pinus pinea*.

On terrestrial sites, such cones have been discovered in houses, cooking pots, and fruit baskets, as well as in graves and temples (Kislev 1988: 75–76, 78; Girard and Tchernia 1978: 118, n. 6). On the wreck at Giens, 61 *Pinus pinea* cones were found strewn among the wine amphoras; it is argued that they were part of the cargo, like the coarseware also found distributed among the amphoras of the ship (Tchernia and Pomey 1978: pls. 6:2, 12; Couvert 1978: 111; Girard and Tchernia 1978). From this evidence it is clear that the seeds of *Pinus pinea* trees were sought in antiquity for ritual purposes and particularly for their food value, as they are today (Meiggs 1982: 44; Kislev 1988: 77).

Columella (*De Re Rustica* 12.30.2) also mentions the use of pine cones in the processing of wine. The rims and necks of wine amphoras are to be rubbed with the
cones whenever the wine is being attended to. Interestingly enough, pine cones were found in the necks of some of the wine amphoras on the wreck at Albenga. The excavator suggests they were to serve an aromatic purpose, to preserve the taste of the wine or other liquids during the voyage (Lamboglia 1953: 155-56). This view is contested by Girard and Tchernia (1978: 118), however, who argue the cones were used as opercula.

Pine cones of undetermined species were found on Wreck 1 at Laurons (Ximénès and Moerman 1987: 174, n. 13), and the scales of pine cones and shells of pine seeds were also discovered in one of the smaller vessels excavated at Fiumicino (Scriniari 1979: 28). Single pine seed hulls (species unidentified) found in two different amphorae on the seventh-century wreck at Yassi Ada are not regarded as remains of cargo carried originally in the amphorae, but it is acknowledged that they could have been transported in perishable containers on the ship. They could also be intrusive to the site; the possibility that they represent dunnage is not raised (Bryant and Murry 1982: 329), and seems unlikely.

PINE CONES ASSOCIATED WITH DUNNAGE

The pine cone from the Caesarea ship might be a remnant of pine dunnage, although neither ceiling planking nor cargo, between which the dunnage probably would have been sandwiched, has survived. Cushioning cargo in the hold of a vessel was common practice in antiquity but was not understood until a vague passage in Homer (Odyssey 5.256–57) was clarified through excavation of the Bronze Age wreck at Cape Gelidonya. Twigs and sticks of (probably oak) brushwood were found lying on top of what were probably ceiling planks, at right angles to them. The primary cargo of copper oxhide ingots had been placed on top of the brushwood pile (Bass 1967: 49, figs. 47, 48, 51, fig. 53). Another Bronze Age wreck recently excavated at Uluburun, Turkey, has displayed extensive quantities of thorny burnet, a common Mediterranean shrub, beneath the copper ingots (Bass 1987: 696, 729). A thick layer of dunnage consisting of well preserved twigs and branches of pine and pistachio (Pistacia palaestina) were found in the bottom of the wreck at Ma'agan Michael, Israel. Some of the pistachio leaves appeared to have been quite fresh when the vessel was laded and/or sank (Kahanov 1991: 5; Linder 1992: 29; J.P. Rosloff, personal
communication). Pine dunnage was found on Wreck 3 at Planier Island, as well as on the wrecks at Cavalière and Pantano Longarinì (Gianfrotta and Pomey 1981: 270). Although it was not believed initially that dunnage was used in the hold at Giens (Tchernia and Pomey 1978: 20–21), Gianfrotta and Pomey (1981: 270) report that pieces of pine, elm, and oak served that purpose. Branches of juniper, heather, and rush were wedged between amphoras on the ship, presumably to prevent breakage (Couvert 1978: 111; Tchernia and Pomey 1978: 20–21). Many species of woods, including pine, are thought to have served as dunnage on the Punic ship at Marsala (Frost 1981b: 59, fig. 20:b, 79–83, 99).\(^1\)

CONCLUSION

With the foregoing information it remains impossible to determine the specific purpose of the Caesarea pine cone. Use as foodstuffs is attested in the ancient and archaeological literature, and pine dunnage was common. Had the Caesarea pine cone been retrieved, determination of its state of maturity might have provided evidence of its purpose (Girard and Tchernia 1978: 117; Kislev 1988: 76). Yet the issue would have remained problematic. If the cone was mature, use either as food or dunnage is possible. If immature, it might have clung to a pine branch used for dunnage, or it could have been in the process of maturation for consumption at the appropriate time by crew or passengers.
Notes

1. The deep wreck at La Secca di Capistello exhibits brushwood dunnage beneath amphorae and spread over the interior of the hull (Frey, Hentschel, and Keith 1978: 295). On Wreck A at Chrétienne are twigs and branches that probably served to protect the cargo (Dumas 1964: 159; Frost 1963: 182, pl. 20). Tendrils, pruned branches, straw, and bundles of sticks were used to pad and facilitate stowage of the amphorae on the dolia wreck at Diano Marina (Pallarés 1985a: 642; 1985b: 590), and straw is also in evidence as dunnage on a wreck in la Baie de l’Amitié (Pomey et al. 1988: 5). Dunnage consisting of heather or brier root and vine shoots was found between the amphorae and ceiling planks of Wreck 1 at Port-Vendres (Liou 1974: 427, n. 2, 430–31, fig. 12). See Parker 1992a for more wreck sites that include evidence of dunnage.
CHAPTER XIII

PRELIMINARY RECONSTRUCTION OF THE CAESAREA HULL

The reconstruction is based upon excavation data supplemented by the comparative material and relevant literary evidence discussed above.

MINIMUM BEAM AND LENGTH

Probe data indicate a minimum length of 34 m for the Caesarea ship. Absence of the keel prohibits more than an estimation of the ship's beam, but minimum overall dimensions and general hull features can be established. Currently, we have no means of identifying the midship frame, and very little evidence for the keel's original position with respect to the hull remains. No evidence of a maststep, maststep stringer, or keelson, in the form of fastenings or fastening holes in floor timbers, or notches or impressions on the frame tops, has been discovered. Nor are there cuttings in the west extremities of the floor timbers or half-frames that could have served as limber holes. The floor timbers do not increase markedly in their molded dimensions as they approach the keel edge of the wreck and there is no indication that the western-most preserved plank represents the garboard. It does not thicken from outboard to inboard nor is it thicker than the adjoining plank. However, that the keel was originally rather near the extant remains is suggested by the fact that half-frames 8, 10, and 22 (of the frames recorded to date) terminate as much as 0.40 m from the broken west extremities of their adjacent floor timbers. Because half-frames normally extend to very near the keel in Graeco-Roman ships that have been cataloged, the same could be expected in the Caesarea hull.

For these reasons, reconstructed dimensions are conservatively derived from the recorded frame with the maximum span and the general shapes of the frames documented. The maximum molded beam of the preserved portion of the hull can be approximated and used as a theoretical midship dimension, from which an overall length can be estimated.
The maximum recorded span of 3.8 m occurs in frames 27 and 28; half-frame 38 spans 3.6 m, and floor timber 13 extends almost 3.4 m. These timbers all have curvatures fuller than that of La Madrague de Giens frame 113 (fig. 63), which might be the midship frame of that ship. Rough projections of Caesarea half-frame 38 to a height equal to its preserved span suggest a minimum original span of ca. 4.35 m. When this figure is augmented according to the greater spans of frames 27 and 28, in addition to allowing for the keel and adjacent areas using the Giens frame as a general guide, a minimum molded beam of approximately 10 m emerges.

The latest reconstructed dimensions of the hull at Giens are 37.6 x 8.66 x 4.5 m (Rival 1991: 149). This represents a L:B ratio of ca. 4.34:1, and that of the Caesarea ship probably was not much different. Ships exceeding about 30 m in length with too much beam cannot hold course or maneuver well at sea. In fact it has been suggested that the keel and cutwater of the Giens vessel were intended to combat such problems (Pomey 1982: 134–39; Tchernia 1987). Based on his study of impressions in concrete at Portus and other factors, Testaguzza (1970: 105–19) estimates the dimensions of the ship that carried an obelisk to Rome for Caligula (Pliny, Nat. 16.40.201, 202) to have been 104 x 20.3 m, for a L:B ratio of 5.1:1. Casson (1986: 188–89 and nn.; 367, n. 23) notes the uncertainty of this calculation, and in any case the extraordinary task for which this ship was built mitigates against its use as evidence for representative L:B ratios in merchant ships. This is also true for the Lake Nemi ships, but for completeness it should be mentioned that they were built with ratios of 3.57:1 and 2.85:1 (Uceli 1950).

The scant literary evidence for the proportions of big ships supports an argument for a L:B ratio near 4:1, or at least greater than 3:1. The Isis described by Lucian (Navigium 5) was an Alexandrian grain ship 120 cubits long (ca. 53 m) and better than a quarter of that in the beam. In other words the L:B ratio was less than 4:1, but perhaps not much less, if we credit Lucian with giving a ratio closer to 4:1 than to any other. Procopius of Caesarea relates that Aeneas’ ship measured 120 ft long and 25 ft wide (De Bello Gothico 8.22.9), a ratio of 4.8:1. Because this was presumably a warship, however, the ratio cannot be used to argue for characteristic L:B ratios in large merchant ships.

Some smaller seagoing Graeco-Roman ships that have been well documented and reconstructed exhibit L:B ratios near 3:1, but a larger number indicate that L:B ratios significantly less than 3:1 were common. The Kyrenia ship is reconstructed to 13.86
Fig. 63. Comparison of Caesarea frames with the frame thought to be the midship frame of the hull at La Madrague de Giens. The flats of all frames are oriented parallel to one another to illustrate the greater sweep and fullness of Caesarea frames 13 and 38. The vertical axis of the Giens frame is therefore slightly inclined. (Caesarea frames after figs. 19–21; Giens frame after Pomey 1978a: pl. 36.)
in length and a molded beam of 4.2 m (Steffy 1985b: 100, ill. 20), a ratio of 3.3:1. The well-preserved Laurons 2 wreck is believed to have measured 15 x 5 m (Gassend, Liou, and Ximénès 1985: 103–5). At Cavalière a ship wrecked that is estimated to have had a ratio of about 2.6:1, with reconstructed dimensions of ca. 11.98 x 4.6 m (Charlin, Gassend, and Lequément 1979: 79–80). The Bourse hull is thought to have been 23 m long and 9 m broad, yielding a ratio of 2.55:1 (Gassend 1982: 94).

Similarly, the fourth-century wreck at Yassi Ada is reconstructed to about 20 m in length with a molded beam of just under 8 m, proportions slightly less than 2.5:1 (van Doorninck 1976: 119). Wreck 3 at St.-Gervais probably measured about 17 x 7.5 m, for a ratio of 2.26, which is nearly identical to the 2.25 ratio proposed for the Port-Vendres 1 wreck (Liou and Gassend 1991: 258). Wreck C at Chrétienne is reconstructed to dimensions of 15–16 x 5.5–6 m, for L:B ratios ranging from 2.5:1 to 2.9:1 (Joncheray 1975a: 69–77).

A comparison of the Caesarea frames with those of the Giens hull reinforces the notion of a large ship. Average center-to-center spacing in both vessels is ca. 0.25 m, but the Caesarea frames are sided much more and thus spaced up to 33 percent closer together. A comparison of frame sections at the turn of the bilge shows that sectional areas of measured Caesarea half-frames and futtocks are, respectively, about 190 percent and 140 percent larger than their Giens counterparts. Therefore, a conservative estimate based on our evidence and the comparative material yields dimensions of about 10 x 40 m, while a length nearer 45 m is likely.

GENERAL HULL SHAPE AND BASIC STRUCTURE

Watercourses placed closer to the turn of the bilge than to the keel and the flatness of the frames prior to the turn of the bilge suggest a flat bottom. The flat-bottomed second Nemi ship, though not a seagoing craft, seems to offer a helpful parallel. It displayed a row of watercourses beneath each of its four sister keelsons, in addition to the limber holes at the keel. The significant increase in molded dimensions of the Caesarea half-frames at the turn of the bilge suggests the need for extraordinary strength in this part of the hull. This is also consistent with a flat bottom and consequent potential weakness in the transition to the upper portion of the hull. With only a few recorded frame profiles and no evidence for the degree of deadrise,
however, further reconstruction of sectional shape is completely speculative.

A Second Layer of Planking Near the Keel

Two construction details are best explained by the original existence of a second layer of planking at the inboard edge of the hull remains. First, the plank along the west or keel edge is 0.09 m thick while the plank at the opposite edge measures 0.094 m in thickness. Second, the large fastenings (presumably among others still unrecorded) in the broken inboard extremities of floor timbers 15 and 25 protrude from the exterior surface of the western-most plank.

The original shaft length of the fastening in floor timber 15 is reconstructed to ca. 0.37 m (the upper portion of the fastening in floor timber 25 is lost). Its upper extremity terminated ca. 0.01 m short of the frame top, while the underside of the head still remains approximately 0.055 m from the outer planking face. If 0.37 m is the original length of the fastening, i.e., if it was not broken in antiquity, and if its vertical position in the floor timber has not changed since the ship was built, then 0.055 m could well represent the thickness of an outer planking layer in this part of the hull. But this possibility is clouded by the fact that the head of the fastening in floor timber 25 is approximately 0.10 m from the outer planking surface. Were these metal fastenings pulled away from the single planking layer in the course of the wrecking event or later? A treenail also discovered protruding about 0.05 m from the outer planking face near floor timber 25 might answer the question. No empty treenail hole was observed on the frame top, and indeed it seems improbable that the treenail would have been pulled out of the frame like the metal fastenings could have been. It is much more likely that when a plank of the second planking layer was stripped from the hull, the treenail remained in place while the fastening in floor timber 25 could have been partly dislodged and pulled away from the frame and inner plank.

In consequence, a second planking layer near the inboard edge, and therefore near the keel, is plausible. This would be consistent with the standard scheme in Graeco-Roman hulls of a greater planking thickness near the keel that thins and becomes uniform by the third or fourth strake from the keel. Finally, the distance that the fastening in floor timber 15 could have protruded above the frame top, ca. 0.045 m, seems too thin to represent the thickness of a stringer in a large hull.
**Stringers**

It is all but certain that stringers provided a floor for much of the ship’s hold, though their disposition is unknown because few fastenings are evident on the frame tops. The most notable of these fastenings are large copper or bronze nails (in view of their taper), or perhaps bolts.

Remnants of such fastenings have been observed near the outboard extremity of half-frame 12, in half-frames 22, 24, 26, and in futtock 25 (fig. 42). The best example is the one that protruded 0.08 m above the top of half-frame 12 about 0.93 m from its inboard extremity (fig. 33). A thickness of 0.08 m is quite suitable for stringers on a big ship, and further support for this idea rests with the fact that all fastenings found to date save one have been found in half-frames, which generally are molded more than the floor timbers except near the keel. In constituting a series of timbers elevated above the floor timbers through (presumably) the hull’s length and most of its breadth, the half-frames would have been the best timbers to which the stringers could be fastened. Futtock 25 is molded enough to be used in the scheme and others probably are as well.

As noted above (pp. 175, 177), I have found only one other instance (at Punta Ala) of the use of such a method to bind stringers to frames. But if the Caesarea fastenings are nails driven from below, troublesome questions arise. Normally, when a thick and thin timber are fastened together it is the thinner one that is pierced first by the fastening. Moreover, stringers easily could have worked off of nails driven from below, unless they were clenchd or otherwise modified to prevent it. Use of clenched nails is certainly a possibility, even likely, but a solution to this problem can also be provided by the washers found on the site, one of which was found beneath the west planking edge between frames 11 and 12—less than 1 m from the fastening in floor timber 15. If washers were used with the fastenings, the latter may be regarded as bolts.

The distribution of these fastenings across the hull, assuming they did help secure stringers, does not allow precise determination of stringer or ceiling plank widths. Yet the standard scheme of alternate stringers and ceiling planks is easily accommodated by the information at hand, at least for the area outboard of the aligned gaps separating the floor timbers and their futtocks (figs. 42, 64). The copper or bronze fastenings in half-frames 22 and 26 are each about 0.25 m from the line of gaps; the outboard (eastern-most) iron nail concretion in half-frame 10 aligns well with the copper or
- Recorded copper or bronze fastening driven from below and protruding above the frame tops, as plotted on frame 13.

- Recorded iron nails in the frame tops, as plotted on frame 13.

Fig. 64. Disposition of copper or bronze fastenings, iron nails, and some possible stringer positions across breadth of hull remains except along inboard (west) edge, as plotted on frame 13. (After fig. 20.)
bronze fastening in futtock 25, as they are both located about 1 m from the aligned frame gaps. Together with the subsequent spacing of the copper or bronze fastenings in half-frames 24 and 12 farther outboard, these fastening locations allow for the use of stringers up to 0.30–0.35 m wide with removable ceiling planks about 0.20–0.35 m in width placed between them. The location of the middle iron nail concretion in half-frame 10, about 0.25 m inboard of the line of gaps between the floor timbers and futtocks, suggests a stringer was fixed there. A stringer on the other side of the line of gaps is also suggested by the iron nail shaft some 0.26 m outboard of the gap between floor timber and futtock 23 that is aligned with the copper or bronze fastenings in half-frames 22 and 26. Thus the line of frame gaps would have been flanked on both sides by fixed stringers while movable ceiling over the gaps provided access to the watercourses below. Finally, the inboard (western-most) iron nail concretion in half-frame 10 is essentially aligned with the one copper or bronze fastening to be discovered still protruding above the frame top, in floor timber 12. A stringer almost 0.08 m thick at this position therefore seems likely as well. The fastenings at the broken inboard extremities of floor timbers 15 and 25 are omitted from this discussion because it is not known if these fastenings originally protruded above the frame tops.

CONCLUSION

This full and capacious hull probably measured some 10 x 40–45 m. Its thick single layer of planks, possibly with a second layer near the keel, together with heavy, close-set frames and stringers possibly through-fastened to the frames and planks, make it the most heavily built Roman ship yet documented archaeologically, with the exception of Caligula’s obelisk freighter. As such, the Caesarea ship would have been capable of the economic transport of heavy bulk materials such as stone, timber, and metals, as well as commodities contained in amphoras or dolia.
Notes

1. Cosma (1970: 514) credits Vitruvius (3.3) with advising that L:B ratios for merchant ships fall between 3:1 and 4:1, but I have been unable to find this information in Vitruvius. The chapter cited concerns architectural proportions. The Talmud recommends that a ship’s breadth measure 1/6 of its length, its depth 1/10, ratios apparently derived from the Biblical dimensions of Noah’s Ark (Sperber 1986: 63–64).

2. On philological grounds, Houston (1987) challenges the believability of the Isis’ dimensions, rightly calling for archaeological evidence to support them. If the material presented here, particularly in this chapter and in Chapters XV and XVII below constitute an acceptable effort toward that end, then the size of the Isis as related in Lucian is not implausible.

3. Whether this vessel was ancient or of Procopius’ time is immaterial here, but see Basch 1985.
CHAPTER XIV

THE DATE OF THE CAESAREA SHIP

The comparative studies reveal that a number of construction and equipment details on wrecks of Graeco-Roman seagoing ships occur within relatively well-defined temporal limits. While these features and the time periods in which they occur cannot be regarded as diagnostic on an individual basis, they do constitute a plausibly homogeneous body of dating evidence for the Caesarea hull when considered as a whole.

- Wrecks dating from the fourth century B.C.E. through the fourth century A.C. display lead sheathing; the median of occurrence is therefore the turn of the millennium. The fourth century A.C. is represented only by one wreck, however, and a maximum of five sites from the second and third centuries A.C. display evidence of sheathing. About 73 percent of the lead-sheathed seagoing hulls represented in the catalog are dated to the last two centuries B.C.E. and the first century A.C. (Table 7), with up to almost twice as many occurring in the first century B.C.E. as in each of the other two centuries. (This information is pertinent only if the lead sheet fragments at Caesarea do indeed represent hull sheathing.)

- Plug-treenail fastenings are not in evidence on wrecks of seagoing ships dated after the first century B.C.E., save two in the third century A.C. (Table 5). They first appear ca. 400 B.C.E., the median of occurrence is roughly 50 B.C.E., and by far the largest number of wrecks date to the first century B.C.E.

- All cataloged lead boxes or suggested portions thereof, with a maximum of possibly two exceptions that may date from the second or first century B.C.E., have been recovered from wreck sites dated to the first centuries B.C.E. and A.C. Slightly more are from the earlier century (Table 8).

- The overwhelming majority of lead pipes found either not associated with or not attached to lead boxes also date to the first centuries B.C.E. and A.C., with just a slight bias toward the first century B.C.E. The median of occurrence is essentially the turn of the millennium.
It is striking that all of these features occur most frequently on wrecks dated to the first century B.C.E. and that the median of occurrence in three instances is essentially the turn of the millennium; the median occurrence of the fourth feature is 50 B.C.E. Yet the first century A.C. is strongly represented in all categories and sporadic appearances of these features in later periods cannot be ignored. Therefore the end of the first century A.C. might serve best as a conservative and realistic terminus ante quem for the ship’s construction. This does not conflict with radiocarbon analyses that indicate the wood was cut no later than about the mid-first century A.C.

A date of 22 B.C.E., when the construction of Caesarea and Sebastos began, is a tenable terminus post quem for the ship’s demise. There is no more than a random chance that the ship wrecked and came to rest where it did before this time, as the nearest Roman ports of any consequence were Joppa, some 50 km to the south, and Ptolemais, about the same distance to the north (fig. 65; cf. Strabo, 16.2.21–30). If the ship had been bound for one of these ports or those farther north or south it probably would have been sailing a number of miles off shore. Therefore it is more likely that the ship somehow was associated with Caesarea and its harbor—after 22 B.C.E. It may have been involved in the transport of materials for the construction of the harbor and city, or in the commercial activities that ensued upon its completion. It is tempting to speculate on the implications of Josephus’ report (Antiquitates Judaicae 20.51, 20.101) that a famine in Palestine was relieved by a shipment of Egyptian grain (in A.D. 46 or 47).

Clearly, a firm date either for the construction of the ship or its loss is difficult to derive solely through a comparative study of construction and equipment details. Moreover, Parker’s demonstration (1990a: 336, fig. 1; 1992a: figs. 3–5) that a marked preponderance of published Graeco-Roman wrecks date to the two centuries B.C.E. and A.C. must be acknowledged. Dating any features evident on those wrecks according to their frequency of occurrence will naturally be biased toward those four centuries. On the other hand, such a preponderance must reflect to some degree the relative number of ships that sailed during those centuries. Therefore the temporal consistency evident in the specific features reviewed above is still provocative. Coupled with the activities known to have commenced at Caesarea in 22 B.C.E., it is submitted that the ship’s career ended in the first century A.C.
Fig. 65. Major ports near Caesarea in the time of Herod the Great. (After Frank 1984: B-25.)
CHAPTER XV

THE CAESAREA HULL IN ITS HISTORICAL CONTEXT

Ships of prodigious size had been plying the Mediterranean well before the Romans started building them, as abundant literary evidence for great Hellenistic warships demonstrates. According to Diodorus Siculus (14.42.2), the first man to think of building quadriremes and quinquiremes was Dionysius of Syracuse (ca. 430–367 B.C.E.), though Pliny (Nat. 7.56.207–8) reports that Aristotle attributed this development to the Carthaginians. The Hellenistic period saw much larger warships (Pliny, Nat. 7.56.207–8; Casson 1969; 1986: 97–123, 137–40; Rougé 1981: 93–96), and recent evidence gleaned from the only wood from within an actual warship ram suggests that warships were heavily built, at least in the lower portion of the hull. The Athlit ram could be from a Ptolemaic “four” or “five” of the late third or early second century B.C.E. (Murray and Petsas 1988: 33–34; 1989: 100, 105, 114; Murray 1991a; 1991b) that was perhaps 35 m long. Its preserved bottom planking averages 0.075 m, and it is believed to have retained this thickness up to the waterline wale, and nearly so in the first plank above that wale. Thereafter, it probably decreased somewhat to minimize vessel weight above the waterline (Steffy 1983: 236, fig. 5, 239–40; 1991: 18–20, 28, 32–37). Bottom planking only slightly thicker than 0.075 m is typical on wrecks of Roman merchant ships of comparable size (see Table 3).

We have testimony to one large grain ship of the Hellenistic period. The Syracusia of Hiero II of Syracuse (ca. 306–215 B.C.E.) was a ship so big—a “twenty”—that no harbor could be found to receive it, so it was given to Ptolemy and simply moored at Alexandria (Athenaeus 5.206d–209b). The capacity of this vessel has been calculated by many, with estimates ranging from 1100 to 3500 tons; most do not exceed 2000 tons (Casson 1986: 185–86; cf. Duncan-Jones 1977).

It is evident that Hellenistic shipwrights had the knowledge and technology to build ships of great tonnage, and did so. Yet one scholar suggests there was little economic justification for such merchant craft prior to the existence of the vast marketplace embodied in the Roman Empire. Only the need to transport great quantities of food in a relatively short sailing season brought economic viability to big
ships, which consequently underwent more extensive development than ever before (Rougé 1981: 78).

As early as the fourth century B.C.E. the Roman state had imported grain for cheap sale at home in times of exceptional need (Levy 1967: 68–69), but in the second century B.C.E. Italian cereal production began to decline seriously (Lewis and Reinhold 1966a: 440–50). Men of the land made up the bulk of the Roman armies engaged in the struggles with Carthage during the third century B.C.E., and their numbers fell accordingly. Those fortunate enough to return to their farms often found them hopelessly mortgaged or beyond recovery. As a result, many farms were ultimately incorporated into the ever-growing number of latifundia, and much of the land was converted to more profitable viticulture and olive production. As large numbers of retired soldiers and rural inhabitants found it increasingly difficult to support themselves, the Italian countryside yielded less and less grain. Moreover, the overland transport of grain on a large scale over any appreciable distance was prohibitively expensive. Thus deprived even of the means of subsistence, more and more people flocked to Rome and other large cities in search of livelihood and relief.

Perhaps inevitably, a chief social, political, and economic issue for the government became that of keeping the burgeoning urban masses fed, particularly in Rome itself. The most effective way to do this was to strive for a secure grain supply for the capital city (Lewis and Reinhold 1966a: 441; 1966b: 138–42). In 123 B.C.E. the tribune Gaius Gracchus sponsored passage of the lex Sempronius frumentaria, which organized a system for the transport and storage of wheat. It also provided for every Roman citizen five modii per month at the fixed and slightly subsidized price of 6 1/3 asses. Grain was first distributed gratis in 58 B.C.E., and at one point during the reign of Augustus the number of (adult male) recipients apparently reached 320,000—each collecting five free modii per month. This was a large portion of the perhaps 1,000,000 souls residing in Rome at the time, and it makes manifest the special importance of the annona. Rickman (1980b: 262–63) points out that well before that time the political significance of the annona was appreciated. In 43 B.C.E. the Senate, seeking to prevent the possibility of one-man rule in Rome, passed among others a decree prohibiting the selection of any single man to control the grain supply for the city as a whole. Augustus understood the issue equally well, and it was not until the end of his reign, despite numerous food riots of no small consequence, that he created the office of praefectus annonae, which effectively did make one man responsible for the city’s
grain procurement. Nor was the dole the only issue. There had to be enough grain available at market to accommodate the remainder of the population (Levy 1967: 77; Casson 1980; Rickman 1980b; Evans 1981; Garnsey 1983; 1986; 1987: 83–89). In Rome’s earlier history most of its imported grain was grown in Sicily, Sardinia, and North Africa, but the annexation of Egypt in 30 B.C.E. made wheat available on a much greater scale.

The acquisition of enough grain to maintain civil order in Rome required special measures, but there seems to be no evidence for an official, government-run “grain fleet.” Any such fleet probably comprised privately owned ships, some of which presumably sailed in convoy when possible, and some of which were the immense grain freighters (Rickman 1980a: 126, 128–31; Casson 1986: 297–99 and nn.). The Isis of the second century was one such vessel. As described by Lucian (Navigium 5), it measured ca. 53 m in length and more than a quarter of that in breadth. Casson (1950: 51–56; 1986: 186–88) calculates for this ship a capacity of over 1200 tons, but beyond Lucian’s description little is known of these great ships. En route from Caesarea to Rome, St. Paul boarded one at Myra that took on 276 passengers—who would have lived on deck—in addition to its cargo (Acts 27.1–28.23), though it probably could have accommodated many more (Casson 1986: 172, n. 26). The ship that embarked from Judea in A.D. 61 with Josephus and 600 passengers (Josephus, Vita 15) may have been a grain ship, according to Rougé (1966: 69; 1975: 78). He estimates this vessel to have been of some 1000–1200 tons, with a minimum deck area of 40 x 15 m. Smaller vessels transported wheat for the state, but such enterprise does not appear to have been particularly lucrative for those involved, in view of the fact that Claudius was reduced to offering special incentives to attract help from the private sector. Latins could acquire citizenship by building a ship with a capacity of at least 10,000 modii of grain (ca. 68 metric tons) and delivering grain to Rome for at least six years, either with that ship or another in its place (Gaius, Institutiones 1.32C). Other enticements included exemption of citizens from the Papian-Poppaean law of A.D. 9. Among candidates competing for public office, this law gave precedence to fathers. Claudius also guaranteed expenses against losses incurred, encouraged winter voyages, and accorded the privileges of mothers of four children to women who undertook to help supply Rome with grain (Suetonius, Claudius 18–19). During the reign of Marcus Aurelius in the later second century, the jurist Scaevo (Digesta 50.5.3) noted that shipowners were exempted from civil service who had built and
provided for the *annona* a seagoing ship of not less than 50,000 *modii* capacity (ca. 340 metric tons—perhaps somewhat less than the capacity of the ship that sank at Gien), or a number of vessels that could carry 10,000 *modii* each.

Supplying Rome with grain clearly was one reason big merchant ships would have become economically desirable and feasible, but other factors were involved. Broadening Roman power and influence, especially after 202 B.C.E. and during the early Principate, brought staggering economic opportunities, to the extent that, despite the conservative traditional values that accorded *virtus* to the man whose wealth was drawn from the land, senators appear to have been tempted rather early on by the profits of maritime exchange. In 219 or 218 B.C.E., legal sanctions were instituted to prevent men of senatorial rank and their sons from engaging in large-scale maritime trade. The *plebiscitum Claudianum* prohibited their ownership of seagoing ships, which were defined as having a capacity of more than 300 jars. The law technically was in force in 59 B.C.E. and as late as the early third century A.C. (D'Arms 1981: 5), but the employment of a slave or freedman as a "front" man to conduct such activities on the senator's behalf was a common and worthwhile means of circumventing the law. In the wake of territorial acquisition, large masses of currency entered circulation. Wealth plundered from Greece poured into Rome over the course of the second century B.C.E., during which time the amount of silver coined by Rome increased 7–14 fold. Between 157 B.C.E. and 50 B.C.E., the number of silver coins in circulation soared more than ten times, and then nearly doubled over the succeeding century (Hopkins 1988: 758–59). Moreover, piracy was eradicated from the seas in the first century B.C.E., and the subjugation of Gaul by Julius Caesar opened the door to a large market for Italian wine. After the civil wars ended in 31 B.C.E., economic exploitation of the provinces rose to ever greater heights, and appreciable trade developed with Arabia, India and the Far East as well. The volume of commercial shipping was great, as were profits, and men were not much afraid of the risks involved (D'Arms 1981: 8–9). The Younger Seneca (*Epistulae Morales* 119.5) mentions maritime trade as a ready avenue to riches. Juvenal (*Satyræ* 14.276–77) sneers that there were more men at sea than on land, so eager were they to be rich, and Pliny (*Nat.* 2.45.118, 2.47.125) comments that huge numbers of men were sailing the seas in search of profit; first pirates and then greed spurred them to risk winter voyages. The famous freedman Trimalchio engaged in highly profitable maritime ventures (Petronius, *Satyricon* 76; D'Arms 1981: 97–120).
Ships could transport staple goods and commodities cheaply and in great quantities (Jones 1964: 841–43 and nn.; Duncan-Jones 1974: appendix 17; Rickman 1980b: 273, n. 7; Evans 1981: 429, n. 5; Greene 1986: 39–43; Sippel 1987; Hopkins 1988: 759, 761–62). The appearance of dolia on shipwrecks of the first centuries B.C.E. and A.C. suggests an increased interest in moving at one time large quantities of wine, olive oil, and related items such as grapes and oil lees (Hesnard, L’Hour, and Long 1986; Fiori 1972; Pallarès 1983a; 1983c–e; 1985a–d; 1991; Brenni 1985; Corsi-Sciallano and Liou 1985: 169–71; D’Atri 1986; D’Atri and Gianfrotta 1986; Tchernia 1986: 138–40; Hesnard et al. 1988; Pomey et al. 1988: 20, 27–28, 30–32; Gianfrotta 1990; Rendini 1992; Carre 1993), and presumably wheat and other dry goods as well. It has been proposed that certain construction features in evidence on the wreck at Ladicopoli may indicate the existence of specialized building practices for dolia carriers (Carre 1993: 27). Salted and pickled fish, fish sauce (garum), metals such as copper, tin, and lead, among many other products and commodities, were widely distributed. Timber, stone, and marble were cut and transported on a grand scale for public and private building projects throughout the Empire. Petronius (Satyricon 117) mentions the lapidaria nautis, a ship type that seems to have been specifically designated for the transport of stone, and Pliny (Nat. 36.1.2) refers to ships built specially to transport marble. Rougé (1966: 76–77) proposes that these ships were built more heavily than others in order to perform their task (cf. L’Hour and Long 1986).

Exotic products and luxury items from Arabia, India, and the Far East found ready markets as well, beginning in the first century B.C.E. and especially in the first two centuries A.C. Caravan routes stretched from the head of the Persian gulf through the Euphrates valley to Palmyra, and thence to ports on the Mediterranean coast. Yet the Parthians controlled several important routes from Central Asia to Syrian ports. The tolls they exacted served to divert much of the Indian and Arabian trade to Alexandria via the Red Sea and the Nile (Lewis and Reinhold 1966b: 203). Hopkins (1988: 770) and Casson (1989: 12, n. 4, 96) cite Strabo’s observations (2.5.12, 17.1.13) that in times prior to his own, significantly fewer trading vessels sailed from Egypt to India and Ethiopia. It seems likely that only luxury items were acceptably profitable after expensive caravan transport (Raschke 1979: 70), for as Strabo (17.1.13) also points out, costly goods would have been subject to high duties in any case (Hopkins 1988: 769–71). Some, however, cite the Periplus Maris Erythraei as evidence that the exportation of luxury goods on a small scale from Arabia and India
was coupled with the large-scale exchange of staple products like pepper, cassia, metals, textiles, and other goods (Raschke 1979: 69–70).

Pliny (Nat. 6.26.104) and the Periplus (39:13.12–13; 49:16.31–32; 56:18.28–29) relate that voyages from Egypt to Africa and India began in July. This is when the southwest monsoon, the Kasi, is half spent (Huntingford 1980: 164–65). In one scholar’s opinion the monsoon, having gathered its full force by this time, was so demanding of ships making the straight run to India that trade could be conducted only by powerful vessels capable of withstanding the punishment (Casson 1984a: 192; 1989: 283–91). Whether most of these ships were built in classic Graeco-Roman fashion, or were native to Arabia and India and so probably built differently is unknown.

The expansion and consolidation of Rome’s dominions after the battle of Zama in 202 B.C.E. created exceptional economic opportunities that culminated in the first century B.C.E. and especially during the Pax Romana. Although large merchant craft may not have been a new phenomenon, their economic practicality and increased numbers must have been, as shipwrights responded to vigorous social and economic forces by providing great ships capable of permanently housing great dolia and of moving grain and other bulk commodities on an unprecedented scale. It is easy to imagine that under these conditions the construction of large merchant ships underwent more exploration and development than ever before. Thus the primarily military impetus for the construction of great ships in Hellenistic times and earlier was partly replaced by an economic one in the Roman period.
CHAPTER XVI

THE CAESAREA HULL IN ITS ARCHAEOLOGICAL CONTEXT

Current archaeological evidence is consistent with the historical outline and indicates that large Roman merchantmen started appearing by the middle of the second century B.C.E. and were common in the first century B.C.E. and thereafter. Wrecks of such ships have been discovered at Punta Scalella (150–140 B.C.E.), Spargi (120–100 B.C.E.), Albenga, Antikythera, Mahdia, Giens, l’isola di Mal di Ventre, and probably at Chrétienne (A) and St. Jordi (I) (all dated to before or near the middle of the first century B.C.E.).

Some construction features of these wrecks, in concert with the information about large warships provided by the Athlit ram, prompt a number of questions about Graeco-Roman shipbuilding. First, were large Roman ships built significantly differently than those of the Hellenistic period and earlier? More fundamentally, did approaches to the construction of large Graeco-Roman vessels differ from those associated with their diminutive counterparts? The data at hand suggest the answer to this latter question is yes: aside from the straightforward increase in planking thickness and tenon volume as vessels increase in size, there are distinct indications that at least some large ships gained more structural integrity from their framing than did smaller ships. If at some point this is found to be representative, we may envision large Roman vessels that were framed not much differently from their Greek and Hellenistic forerunners. This in turn would raise the possibility of an early distinction between approaches to the construction of large as opposed to small seagoing ships. Until more information is at hand, however, it is possible only to point out differences in the documented planking and framing of smaller as opposed to large seagoing ships.
THICKER PLANKING AND MORE MORTISE-AND-TENON JOINTS

Because in classic mortise-and-tenon shell-first construction the assembled planks made up the primary structural component of the hull, the natural thing to do when building a vessel of greater size was to increase the thickness of the planking. To meet better the greater stresses on the planking of a large ship working at sea, in addition to supporting their own increased bulk and weight, such planks were fastened together and stiffened internally with as many tenons, or as much tenon volume, as necessary or possible. This was achieved by staggering the joints across the thickness of a single layer of thick planks, thereby allowing the tenons to be fairly thick and close together without weakening the planks. Examples are found in the hulls at Antikythera and Caesarea.

But the preferred way of building large ships appears to have been the application of two planking layers, perhaps often including at least one layer of hardwood. This arrangement accommodated even more tenon volume and offered some of the advantages of lamination. Examples are found at La Madrague de Giens, Mahdia, and probably Punta Scalaletta, Albenga, and Spargi.

In all these ships, save perhaps the one at Punta Scalaletta, the shipwrights assembled planking shells no thicker than 0.10 m, excluding areas near the keel. Unfortunately we do not have enough data to ascertain if this is the maximum shell thickness used by Greek and Roman shipwrights. Still, there seems to be some indication that planks exceeding 0.10 m in thickness were not favored. Only at Antikythera, Caesarea, and Lake Nemi (and possibly St. Jordi) are the single planking layers over 0.06 m thick, and planks of double-layered ships do not exceed ca. 0.06 m in thickness. Perhaps the practical construction considerations in handling planks of such size and weight set a thickness limit for softwood planking of about 0.10 m, and for hardwoods ca. 0.06 m. In this light, the Punta Scalaletta wreck may indicate the outer limit of planking thickness in standard seagoing ships: two layers each about 0.065–0.07 m thick. As noted, this agrees with the literary evidence for maximum planking thicknesses. Yet what were the Alexandrian grain ships were like? Were they built with two layers of planks comprising 0.13–0.14 m of thickness, or perhaps with two layers each nearly 0.10 m thick, or of even some other configuration?

One factor affecting the maximum practical thickness of planking was the mortise-and-tenon joinery. At some point (still unknown), such joints are not capable
of maintaining the structural integrity of the planking shell. It appears that the joinery in the hulls at Antikythera and Caesarea were believed by the shipwright to be near the maximum, and that if the joints were more closely spaced, or if tenons were appreciably thicker, plank integrity would have been jeopardized. This helps explain the employment of two planking layers, with the attendant advantages of lamination, the more convenient utilization of hardwood planks, and increased tenon volume.

These construction practices suggest the need for more and more hull strength in larger ships, and that this probably could not have been achieved satisfactorily through the shell alone. Deck structures aside, wales and stringers must have been among the primary hull members first used to strengthen big Graeco-Roman hulls. But only more developed framework could maximize their potential benefits.

MORE DEVELOPED FRAMING

Some of the wrecks of big ships cataloged in this study exhibit floor timbers fastened to the keel, scarfed floor timbers and futtocks, frames spaced relatively more closely than are frames in smaller ships, or some combination of these three features. Taken collectively, they hint at distinct efforts to develop framing earlier and to a greater extent in large ships than in small ones, because with very few exceptions they occur in the latter only considerably later, if at all. This is not to suggest such traits constitute evidence of “frame-first” or “mixed” methods, however.

The appearance of frames bound to the keel in large ships predates those in small ships by at least 100 years, perhaps 170 years, and occurs on a much more extensive scale in terms of both the number of wrecks and the quantity of fastenings used (cf. Bolts and Washers in Chapter VII). There is good evidence on the wreck at Spargi (ca. 120–100 B.C.E., ca. 30–35 m) that a large number of the floor timbers were bolted to the keel. This technique is clear and indisputable on the Giens hull (60–40 B.C.E., ca. 38 m). The earliest published example of a similar practice on a notably smaller ship is that of St.-Gervais 3, but this is in a more restricted capacity. On this hull of some 17 m that wrecked in the mid-first century A.D., the two keel scarfs are pierced with copper or bronze bolts that extend through the frames as well. Restricted use is also evident for the next occurrence in small seagoing ships. On Wreck 2 at Laurons, of the late second century and about 15 m in length, nails were used in the four scarfs
in the keel and posts. In the larger Bourse wreck (ca. 23 m long) the concept of fastening frames to the keel is more fully developed. Dated to the late second or early third century, about every eighth frame is bound to the keel with a peined copper bolt. Floor timbers fastened firmly to the keel and posts become more and more common in ships dated to this period and later.

The least important and most tenuously documented clue to a trend toward more developed framing in large ships is that of scarfed floor timbers and futtocks. Evidence from the Lake Nemi ships seems fairly clear, but that from the Antikythera wreck is definitely suspect and that from the Chrétiennenne A and Giens wrecks is dubious at best. In fact the best examples of "made frames" come from a group of three wrecks dating from the second half of the sixth century B.C.E. through the late-fifth or early-fourth century B.C.E. The wreck of a ship originally some 13 m long discovered off Ma’agan Michael, Israel, exhibits 14 frames comprising crotch-timber floor timbers and their futtocks. The latter are fastened to the former with three-plane horizontal scarfs affixed with usually three treenails. Carpentry details affirm undeniably that the frames were "made" before installation (Linder 1989; 1992: 34; Rosloff 1990 and personal communication). The Bon-Porté vessel, a sewn boat of some 10 m dated to the second half of the sixth century B.C.E., also displays evidence of pre-assembled frames. Single-unit frames consisted of two frame components joined by a scarf fastened with two small treenails driven diagonally. No frames were discovered fastened to the planking, but lashing is suggested (Liou 1975: 595–97; Joncheray 1976b: 26–27). The frames of a late-sixth or early-fifth century ship that measured at least 17 m and sank at Gela are of the same configuration as those at Bon Porté. Two frame components were joined with three treenails driven vertically through the scarf (Freschi 1991: 206–7). Thus the frames in these vessels were single units and did not consist of floor timbers and futtocks alternating with half-frames and futtocks, as was typical in later Greek and Roman ships. This evidence clearly raises more questions than it resolves with respect to the development of Graeco-Roman framing practices, but these wrecks may, along with Giglio wreck of ca. 600 B.C.E., represent elements of a different shipbuilding tradition. Scarfed one-piece frames do not occur until the third or fourth century in small Roman ships, and in no more distinct or robust form than that in evidence for earlier big Roman ships. Configurations like those at Lake Nemi and Chrétiennenne A have been noted on Wreck 1 at Port-Vendres (Liou 1974: 423) and the largest vessel at Fiumicino (Testaguzza 1970: 145). One floor timber and futtock on
the fourth-century wreck at Yassi Ada were joined with an unfastened vertical scarf, and two futtocks were fastened together in a diagonal scarf with a treenail that was driven from the hull’s exterior (van Doorninck 1976: 124).

Aside from frames bound to the keel, the appearance of close-set frames potentially represents the most important difference between the framing of large and small ships, because it never occurs in wrecks of the latter. It is displayed, however, only by two large wrecks, perhaps a third. In the hulls at Giens and Caesarea, frames are significantly closer to one another than their sided dimensions. In the central portion of the Spargi wreck, the spaces between frames and their sided dimensions appear to be roughly equal. This is not the case at Punta Scaletta and probably not at Albenga. The Kyrenia ship will suffice as a representative of the framing found in smaller vessels. With frames sided an average of 0.09 m at Strake 6 and an average room and space of 0.25 m (Steffy 1985b: 84), spaces between frames thus average 0.16 m, 177 percent of their sided dimensions.

With the sparse information at hand, it cannot be argued that the placement of frames more closely together than their sided dimensions was a common characteristic of a significant number of large Graeco-Roman ships. Yet the evidence in the Giens and Caesarea hulls is nevertheless clear and compelling in its implications for the development of framing in ships built with mortise-and-tenon joinery.
Notes

1. A small boat of the first century B.C.E. or A.C. was found at Kinneret on the Sea of Galilee that had at least eight floor timbers and half-frames nailed to the keel, though few, if any, were originally so (Steffy 1987: 372; Wachsmann et al. 1990: 36, 39).
CHAPTER XVII

CONCLUSION:
THE CAESAREA HULL IN ITS TECHNOLOGICAL CONTEXT

LARGE SHIPS AND THE DEVELOPMENT OF FRAMING

The details outlined in the preceding chapter constitute evidence of some attempts to impart more support to the planking shell by means of frames. Interestingly enough, however, fastening frames to the keel and placing them close together might have eliminated the need to explore further the advantages of framework. This apparently afforded adequate enhancement both of longitudinal and lateral integrity, judging from the evidence at hand, which unfortunately does not include good data regarding the deck construction of large ships. Decks and their associated clamps, wales, beams, and stanchions would have contributed a great deal of strength to the hull structure.

Improved Longitudinal Stiffening

The battle against hogging and sagging dates at least to the Fifth Dynasty of Old Kingdom Egypt. A heavy rope or “hogging truss” extending from stem to stern was an early device used to combat the problem (Casson 1986: figs. 14, 17, 18; Bass 1972: 21, fig. 17, 29, ill. 16, 32–33, ill. 24). Classical triremes and larger ships, including the Alexandrian grain ship that bore St. Paul from Myra to Malta (Acts 27.17), were fitted with a ὕποτόμα (hypozoma) that is thought to have served a similar purpose, but this piece of equipment is not yet understood (Morrison and Williams 1968: 200, 294–98; Kennedy 1976; Rougé 1981: 43–44; Casson 1986: 91–92, 211, n. 45; Morrison and Coates 1986: 170–72). Holes 0.04 m in diameter centered in the chocks or floor timbers of the hull at Grand Congloué are suggested by Benoît to have accommodated cables that improved longitudinal stiffness (Benoît 1961: 138, 141). This seems unlikely, however, because the mechanical advantage of a rope placed so low in the hull would have been negligible, and the benefits of a rope only 0.03–0.04 m in diameter to a ship some 23 m long would seem to have been minimal as well.
Numerous floor timbers bound to the keel, closely spaced frames, and the possibility that the planks, frames, and stringers were commonly fastened on the Caesarea hull (as they were on the Punta Ala hull of about A.D. 250) appear to represent at least some of the ways in which the Romans addressed the problems of hogging and sagging. This of course would have been in addition to the normal employment of garboards and associated strakes that were thicker than those higher up in the hull. Improving the stringer scheme and sometimes fastening ceiling planks to the frames, along with the utilization of more and/or larger wales and clamps and a well developed deck structure with beams and stanchions, would have been among the most convenient means of improving the longitudinal strength of a big ship missing a stiff spine and integrated skeleton.\(^1\) In order to maximize the contributions of these longitudinal stiffeners, however, they had to be fastened to close-set frames. By sandwiching heavy outer planks and wales and interior stringers and clamps around a relatively large number of frames per unit of hull length, there was achieved an appreciable reduction of the flexibility exhibited, for example, by a long plank supported only at its ends. Further, the more robust the frames, the stiffer a given pair of planks sandwiched around them could be made.

Although documentation of the number of stringers on the Caesarea ship is incomplete, it appears possible that timbers some 0.08 m thick were used in this capacity, probably as part of the typical Roman system comprising fixed stringers alternating with removable ceiling planks. If the interpretation of the fastening evidence at Caesarea is correct, stringers commonly fastened to planking and close-set frames represent, for the lower portions of big Graeco-Roman hulls, the most advanced means yet known of dealing with hogging and sagging.

**Improved Lateral Support**

Further support for the idea that frames were more important in big ships earlier than they were in smaller ones rests with the unique framing pattern of the Caesarea ship. The floor timbers/futtocks gaps are aligned down the length of the hull. This is undoubtedly the most intriguing and puzzling framing feature of the wreck. All other Graeco-Roman ships I have been able to study, with one exception,\(^2\) display floor timbers of various lengths that create a pattern of distinctly staggered gaps between floor timbers and futtocks along the hull. There are at least two advantages to this practice. One is the efficient use of material: the shipwright can use a properly curved
timber at an appropriate place with little or no regard for its length at one end or the other. In contrast, the builders of the Caesarea ship surely had to cut off extremities of floor timbers and futtocks as necessary to conform to the aligned-gap scheme. This, of course, required expenditures of labor and materials beyond those associated with other Graeco-Roman ships of which I am aware, as it eliminated from consideration timbers that otherwise could have been used.

Yet the biggest advantage to staggered floor timber/futtock gaps is that more effective support is provided to the shell. Gaps are not concentrated along any one strake or planking seam, so stresses are distributed more evenly to adjacent areas and no zones of weakness are created. Therefore the alignment of such gaps in a large mortise-and-tenon-built hull would have been unwise unless the frames and other structural members were able to compensate adequately. The fact that the Caesarea ship was framed as it was must be an index to exceptional structural integrity provided in great part by the close frame spacing and by the heavy half-frames that in a sense bridged the floor timber/futtock gaps.

**FINAL CONCLUSION AND HYPOTHESIS**

If it is accepted that frames played a greater structural role in larger ships earlier than they did in smaller ones, this question follows: Was the progression from shell-first to frame-first concepts simultaneous in large and small Graeco-Roman vessels?

In relatively small ships (under ca. 20 m in length) of the Greek, Roman, and Byzantine periods, an evolution from the practice of assembling and shaping a shell of planks before many or all framing timbers were installed, to that of fastening a number of floor timbers and full frames to the spine of the hull before the first strake was fitted and controlling transverse hull shapes with frames, is effectively illustrated by the fourth-century B.C.E. Kyrenia wreck (Steffy 1985b; 1994:42–59), the fourth-century wreck at Yassi Ada (van Doorninck 1976), the seventh-century wreck at the same place (van Doorninck 1982; Steffy 1982a), and the eleventh-century wreck at Serçe Limanı (Steffy 1982b; 1994: 85–91). This process has been characterized as a response to deteriorating economic conditions that began in the late Roman period and spurred development of faster and cheaper construction methods in the following centuries.
But the process has not been documented for ships measuring more than some 30 m in length, due primarily to a lack of good excavations and studies like those just cited. This must be one reason our question has not been addressed to date. Yet the extant evidence demonstrates clearly that frames were more important earlier in large ships than in smaller ones. I suggest that fundamental differences between the structural dynamics in large and small ships were recognized and addressed differently by a sophisticated shipbuilding tradition that also included systematic guidelines governing material usage, planking thicknesses, and joinery requirements for ships of various sizes.

The archaeological and historical evidence urges the same recognition, because it is axiomatic that one of the primary forces behind technological development is the desire or necessity to adapt to new socio-economic conditions or circumstances. When structures more technically complex and demanding than their predecessors are to be constructed, new problems are posed and their solutions fostered. Therefore, vessels like the great Hellenistic warships and the extraordinarily large grain freighters of the Roman empire represented the "cutting edge" of shipbuilding technology. They served to elicit and test new techniques and approaches that ultimately could be applied on a broader scale.

In conclusion, I submit the following hypothesis. The construction of big ships, inspired primarily by military considerations in the Hellenistic period and by economic factors in the late Roman Republic and early Imperial period, stimulated advances in hull support based on the augmentation of framing and spinal integrity. This was a prelude to similar developments in smaller ships that began at least by the late second century. With a growing need to economize in labor and materials in a worsening economic climate, shipwrights began to avail themselves more and more of techniques proven in big ships over the previous centuries. In this way they were able to meet the challenges of their day while sustaining a continuum that saw the appearance of rudimentary frame-first construction techniques at least by the eleventh century.
Notes

1. Whether for structural stiffness or not, ceiling planking was conscientiously fastened to the frames on the hulls at Spargi and Diano Marina (see above, p. 148), and would have contributed to longitudinal hull integrity.

2. The St.-Gervais 3 wreck exhibits frames with aligned floor timber/futtock gaps ca. 1.60 m from the keel in the central portion of the hull, and somewhat closer nearer the extremities. The half-frame/futtock gaps are ca. 1.50 m farther outboard. This is suggested to have arisen because the half-frames and floor timbers are essentially of equal length. The two lines of gaps were not allowed to coincide so as to avoid creation of a zone of weakness in the region of the bilge (Liou and Gassend 1991: 220, fig. 80, 229). The alignment of these gaps does not match the precision found on the Caesarea wreck, however, nor are the gaps stated to be associated with watercourses and ropes within them. The St.-Gervais 3 wreck exhibits a rare framing feature as well: at various points the spaces between the framing components are filled with wedges (Liou and Gassend 1991: 227, fig. 86.4, 229).
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