THE RIG OF THE ELEVENTH-CENTURY SHIP
AT SERÇE LIMAN, TURKEY

A Thesis
by
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THE RIG OF THE ELEVENTH-CENTURY SHIP
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ABSTRACT

The Rig of the Eleventh-Century Ship
at Serçe Liman, Turkey. (May 1983)
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Scientists and students from the Institute of Nautical Archaeology and Texas A&M University excavated a medieval shipwreck at Serçe Liman, a natural harbor on the southern coast of Turkey, during the summers of 1977 through 1979. Artifacts date the wreck to c. 1025 A.C. and point to an eastern Mediterranean origin for the ship.

This thesis has undertaken the study of both rigging elements recovered from the wreck site and the hydrostatic features of the ship's hull in order to determine the nature of the ship's rig.

Analysis of the hull indicates that the Serçe Liman ship would have carried two masts: a foremast stepped in the bow and a mainmast stepped midships. A study of the rigging remains, consisting of two partially preserved blocks, a dozen sheaves and a heart thimble, and their distribution supports this hypothesis and also indicates that a group of spare rigging elements was stored in the stern storage area.

An examination of the hydrostatic characteristics of the
hull further corroborates this premise and, moreover, indicates that the sail area needed to efficiently propel this vessel would have been about 100 sq. m.

An overview of sources on medieval ships in the eastern Mediterranean shows that the lateen rig was the most prevalent rig used during medieval times and that some ships carried more than one mast at least as early as the tenth century. Although scarce, evidence for the employment of the square and sprit rigs is sufficient to suggest that both rigs may have seen some use but perhaps only on relatively small craft. However, in this case, neither a square nor a sprit rig would have been feasible for the two-masted rig of the Serçe Liman ship.

The Serçe Liman ship is presently the earliest lateen-rigged vessel known whose sailing qualities can be profitably assessed. Although quite small in size, this merchant ship was capable of making long-distance voyages, and with its round-shaped hull and box-like hold was designed for maximum cargo capacity. The hydrostatic properties of this hull were such that it probably would have retained sufficient righting ability and speed with a double-lateen rig. Thus, the proposed two-masted lateen rig for this ship would have maximized not only her maneuverability, but also her speed and safety.
DEDICATION

To Frederick H. van Doorninck, Jr.,
for keeping wind in the sails,
and me on course.
ACKNOWLEDGEMENTS

During the course of my research, I have become indebted to a great many individuals for their assistance and help. First and foremost amongst these I would like to acknowledge my appreciation and gratitude to Dr. Frederick van Doorninck and Mr. J. Richard Steffy for their invaluable advice, assistance and moral support. For their help during various phases of my research and writing, I would like to give special thanks to Dr. George F. Bass, Dr. Henry C. Schmidt and Dr. Donald Frey. While researching this paper, I had occasion to consult with Dr. Barbara Kreutz and Mr. Joe Schwarzer whose advice and help was greatly appreciated.

For their encouragement and help during the writing of this thesis, I would like to thank Bob Adams, Bill Bayreuther, Suzanne Biehl, Eileen Coldwell, Kevin Crisman, Rick Green, Faith Henchel, Peggy Leshikar, Pilar Luna, Robin and Netia Piercy, Cemal and Sema Pulak, Lisa Shuey, Bruce Thompson and a special thanks to Alison Darroch. To Dr. Fife and all the people at the Texas A&M Hyperbaric Laboratory, I extend many thanks for their support and borrowed office space which allowed me many hours of uninterrupted work. To my parents, I owe more than can be said for their understanding and support.

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CHAPTER I

INTRODUCTION

History and Background of the Wreck

During the summer and fall of 1973, the Institute of Nautical Archaeology (INA) conducted a two-month survey for ancient shipwrecks along the Turkish coast between Bodrum and Antalya.\(^1\) One of the shipwrecks located during the survey was a medieval wreck at Şerçe Liman, a natural harbor on the southern coast opposite Rhodes (Figure 1). Visual examination of the site revealed that the ship's cargo had included an interesting and diverse assortment of glassware. In addition, the wreck appeared to be covered by sand, giving promise that substantial portions of the hull might be preserved. Amphoras visible on the site were tentatively dated to about the twelfth century,\(^2\) although later excavation of the site revealed that the ship dated to the eleventh century.

The shipwreck was selected for excavation because of its unique glass cargo and because no Mediterranean shipwreck from a similar time period as yet had been excavated.\(^3\) In particular, it was hoped that this excavation might yield important new evidence concerning the design and construction

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This manuscript conforms in style and format to the American Journal of Archaeology.
Figure 1: Maps showing the location of the wreck site on the southern coast of Turkey.
of eastern Mediterranean ships of this period, since very little information on the subject is provided by historical sources. Excavation of the Serçe Liman medieval wreck was carried out by archaeologists and students from INA and Texas A&M University during the summers of 1977 through 1979.4

The ship had sunk a short distance inside the harbor mouth near the eastern shore and had come to rest at the base of an underwater ridge of exposed limestone that extended out from the shore toward the southwest for a distance of about 75 m. The ship settled on her port bilge, her bow facing away from the harbor mouth toward the northwest. Collapsed and flattened on the seabed, the wreck extended over an area that measured 18 m along the longitudinal axis of the hull and 14 m across. The area of seabed surrounding the site consisted almost entirely of a fairly flat expanse of deep sand, sloping gently toward the southwest from a depth of 33 m along the downslope edge of the wreck.

On-Site Mapping and Recording Procedures

The wreck site was sufficiently flat and level to permit the positioning of a rigid system of grid frames directly on the seabed for mapping purposes. Rectangular frames of angle-iron, measuring 4 m by 2 m and divided by a crosspiece into two 2-meter grid square areas, were wired together to form the grid, which was oriented so that the longitudinal axis was parallel to the ship's keel.

This grid system was labeled alphabetically along its
longitudinal axis beginning at the wreck's forward end and numerically in the downslope direction (Figure 2). Each 2-meter grid square was subdivided into four 1-meter-square quadrants: upper left (UL), upper right (UR), lower left (LL), and lower right (LR). These quadrants in turn were subdivided into four smaller quadrants numbered 1 through 4 (Figure 3), so that artifact locations could be described in terms of 50-centimeter-square areas within each grid section. As each artifact or group of artifacts from the same area was raised, it was assigned a lot number. Thus, for example, an item labeled Lot No. 41 05 LL2 was from the forty-first group of objects raised from the wreck and had been recovered from area "2" in the lower-left quadrant of grid square 05.

A general wreck plan including both artifacts and principle hull remains was made from photographs taken of the grid squares at frequent intervals during the course of the excavation (Figure 4). A detailed plan of the hull remains also was made, but in this case grid photographs were supplemented by numerous close-up photographs, drawings made under water, and some controlled measurements.

Only about 20 percent of the hull survived. Timber distribution was almost entirely limited to the bottom of the vessel and a rather substantial part of the upper port stern area. Hull sides otherwise were represented by only a few dozen small and widely scattered fragments. The hull bottom was sufficiently well-preserved to present a fairly complete idea of its planking and framing pattern and its construction
Figure 2: Wreck plan of the eleventh-century Serçe Liman wreck, showing positioning and labeling of the grid over the site.
Figure 3: Example of 2-meter grid square with subdivisions.
Figure 4: Wreck plan showing artifacts and hull members.
to above the turn of the bilge, The only internal hull members which survived were a portion of the keelson and some ceiling strakes and transverse ceiling planking, all located in the after part of the hold.

Almost all of the hull remains were mapped and raised during the 1978 field season. Preparatory to mapping, primary hull members were identified with white plastic labels. The keel, stem and sternpost were labeled as such.
In labeling the frames, the location of the midship frame at the hull's widest point was first determined. Frames forward of this point were then labeled alphabetically in sequence toward the bow; frames aft of this point were labeled numerically toward the stern (Figure 2). Planking strakes were numbered outward from the keel, with the designation S used for starboard planking and P for port planking. Wales, ceiling strakes (designated CP), transverse ceiling planking (designated TC), and hull members of unknown function (designated UM) were tagged with smaller, Dymo labels that were legible in close-up photographs. Since it was clear that many of the hull remains, particularly planking, would break up into smaller pieces upon removal from the seabed, each potential fragment also was tagged with a Dymo label.

Off-Site Recording Procedures

Once the hull remains had been labeled and mapped, they were raised and transported to the Bodrum Museum, where they were cleaned, recorded, and conserved. After an initial
evaluation of the wood remains had been made, during which they were measured, sketched, and described in a preliminary catalogue, deposits of iron-oxide concretion adhering to them were removed with a pneumatic chisel. Multiple views of each remnant then were recorded through drawings and photographs. Full-scale drawings of each remnant, made by the author, were done on clear acetate placed on transparent glass positioned directly above the wood, onto which were recorded all significant features including fastenings, wood-grain patterns, tool and pressure marks, and stains. The photographic record consisted of pairs of stereo photographs in which an entire remnant was included in both photographs. A second series of overlapping close-up photographs was made to show surface features in greater detail. As there are plans to physically reconstruct the Serçe Liman vessel, these hull remains are now being conserved with polyethylene glycol; conservation should be completed early in 1983.5

Preliminary Hull Reconstruction

A reconstruction and analysis of the hull, which is being undertaken by J. Richard Steffy, was begun with the fabrication of a 1:10 scale-model diorama of the hull remains in situ on the seabed (Figure 5).6 By revealing in three-dimensional perspective the final disposition of the hull remains on the seabed, the diorama facilitated revision of the wreck plan in which all of the remains that had become dislocated during the process of wreck dispersion were
Figure 5: Diorama. (From J.R. Steffy, "The reconstruction of the 11th century Serçe Liman vessel," JNautArch 11 (1982) 14, Figure 1.)
replaced as closely as possible to their original positions (Figure 6). Thus, the revised wreck plan shows the hull member fragments repositioned within the flattened-out hull as though there had been no dislocation.

A three-dimensional fragment model of the hull was then constructed (Figure 7). In this model, detailed, 1:10 scale replicas of the timbers were restored to their original positions within the hull through alignments of nail and treenail holes, wood-grain patterns, frame impressions on planking, and similar features. Once the fragment model had been completed, measurements were taken from it to produce a lines drawing of the hull (Figure 8); from this, construction plans then were made. The lines drawing and the construction plans made possible a study of the hull's structure and the calculation of principle hull dimensions, tonnage, draft, and hydrodynamic factors.

Hull Remains

The Serçe Liman vessel, built almost entirely of pine with the exception of her elm keel, had a length of 15 m and a moulded beam of 5.13 m. She had a deep, full-ended hull with a rockered keel and steep sheer. Her completely flat bottom amidships, sharp turn of bilge, and steep, straight sides combined to produce a box-like hold.

The hull was lightly timbered. Each frame was fastened to the keel by a single iron spike, and was on the average sided 12-14 cm and moulded 15-18 cm at the keel. The
Figure 6: Revised wreck plan of hull members. (From J.R. Steffy, "The reconstruction of the 11th century Serçe Liman vessel," JNautArch 11 (1982) 15, Figure 2.)
Figure 7: Fragment model. (From J.R. Steffy, "The reconstruction of the 11th century Serçe Liman vessel," JNautArch 11 (1982) 17, Figure 3.)
Figure 8: Hull lines of the Serçe Liman ship. (From J.R. Steffy, "The reconstruction of the 11th century Serçe Liman vessel," JNautArch 11 (1982) 31, Figure 13.)
planking, nailed and treenailed to frames, had an average thickness of 3.5 cm. Four pairs of wales, approximately 15 cm in diameter and made from logs cut in half lengthwise, girdled the sides of the hull.

The hull's framing is particularly interesting. Within the hold area, the frames had floors consisting of a short arm that ended inboard of the turn of the bilge and a naturally curved long arm that extended up past the turn of the bilge. Floors with long arms to port alternated with floors with long arms to starboard. Short arms abutted or were scarfed to futtocks and in some instances were fastened to the futtock with one or two iron nails. Short floors, cant frames and half-frames were used in the bow and stern.

The keel had a sided and moulded dimension of only 11 and 16 cm, respectively. However, the keelson, bolted to the keel between frames, was much larger, being sided 18 cm and moulded 20 cm. Although the keelson survived only between frames 2 and 8, it originally extended to either end of the hull, as evidenced by keelson bolts, pressure marks and discoloration on underlying frames.

This ship is of exceptional interest since it appears to be the earliest extant example we have of a seagoing vessel in which the construction of frames played the primary role in determining overall hull shape and in which frames were, in part, erected before planking of the hull was begun. After having set up his keel, stem, and sternpost, the shipwright erected ten frames amidships. He then fastened
to them and to the posts three main bottom planks on either side of the keel and one or more of the lower side planks on either side of the hull. These belts of bottom and side planking gave the rest of the hull its shape. Using the curve of the planking as a guide, the shipwright then shaped and installed all of the other frames, after which he completed planking the hull. Recurring evidence of rigid symmetry in the shape of the hull suggests that a system of controlled measurement was employed in its construction. Evidence of such systematic measurement has not as yet been detected in extant hulls from earlier periods.

Ship's Gear: Anchors

The ship was carrying eight iron anchors when she sank. Either three or four were bower anchors, carried on the bows ready for use, and the rest were spares (Figure 9). Minute traces of wood detected within the stock apertures of the two bower anchors studied to date—the forward starboard and the after port bower anchors—indicate that wooden stocks had been used with the anchors. No iron stocks were found on the wreck. The disposition of the spare anchors on the wreck indicates that they had been stacked together a short distance forward of amidships, probably on deck.

Ship's Gear: Rigging Elements

Remains of rigging gear recovered from the wreck consisted of three partially-preserved blocks, a heart thimble,
Figure 9: Wreck plan showing distribution of anchors and rigging artifacts.
a pin cap, and a dozen sheaves. One block was found concreted to the forward port-bower anchor, while a second block and two separate sheaves were recovered aft of midships. The third block not discovered in situ, was found just forward and downslope of the stern area. The remaining sheaves, heart thimble, and pin or pin cap were spares stowed in the stern, where implements for shipboard repairs were kept (Figure 9).

This thesis will undertake a study of these rigging elements in an effort to determine their functions and the nature of the ship's rig. The study will begin with an examination of rig types predominant in the Mediterranean during the Medieval period. A detailed description of the rigging elements and an analysis of their distribution on the wreck will be discussed. Preserved hull structure will be examined for further clues concerning the ship's rig type. Although no
Ship's Cargo: Date and Nationality of the Vessel

Coins and glass coin-weights from the wreck presently give the best evidence for the date of the ship's sinking. Three Islamic gold coins and fifteen clippings from other Islamic gold coins were recovered; the three complete coins are Fatimid quarter dinars, probably minted between 1000 and 1009. Roughly half of some forty copper coins found are still legible and appear to be later issues of the Byzantine emperor Basil II (976-1025). Sixteen glass coin-weights from the wreck are all Fatimid issues; fourteen still retain legible Arabic inscriptions. Four of these can be dated to 1020/21, and three to 1024/25 or possibly to 1021/22. Other weighing equipment included three different-sized balances, two sets of balance-pan weights apparently based on Islamic units of weight, and a Byzantine steelyard equipped with a balance pan.

Most of the coins and weighing equipment were found in the stern area within several concentrations of artifacts that also included some jewelry and four lead sealings, one of which was an unused blank. One of the pieces of jewelry, an ornate gold earring, may be Fatimid. On the other hand, two of the used lead sealings, still partially legible, are Byzantine. Perhaps the sealings had been used to seal and certify the value of purses of coins or jewelry.

The ship was carrying a variety of cargo when she sank; the heaviest and bulkiest of which was just under three metric tons of glass. This large cargo consisted of cullet in
the form of chunks of raw glass, broken glassware, and waste products from the manufacture of glassware. Some eighty or more intact glass vessels also were aboard the ship. Most or all of the intact glassware appears to be Islamic, and examples of much of the intact glassware occur in the glassware cullet. Preliminary results of lead-isotope studies of select samples of the cullet being undertaken by Dr. Robert Brill of the Corning Museum of Glass in Corning, New York suggest that some of the cullet may have had a northwest Iranian origin, while parallels for the glass lamps, the only glassware category as yet studied thoroughly, point to a region extending from the Syro-Palestinian coast to northwest Iran as the most probable area of origin.

Secondary cargos other than the intact glassware included some eighty amphorae of wine and various ceramic wares. Greek letters or monograms inscribed on the shoulders of most of the amphorae recovered indicate that they are of Byzantine origin. Around three-dozen redware cooking pots may be Byzantine as well, since at least two of them also bear Greek monograms. On the other hand, some forty glazed bowls and a dozen whiteware and redware gargoulettes all appear to be Islamic. The whiteware gargoulettes may be Egyptian.

One of the most interesting small cargos carried by the ship was a one-half to one kilogram quantity of the mineral orpiment (arsenic trisulphide). Having a variety of uses—as a yellow pigment, for inlay work, in medicines, and, when mixed with lime and lye, as a depilatory—orpiment was mined
in the Hellespont and in Cappodocia.\textsuperscript{15}

Two pairs of small, rotary millstones on board also may have been part of the cargo.\textsuperscript{16} As with the glass lamps, these also may well have come from the Syro-Palestinian coast since it is known that this region was an important exporter of millstones at this time.\textsuperscript{17} The fact that two or three of the Serçe Liman millstones were found on the surface of the wreck rather than down low within the hull has lead to speculation that they may have been used on the ship for the grinding of grain or lentils for shipboard consumption. However, an Islamic ship dating to around the ninth century that sank at Agay, France appears to have been carrying at least seven millstones on her deck.\textsuperscript{18}

Almost all of the ship's cargo and ballast, the latter consisting of two tons of large limestone and beachrock boulders and limestone cobbles, were carried within the after half of the hull. Since the ship could not have sailed so completely out of trim, it would appear that the forward part of the hold contained a major cargo that has perished entirely.

The wreck yielded a wide variety of artifacts related to shipboard life. Tools for making repairs included axes, adzes, chisels, a bow drill, a saw, a mallet, and nails and tacks. A multi-tined fishing spear, three copper netting needles, both folded and small cylindrical lead weights for fishing nets, and over two-dozen bark floats for perhaps three larger nets give evidence for fishing, probably both a pastime and
to augment shipboard diet. Over a hundred folded net weights recovered are decorated with geometric patterns in relief similar to designs found in Byzantine decorative art; several bear Greek inscriptions, including an abbreviation of the name "Jesus" written in retrograde.

In addition to fish, analysis of seeds and bone fragments show that the shipboard diet appears to have included lentils, olives, various nuts and fruits, sheep and/or goat, and pork. Evidence for shipboard cooking consists of several fire-blackened cooking pots and approximately three-dozen pieces of charcoal. Only one ceramic lamp for illumination at night was recovered and is similar to contemporaneous examples from Egypt.19

Pastimes during the voyage included the playing of chess and backgammon as evidenced by gaming pieces found: chess in the stern where the more cosmopolitan passengers or merchants relaxed and backgammon in the midships area which crew members frequented. For repelling attacks or foreign aggression, the ship carried a substantial complement of defensive weapons. At least nine lances, some sixty javelins, and remnants of perhaps two swords were recovered from the wreck. One of the swords has a bronze hilt decorated on either side with an ornate bird that appears stylistically to be of Indian origin.20

At this early stage in the study of the artifacts from the wreck, the nationality of the ship and her crew and the ship's route on her last voyage remain quite uncertain. The
presence of pork bones as well as net weights with Christian inscriptions in Greek does suggest the possibility that there were at least some Christians on board, although these items presently give no clue to those passengers' place of residence. The ship was carrying both Byzantine and Fatimid coinage and weighing equipment but was perhaps better prepared to trade in Fatimid than in Byzantine ports. And, as previously noted, preliminary results of lead-isotope studies of the cullet suggest that it may have had a northwest Iranian origin. These factors raise the possibility that the ship had set out on her last fateful voyage from the eastern Black Sea, where the Byzantine port of Trebizond was at the time an important, if declining, entry port for eastern Islamic products into Byzantine waters.21 Perhaps the ship then had taken on the Byzantine wine amphoras and cooking pots somewhere on route from the Black Sea to Fatimid Syria or Egypt. On the other hand, Aleppo was at this time emerging as the principal gateway for eastern Islamic products into the Mediterranean.22 Thus, another possibility is that the ship was sailing westward with her mixed Islamic and Byzantine cargos, perhaps to Fatimid North Africa or Sicily. In any event, the ship's contents taken as a whole point to the eastern Mediterranean as her most probable home waters, and a study of both the vessel and her accoutrements will yield important new information for further studies on maritime life and commerce in this area during the early eleventh century.
In an effort to better understand the economic dynamics of ancient and medieval maritime trade, historians have attempted to study and to define the duration of those trading voyages. A. Udovitch notes that to understand fully the influence of maritime trade on commerce, one must understand the importance of tempi di percorrenza, "the time it took ships, men and merchandise to move from one point on the Mediterranean to another."\(^{23}\) Time and safety were major considerations in a merchant's evaluation of the potential for success of his endeavors to acquire goods cheaply and to transport them to places where the demand and prices were high.\(^{24}\)

Unfortunately, not much is known about the sailing capabilities of the ancient and medieval vessels upon which much of the wealth and commerce of those times depended. For the most part, such information comes from accounts of voyages that are sketchy and incomplete. These sources yield only a general notion of the speed and sailing performance of ancient and medieval ships but leave entirely unclear the capabilities of ships of any particular type or size. For this reason, the validity of attempts to compare the speed and sailing performance of ancient and medieval ships is highly questionable.\(^{25}\) More data are needed concerning the speed and sailing performance of particular ships of known design and size.

To date, perhaps only three shipwrecks have been exca-

vated in the Mediterranean in which enough hull remnants
survived to allow for reliable hydrostatic studies. The reconstruction of the hull design and sail plan of the fourth-century B.C. Kyrenia ship by J.R. Steffy will yield valuable information concerning the hydrostatic properties and sailing abilities of a vessel of the Classical Greek period, and the excavation and reconstruction of the first-century B.C. La Madrague de Giens ship promises to provide similar data for a vessel of the later Roman period. The Serçe Liman wreck now offers the opportunity to learn how a particular medieval period vessel sailed. From a study of its rig, substantial progress may be made toward reaching a fuller understanding of the design, construction and sailing abilities of one type of medieval ship.
CHAPTER II

MEDIEVAL RIGS

Although medieval ships in the Mediterranean have not been neglected by modern scholars, a dearth of detailed primary material has made their study difficult. No doubt this reflects the human penchant to take utilitarian objects for granted and thus to record them only minimally. Certainly, this has been true in the case of ships, especially those of medieval times.

During the medieval period, the eastern Mediterranean was trafficked heavily by ships from many ports. The Serçe Liman vessel was one of several ship types that plied these waters during this time of intense maritime activity and, presumably, each type utilized a rig which best suited the needs of commerce and warfare during the period. 28

In order to establish the type of rigging carried by the Serçe Liman ship, it is necessary first to review and summarize available evidence on the types of rigs in use in the Mediterranean during medieval times. What forms of propulsion were eleventh-century ships utilizing? What were the prevalent sail types and how many masts might a vessel have carried? What were the basic types of ships extant during this period?

Available primary sources such as representational art and literature yield little information on the rigging of
medieval ships prior to the thirteenth century. Although these references do reveal that the lateen rig was predominately used in the Mediterranean during medieval times, there also is evidence to suggest that the square sail and possibly the sprit sail were employed as well. Detailed descriptions of even lateen rigs are lacking prior to the thirteenth century. The few extant ship representations give only general, stylistic depictions of rigging, while written references to rigging are meager and often subject to varying interpretations.

Lateen Sail

Medieval illustrations show the lateen sail to have been the most commonly used rig during that period in the Mediterranean. Perhaps its earliest depiction is from a gravestone relief dating to the second century A.C., although not all scholars are in agreement that this relief shows a lateen sail. Some have suggested that the yard in the relief is that of a square sail curved by the artist to fit within the arch of the gravestone, while others have proposed that the sail type belongs to a high pitched lug. In any case, most scholars have accepted this as a representation of a fore-and-aft sail. A graffito of an early lateener and a fourth-century mosaic depicting a lateen vessel under sail suggest that lateen-rigged vessels may have been numerous enough to have become models for at least a few artists in Roman times.
Perhaps the first written allusion to a lateen sail comes from a letter written by Synesius in 404 A.C. concerning his voyage on a ship from Alexandria to Cyrene. In Procopius' *History of the Vandalic Wars*, a passage discussing an expedition of ships sent from Byzantium to Africa in 533 mentions an order for the commanding ships to paint the upper angle of their sails red for purposes of identification:

So, at the sailing of the expedition, he (Belisarius), on careful consideration, gave an order that the three ships carrying the officers in chief command should have almost as much as a third of the upper angle of their sails painted red. Although it also has been postulated that this description of the upper part of a sail might equally have applied to other forms of fore-and-aft sails, this passage has been accepted by many scholars as an indication for lateen-rigged ships in the Mediterranean as early as the sixth century.

During the assault on Thessalonika in 904, the Arabs constructed siege towers by lashing the steering oars to their masts and outer ends of the spars. From the passage in which this construction is described, R.H. Dolley has concluded that only lateen rigs could have afforded the proper structural foundation on which such towers could have been built. Most scholars have accepted Dolley's interpretation, although R. LeBaron Bowen disagrees that the Arab ships needed to have been lateen-rigged for the type of construction described. Bowen believes that the constructional description in the passage is unclear and offers the alternative interpretation that the engineering of the towers could
have occurred just as easily on a square-rigged vessel. 39

Although there is considerable controversy concerning the validity of supposed references to lateen sails in written sources of the early Byzantine period, ship representations reveal beyond doubt that lateen sails were used in the Mediterranean from the ninth century on (Figures 10-42). The most generous body of representations of lateen-rigged ships comes from medieval illuminated manuscripts. Unfortunately, the artists involved took great liberties in their renditions, so that a deceptively wide variety of sail shapes and tackle representations were produced. Many of the early illuminations depict lateen sails as inverted triangles with little or no angle to the yard (Figures 15, 16, 23, 24, 30, 32). While a few artists recorded a single mast stepped far aft or extremely far forward, most settled for simply drawing a mast somewhere near a mid-point within the craft. In general, the hull design of these depictions is similar; they are full-ended hulls, fairly symmetrical in shape; and almost all are navigated with steering oars. Although none of the early and mid-medieval vessels are seen as having stern- or forecastles, some do carry stern projections, which in some cases appear to support a transom-like structure (Figures 18, 22, 23, 27, 32, 36). Time-like stern projections on many of the craft undoubtedly represent the after ends of the sternpost and wales and, along with the partial transom-like platforms they support, may be the foundational antecedents of later full transoms and sterncastles.
Figure 10: Single-masted, lateen-rigged vessel. Ninth-century miniature from the Chludov Psalter. A halyard with block, serving as a backstay, appears to run through a block-like fitting beneath a round-shaped masthead. Another line with block that also appears to run through the block-like fitting may be a second halyard or may be a shroud. A tackle is shown attached to the forward end of the yard. The vessel has a steering oar mounted on a wing-like outrigger on either quarter. (Adapted from M.V. Shchepkina, Miniatures of the Chludov Psalter (Moscow 1977) Figure 96.)
Figure 11: Two single-masted, lateen-rigged vessels, one with a furled sail. Miniature from a copy of The Homilies of St. Gregory of Nazianzenus dated c. 880. Each vessel had a pair of halyards with blocks aft of the mast, hook-like mastheads through which the halyards appear to run, a pair of shrouds with blocks on the mast's forward side, and a pair of braces run through blocks attached to the upper end of the yard. A pair of tackle, one shown with a block, are visible on the vessel with the unfurled sail. (From H.A. Omont, Miniatures des Plus Anciens Manuscrits Grecs de la Bibliothèque Nationale (Paris 1929) plate XX.)
Figure 12: Two single-masted vessels. Taken from a miniature of The Homilies of St. Gregory of Nazianzenus dated c. 880. The sail of only one of the vessels is clearly visible and is furled. Halyards, shrouds, braces and tackle appear to be depicted. (From H.A. Omont, Miniatures des Plus Anciens Manuscrits Grecs de la Bibliothèque Nationale (Paris 1929) plate LX.)
Figure 13: Single-masted vessel with a furled lateen sail. Taken from a copy of a miniature of The Homilies of St. Gregory of Nazianzenus dated c. 880. Although the depiction is in very poor condition, some rigging lines are evident including a halyard, which appears to run through a hook-shaped masthead. (From H.A. Omont, Miniatures des Plus Anciens Manuscrits Grecs de la Bibliothèque Nationale (Paris 1929) plate LXL.)
Figure 14: Single-masted, lateen-rigged vessel. Taken from The Homilies of St. Gregory of Nazianzus dated c. 880. The highly stylized depiction of rigging shows halyard and shroud lines running from the masthead, which—now almost entirely obliterated—may have been round. Small rectangular shapes on the rigging lines probably represent blocks. A steering oar is mounted on an outrigger on the quarter. (Adapted from B. Landström, The Ship (New York 1961) 81.)
Figure 15: Single-masted, lateen-rigged vessel. Taken from a copy of The Homilies of St. Gregory of Nazianzenus dated c. 880. In this simplistic depiction, the sail is stylistically rendered as an inverted triangle. Halyard, shroud and brace lines appear to be shown. (From H.A. Omont, Miniatures des Plus Anciens Manuscrits Grecs de la Bibliothèque Nationale (Paris 1929) plate CXVII 16.)
Figure 16: Single-masted, lateen-rigged vessel. Taken from a copy of a miniature of The Homilies of St. Gregory of Nazianzenus dated to the eleventh century. The sail is stylistically rendered as an inverted triangle, and the sole rigging line visible is so misplaced that it is of uncertain function. The stern is tripartite in form. Two tholepin-like features project from the vessel's bulwarks. (From George Galavaris, The Illustrations of the Liturgical Homilies of Gregory Nazianzenus VI (Princeton 1969) Figure 237, plate XLIII.)
Figure 17: Lateen-rigged vessel with a single mast stepped far forward in the bow. Taken from a copy of a miniature from a Greek manuscript dated c. eleventh century. A halyard, tackle and brace all appear to be shown, with the halyard running through a round masthead and angling over to the upper side of the yard. A transverse, rectangular platform-like structure is shown in the stern. The sail tack tackle appears to be lashed to one of two thole-pin-like features projecting from the vessel's bulwarks. (Adapted from S.M. Pelekanidis et al., The Treasures of Mount Athos II (Athens 1975) Figure 348.)
Figure 18: Single-masted, lateen-rigged vessel. Taken from a copy of the miniature from the Bristol Psalter dated 1066. A halyard, or shroud, braces and two tackles, all with their blocks, are clearly shown. The masthead is hook-shaped. Two steering oars are shown, one in water and one raised up, mounted on either side of an open stern structure. The original depiction has excellent detail, including the rendering of frames on the visible inner face of the hull's starboard side. (From the Bristol Psalter, courtesy of Dr. Barbara Kreutz.)
Figure 19: Single-masted vessels. Tenth-century graffiti from Bulgaria. Only vessel B shows a sail, which appears to be a lateen. (Adapted from Dimitar Ovcharov, "Ship graffiti from medieval Bulgaria," JNaut Arch 6 (1977) 59-61, Figures 2, 4 and 5.)
Figure 20: Single-masted, lateen-rigged vessel. Taken from a copy of a miniature from a Greek manuscript dated to the eleventh century. The masthead is hook-shaped. The vessel has three tholepin-like projections similar to those seen on vessels in Figures 17 and 18. (Adapted from the Vaticana, Barbarini Grams 372 Psalter fol. 145 vo. at the Princeton Index of Christian Art.)
Figure 21: Single-masted, lateen-rigged vessel. Taken from a copy of a miniature from The Life of St. Eustathius dated to the eleventh century. A halyard runs through a hook-shaped masthead. Two lines on the after side of the mast may be shrouds. A brace runs through a block attached to the upper end of the yard. A steering oar is mounted at either end of a cross-beam traversing the quarters. (Adapted from S.M. Pelekanidis, The Treasures of Mount Athos II (Athens 1975) 208, Figure 329.)
Figure 22: Single-masted, lateen-rigged vessel. Taken from a copy of a miniature from the Psautier Barberini dated to the eleventh century. The masthead is hook-shaped. Three tine-like projections at the stern carry a transverse, rectangular platform-like structure. (Adapted from S. Der Nersessian, L'illustration des Psautiers Grecs du Moyen Âge II (Paris 1970) Figure 271.)
Figure 23: Single-masted, lateen-rigged vessel. Taken from a copy of a miniature from the manuscript Jonas and the Whale dated to the eleventh century. The sail is stylistically rendered as an inverted triangle. The masthead is hook-shaped. A halyard, brace and tackle are shown. Three tine-like projections at the stern carry a transverse, rectangular platform-like structure. (Adapted from S. Der Nersessian, L'illustration des Psautiers Grecs du Moyen Age II (Paris 1970) Figure 317.)
Figure 24: Single-masted vessel. Taken from a miniature from an eleventh-century copy of The Homilies of St. Gregory of Nazianzenus. The sail is furled, but the strongly curved yard compares well with some of the yards in other Byzantine miniatures that show lateen sails stylistically rendered as an inverted triangle. The masthead is round. The stern has three tine-like projections. The vessel is being propelled by four oars, and one steering oar also is shown.
(Adapted from George Galavaris, The Illustrations of the Liturgical Homilies of Gregory Nazianzenus VI (Princeton 1969) Figure 103, plate XVI.)
Figure 25: Lateen-rigged vessel with single mast stepped far forward in the bow. Taken from a copy of a miniature from Giorgio dei Greci Lectionary dated to the eleventh century. Halyard lines run through a hook-shaped masthead. (Adapted from Giorgio dei Greci Lectionary, Fol. 63ro Greek at the Princeton Index of Christian Art.)
Figure 26: Single-masted vessel with mast stepped far forward in the bow. From a twelfth-century floor mosaic in Otranto, Italy. One sailor appears to be hauling on a brace line. The only other rigging depicted are lines which extend from the mast top to the yard on either side of the mast. (From a postcard of the Otranto floor mosaic, courtesy of Dr. Barbara Kreutz.)
Figure 27: Single-masted, lateen-rigged vessel. Twelfth-century mosaic in the Basilica of St. Mark, Venice. A halyard, tackle and brace are depicted. The vessel carries a sterncastle structure. A steering oar is shown enclosed within this structure on the visible quarter. (From Friedrich Moll, Das Schiff in der Bildenden Kunst (Bonn 1929) plate BXe, Figure 128.)
Figure 28: Single-masted, lateen-rigged vessel. From a copy of a relief from Pavia, S. Pietro, Ciel d'Oro dated to the twelfth century. Halyards, shrouds, tack and braces are shown, all with blocks. The halyard runs through a round-shaped masthead, and the yard is made of two spars lashed together. The steering oar visible is mounted through a square oar-mount. (From Friedrich Moll, Das Schiff in der Bildenden Kunst (Bonn 1929) plate Fa., Figure 29.)
Figure 29: Lateen-rigged vessel with a single mast stepped forward near the bow. Taken from a copy of The Homilies of St. Gregory of Nazianzenus dated to the twelfth century. The masthead is hook-shaped. Both the halyards and shroud lines appear to be depicted. The helmsman holds a brace in his hand. The stern ends in three tine-like projections. The vessel is being propelled by both the sail and a pair of oars. One steering oar also is shown. (From George Galavaris, The Illustrations of the Liturgical Homilies of Gregory Nazianzenus VI (Princeton 1969) plate XXVII, Figure 140.)
Figure 30: Two-masted, lateen-rigged vessel. Drawing from a twelfth-century Arab manuscript. The vessel and its sails are very stylistically drawn. One sail is furled; the other is rendered as an inverted triangle. Rigging lines extending down from the ends of either yard probably are tackles and braces. (From Frederick van Doorninck, Jr., "Byzantium, mistress of the sea: 330-641," A History of Seafaring, ed. by George F. Bass (New York 1972) 145, Figure 12.)
Figure 31: Two-masted, lateen-rigged vessel. Taken from a copy of a miniature from a thirteenth-century manuscript. The vessel has a steering oar mounted on an outrigger on either quarter and a small sterncastle. (Adapted from Hugo Buchthal, Miniature Painting in the Latin Kingdom of Jerusalem (Oxford 1957) plate III.)
Figure 32: Single-masted, lateen-rigged vessel. Taken from a photograph of a thirteenth-century enamelled bronze plate in the Basilica of St. Mark, Venice. The sail is rendered as an inverted triangle. The masthead is hook-shaped. Two braces and two tackles are shown. A pair of lines running down from the masthead represent halyard and/or shroud lines. Two tine-like projections at the stern support a transverse, platform-like structure. The vessel is being propelled by both the sail and oar, and a pair of steering oars are also shown. (Adapted from H.R. Hahnloser, *La Pala D'Oro* (Firenze, Italy 1965) Tav. XLI.)
Figure 33: Single lateen-rigged vessel. A thirteenth-century relief from the facade of a cathedral in Grossetto. Mast carries hook-shaped masthead and furled sail. Both oars and steering oar are shown. No rigging lines are visible. (From Friedrich Moll, Das Schiff in der Bildenden Kunst (Bonn 1929) plate Fa., Figure 121.)
Figure 34: Two-masted, lateen-rigged vessel. A thirteenth-century graffito at Finale Ligure. As is normally the case in medieval representations of multi-masted lateeners, only the forwardmost mast has a pronounced forward rake. A lateen sail is indicated on the after mast by a triangle. Two sets of double slashes in the stern probably represent steering oars. (Adapted from Marco Bonino, "A Medieval Graffito at Finale Ligure," MM 61 (1975) 292.)
Figure 35: Three-masted, lateen-rigged vessel. From the thirteenth-century mosaics of San Marcos. Halyard and shrouds are shown but with no distinction between them. Tack tackle and braces are visible on the foremast. Steering oars are carried on the quarter along with a sterncastle-like structure. (Adapted from B. Landström, The Ship (New York 1961) 82, Figure 212.)
Figure 36: Two-masted, lateen-rigged vessels. Thirteenth-century mosaic in the Church of St. John the Evangelist, Ravenna. Only the foremost on both vessels has a foreward rake. Tackle lines appear to be indicated on both representations. The stern of vessel B has two tine-like projections and a castle-like structure. (Adapted from B. Landström, The Ship (New York 1961) 87, Figure 230.)
Figure 37: A thirteenth-century, three-masted, lateen-rigged vessel. From the mosaics of San Marcos. Tack tackles are depicted on only the mizzen and foremast. Both shroud and halyard lines appear to run along either side of all three masts. (Adapted from B. Landström, The Ship (New York 1961) 82, Figure 211.)
Figure 38: Vessel propelled by oars and sail. Faience fragment in the Arabic Museum, Cairo, dating to the twelfth or thirteenth century. The sail, probably lateen, is rendered as an inverted triangle. (Adapted from Musée National Arabe, La Céramique Egyptienne de L'Époque Musulmane (Cairo 1922) plate 124.)
Figure 39: Two-masted, lateen-rigged vessel. Thirteenth-century miniature in the National Library, Paris. This miniature shows halyard lines only on the foremast. (Adapted from B. Landström, The Ship (New York 1961) 87, Figure 229.)
Figure 40: Two-masted, lateen-rigged vessel. Thirteenth-century relief on the Leaning Tower of Pisa. This relief depicts braces, tack tackle and lifts. A halyard is seen on only the mainmast. (Adapted from B. Landström, *The Ship* (New York 1961) 86, Figure 227.)
Figure 41: Single-masted, lateen-rigged vessel. Taken from a copy of a wall painting from the Church of St. Nicholas Orphanus in Salonica dated to the early 1300s. A pair of halyards run through a round masthead. A brace also is shown. Both rowing oars and a steering oar appear to be depicted. (Adapted from D.T. Rice, Byzantine Painting (New York 1963) Figure 99.)
Figure 42: Single-masted, lateen-rigged vessel. Miniature from a Greek manuscript dated to 1368. It depicts halyard lines, block and lifts. (Adapted from Christiane Villain-Gandossi, "Le Navire Medieval A Travers Les Miniatures Des Manuscrits Francais," The Archaeology of Medieval Ships and Harbours in Northern Europe, ed. by Sean McGrail (London 1979) 211, Figure 12.10.)
The lateen rig would appear to be the only ship rig that is depicted in Mediterranean representational art between the sixth and twelfth centuries. It seems clear that it had become the dominant rig in the medieval Mediterranean at least as early as the ninth century and very possibly earlier, particularly in view of the fact that many of the earlier Byzantine manuscript miniatures depicting lateen sails were probably copied from earlier works. These ship depictions establish the enormous popularity of the lateen rig between the ninth and twelfth centuries.

Sprit Sail

Several obvious representations of sprit-rigged vessels occur among the extant ship representations from tombstones and sarcophagi of the ancient Mediterranean world. These pictorial bas-reliefs reveal that the sprit rig was in use during the Roman period from at least as early as the second century B.C. However, no literary or representational evidence for the employment of this rig in the Mediterranean exists after the third century until the fifteenth century, when the rig reappears in representational art (Figure 43).

Pictorial evidence shows that the sprit rig had appeared in northern European waters by the fifteenth century. Perhaps the sprit rig had gone out of use in the Mediterranean and was later independently invented by the Dutch. However, it also could be argued that the sprit rig was transported to northern European waters by Dutch and English sailors.
Figure 43: Islamic painting showing sprit-rigged craft. (Adapted from W. Arnold Thomas, Painting in Islam (New York 1965) 115, plate LI.)
frequenting the Mediterranean. The lack of medieval representations of sprit-rigged vessels in the Mediterranean may be due to this rig being used mostly on small craft. If this were the case, as is likely, the rig could easily have been overlooked by medieval artists who would have preferred larger, more common merchant vessels as models for their depictions of religious voyages.

Square Sail

The oldest-known rig, the square rig, was apparently the only rig used in the ancient Mediterranean world until well into the last millennium B.C., our earliest evidence for a fore-and-aft rig probably dating to the second century B.C. The square rig continued as the dominant rig in the Mediterranean throughout the Roman period but then became eclipsed by the lateen rig in early medieval times. A square-rigged vessel depicted in a sixth-century Byzantine mosaic in Ravenna reveals that the square rig was used until that time, but the rig then completely disappears from representational art in the Mediterranean until it reappears in the thirteenth century. (Figure 44).

The re-emergence of the square rig in the fourteenth century as a major rig within the Mediterranean undoubtedly owed much to the influx of square-rigged ships from northern Europe at that time. There is reason to believe, however, that it may never have completely disappeared from the Mediterranean.
Figure 44: Two single-masted, square-rigged vessels dated to the thirteenth century. (Adapted from Marco Bonino, *Archeologia e Tradizione Navale Tra La Romagna e il Po* (Ravenna, Italy 1978) 178, Figure 12.)
In the twelfth century, the Byzantine scholar Eustathios in his commentary on Homer's _Odyssey_ makes mention of the word σαγολαίφεα (sagolaiphea). He states that the more common folk used this word, deriving it from σαγός (sagos), meaning cloak, and λαίφος (laiphos), meaning sail. The modern Greek authority on Byzantine maritime life, P. Koukoules, has argued that Eustathios' σαγολαίφεα must be a square sail that in modern times, in the Aegean, has been called σακολαιβί or (sakolaivi) or τσακολαίφα (tsakoliapha). The vessels carrying this sail have the same name and, as Dr. Koukoules failed to note, are either square-rigged or sprit-rigged. Thus, while the passage in Eustathios indicates that a square shaped sail was known to the Byzantines in his day, we are left uncertain whether it was used with the square rig, the sprit-rig, or both.

A further indication that the square rig may not have disappeared from the Mediterranean is the fact that when the rig does reappear on Mediterranean ships in representational art, the yard is still supported by topping lifts just as it was in ancient times. Moreover, while the earliest of these representations which shows topping lifts dates to the fourteenth century, topping lifts do not appear in northern European ship representations until the end of the fifteenth century.

There is possibly one other piece of evidence for the square rig's continued use in the Mediterranean throughout the medieval period. Northern European ships adopted through-
beams and crenelated castles from Mediterranean ships in the
wake of the renewal of substantial maritime contact with the
Mediterranean at the beginning of the Third Crusade (1188). It was also at this time that the Northern square rig was im-
proved by the introduction of the bowsprit with its bowlines,
which helped keep the leading edge of the sail flat when
sailing into the wind. It is generally thought that this
was a Northern innovation, but it may have been adopted from
Mediterranean square rigs, since there is evidence for the
use of bowlines during the Roman period. A Roman mosaic from
Themetra in Tunisia depicts a two-masted, square-rigged mer-
chantman with apparent bowlines running back to the main sail
from the upper end of the forward-raking artemon mast set in
the bow.

Medieval Ships

Information concerning medieval ships in the Mediterra-
nean is complicated by the confusing variety of terms referring to ship-types used in the written sources. It is apparent from studies attempting to clarify both Muslim and Byzantine
ship terms that often a single term could describe a variety of ship-types or a variety of terms could refer to a single
ship-type. Three general classes of ships do, however,
emerge: long, narrow galleys propelled by both oars and sails
but primarily by oars; tarida-type vessels, having broader,
roomier hulls than galleys and propelled by both oars and
sails but primarily by sails; and ships propelled solely by
sails. Although the majority of medieval ship representations seem to depict vessels that were only sailed, some show vessels propelled by both oars and sails.

When the Muslim conquerors first entered the Mediterranean world in the seventh century, they were forced to establish naval forces adequate to face those of their Byzantine adversaries. To accomplish this, they drafted local shipwrights in the conquered Byzantine provinces, who undoubtedly reproduced the types of ships they already knew. Thus, the first Muslim war galleys are assumed to have been quite similar to Byzantine war galleys (dromons). Byzantine and Muslim writers of the period provide little information as to how they might have differed, other than that the Muslim warships tended to be of somewhat larger, heavier construction and slower.

The Muslim practice of conducting annual raids against Byzantine coastal regions for booty and slaves even during the winter months generated a need for all-weather warships with roomy holds and was probably a major factor in the development of tarida-like galleys with broader, rounder hulls that relied more heavily on sails for their propulsion. The earliest mention of the tarida is in Venetian records of the ninth century, but the name and the vessel-type are probably of Arab origin. By at least as early as the eleventh century, taride were being used as horse transports. Such vessels were also adapted early on for use as merchantmen. Indeed, it has been suggested that the tarida ship-type
with its lateen rig may have been particularly characteristic of ships in the ninth to eleventh centuries in the Mediterranean.\textsuperscript{64}

Some common Muslim merchant ship-types have been partially defined, so that we have a general notion of what they were like. The \textit{qumbar} was a large sailing ship that carried passengers and heavy cargo over much of the Mediterranean.\textsuperscript{65} The \textit{gārib}, which also carried passengers and heavy cargoes on long, open-sea voyages, was an open vessel relatively unprotected from attack, which depended primarily on oars for its propulsion. While often used as an independent transport vessel, it was at times attached to a larger sailing ship and used as its service boat for the transport of cargo and passengers to and from the shore.\textsuperscript{66} The \textit{ghurāb} was a galley used in warfare and piracy but sometimes also as a merchantman carrying cargo and passengers.\textsuperscript{67} It is perhaps noteworthy that each of these three types of Muslim merchantships appears to have belonged to a different one of the three general classes of ships mentioned above.

The term used to refer to a ship type seems in some cases to have been descriptive of hull shape. \textit{Ghurāb}, for example, has for one of its meanings "sword edge" and thus may refer to the slender, cutting shape of a galley.\textsuperscript{68} \textit{Hajm}, a word that normally designates a large drinking bowl, was also the name of a type of Muslim ship that sailed between Sicily and Egypt; the name suggests that this type of vessel may have been characterized by a relatively round hull.


Qarrāba, meaning box or chest, was also the name of another type of ship used on the same route; perhaps this ship-type possessed a more box-like hull. 69

Medieval Ships: Rigging and Mast

Although stylized and simplistic in rendition, a great many of the medieval representations of lateen-rigged ships depict running and standing rigging and their respective blocks. Unfortunately, the representations are too schematic to provide any detailed information about the design and components of the rigging elements involved. Running rigging depicted includes one or two tack tackles (Figures 10-12, 17, 23, 27, 28, 30, 32, 35, 36, 37, 40), braces (Figures 11, 12, 15, 17, 22, 23, 27-32, 40, 41) and halyards (Figures 10-15, 17, 21, 23, 25, 27-29, 35, 37, 39, 41, 42). There is sometimes an obvious intent to show both halyards and shrouds, but the two are difficult to distinguish one from the other (Figures 14, 15, 18, 21, 29, 32, 35, 37). Occasionally, a halyard is shown also serving as a backstay (Figures 10, 19). Many of the representations show a round or hook-shaped feature on the masthead block through which the halyard ran (Figures 10-14, 17, 21, 25, 28, 32). 70 A similar form of masthead block is still used on modern dhows. 71

Our earliest evidence for medieval Mediterranean ships with more than one mast dates to the tenth century. Although the rig of the vessels involved in the Arab assault on Thessalonika in 904 has been debated, no one has expressed
doubt that these warships had more than one mast, since the masts that helped to support the makeshift siege towers constructed on the ships must have been located well forward in the bow. In an eleventh-century miniature depicting an amphibious siege, soldiers are seen charging across makeshift gangways hung from the masts of two vessels planked and lashed together, each of which carries two masts. 72 A contemporaneous passage concerning the construction of wooden castles on the largest dromons in the Byzantine fleet in paragraph 7 of the θαλασσομαχίας of the Emperor Leo VI only makes sense if one assumes that these warships also had more than one mast. 73 Three-masted warships were known in the medieval Mediterranean certainly as early as the eleventh century. In 1081, during the First Crusade, a three-masted pirate ship was seen and recorded by the Byzantine princess Anna Comnena in her biography of her father, Alexius I. 74 In 1192, the fleet of Richard I of England fought a Muslim three-masted vessel, 75 and a contemporaneous Arab writer, Bahā'-ad-Dīn, makes mention of the many sails of King Richard's galley. 76

We first hear of merchant ships with more than one mast in a twelfth-century source. The Genoese yearbook of 1137 mentions the voyages of several two-masted vessels. 77 Certainly by the thirteenth century, two-masted merchantmen were commonplace, and three-masted merchant ships also then make an appearance in representational art. (Figures 35, 37).

All medieval representations of two- and three-masted ships show a decidedly forward rake to the foremost and
either a straight or slightly canted mainmast (Figures 30, 31, 34-37, 39, 40). Mast tops are shown in many representations but not in those of earlier date; they seem to appear only after the twelfth century. 78

Thirteenth-century Genoese contracts concerned with ships acquired by Louis IX of France for the Sixth and Seventh Crusades contain the earliest written descriptions we have of the Mediterranean lateen rig. 79 The most informative of these contracts, involving a two-masted ship called the Paradisus, give not only the dimensions of the masts and yards and the number and sizes of the sails, as do other of the contracts, but also a listing of the standing and running rigging for either masts, thereby making possible a fairly accurate and complete reconstruction of the ship's rig. 80

Two wrecks discovered in northern Italy provide some archaeological information regarding the placement of masts on two-masted, lateen-rigged sailing craft in late medieval times. 81 One of these, the First Contarina ship, dating to about 1300, still had both mast steps in place when excavated (Figure 45). The other, the Logonovo boat, dating to about 1400, had only a mast step in the bow remaining, for a mast that probably raked forward. The position of a forwardraking mast set in the bow would have been impractical for a single-masted craft. An hypothesized second mast produces a more feasible rig (Figure 46).
Figure 45: The First Contarina ship. (Adapted from Marco Bonino, "Lateen-rigged medieval ships," *JNautArch* 7 (1978) 14, Figure 4.)
Figure 46: The Logonovo boat. (Adapted from Marco Bonino, "Lateen-rigged medieval ships," *JNautArch* 7 (1978) 16, Figure 5.)
CHAPTER III

RIGGING ARTIFACTS FROM THE SERÇE LIMAN WRECK

Rigging artifacts excavated from the Serçe Liman medieval wreck include portions of three blocks, fifteen sheaves, a heart thimble, pin cap, and a sheave of unknown function. This chapter will include detailed descriptions of the artifacts followed by an analysis of their distribution on the site. Possible functions of these rigging elements will be discussed, comparative material from other periods being cited whenever possible.

The catalogue that follows begins with a description of the three blocks. The sheaves are next described in a sequence based on relative size beginning with the largest and ending with the smallest sheave. The catalogue ends with miscellaneous pieces. The provenience of each artifact is indicated by its Lot Number (Lot No.), and its Glass Wreck Number (GW), a temporary number for cataloguing and drawing purposes, is also given. All measurements are in meters. Figure 47 illustrates the terminology and abbreviations used in describing the sheaves. The following is a list of abbreviations used in the catalogue descriptions:
D. Diameter
Ht. Height
L. Length
Max. Maximum
Mid-th. D. Mid-thickness Diameter
Pres. Preserved
Th. Thickness
W. Width

Figure 47: Diagram of a sheave illustrating the terminology used in the catalogue.
Blocks

Rl. Block. GW 544.
Figures 48-51. Lot No. 913 I4 LR.
Th. 0.103.

This block was found concreted to the downslope arm of the ship's forward port-bower anchor (Figure 50). The part that survives includes portions of either end, one face and one side. All surfaces are slightly eroded and "petrified" through the permeation of the wood by iron oxide. Three sheave slots are preserved to varying degrees. The restoration of the block, shown in Figure 51, is based on the assumption that the block was symmetrical in design and had three sheaves. The longitudinal axis of the middle sheave slot is also the longitudinal axis of the restored block. Two holes passed through the block's width: the pin hole and, near the block's wider end, a large (0.049 x 0.026) elliptically shaped hole. In both cases, the distance between the hole's center and the partially preserved block face is the same. The block has been restored so that both holes are equidistant from either face.

In its restored condition, the block tapers in width from 0.189 to 0.169 and has a thickness of 0.103. This thickness was reduced at the block's narrower end
Figure 48: Block Rl. Front and side view.
(Scale 1:2)
Figure 49: Block RL. Side and end view.
(Scale 1:2)
Figure 50: Block R1 in situ on the wreck site, concreted to the arm of the port-bower anchor. (Photo by Don Frey.)
Figure 51: Block R1 as restored. (Drawing by the author.)
by a 0.081-wide and 0.01-deep cutting in the partially preserved face. The block's thickness at this end has been restored to 0.041 on the assumption that an identical cutting occurred on the other face. The best-preserved sheave slot is 0.153 long and 0.026 wide. Only the width measurement of one of the other slots is preserved, and it also is 0.026. Two sheaves were found in place: R5 remains concreted to the block; R9 was removed before the block was raised. Both are of slightly different diameters. No traces of the pin were found. The pin hole, preserved only within the block's extant side, had a diameter of approximately 0.022 x 0.027. The hole's outer end had been cut to a depth of about 0.01 into a now somewhat eroded opening of octagonal shape, measuring approximately 0.028 x 0.031. The remnant of a wooden, mushroom-shaped pin cap or pin itself was found still in place, its stem fitting snugly within the opening. The cap's diameter was slightly larger than the opening. The cap was broken off during the cleaning of the block and, unfortunately, has disappeared, but a small portion of the stem remains in place. One complete and one partially preserved hole pass through the thickness of the block's narrower end. The holes are tangential to the edge of the cutting on the partially preserved face. In either case, the hole's center is aligned with the longitudinal axis of a sheave slot. The complete hole has a diameter of 0.038; the diameter
of the partially preserved hole is approximately 0.043.
A conical-shaped hole, 0.03 deep and with a surface
diameter of 0.026, occurs in the block's larger end.
The hole is aligned with the longitudinal axis of the
block as restored, but its center is only 0.052 in from
the block's partially preserved face.
R2. Block fragment. GW 543.

Figure 52. Lot No. 459 05 (not on plan)
Pres. L. 0.204. Pres. W. 0.063. Pres. Th. 0.058.

Figure 52: Block fragment R2.
(Scale 1:2)
Part of one side, the adjacent sheave slot, and possibly one face of this block are preserved. The side and face surfaces are completely eroded. The ends of the sheave slot are discernible but eroded. The length of the slot was not greater than 0.121; its width is unknown. Half of the pin hole's circumference survives within the preserved side of this block; the hole originally was approximately 0.017 in diameter. If the part of the remaining face still retains the original edge and if one assumes that the pin hole was centered between the two faces, then the block's original thickness was approximately 0.106. Pressure marks occurring equidistant to either side of the pin hole on the well-preserved inner surface of the sheave slot indicate the use of a sheave with a face diameter of c. 0.068. The eroded remnant of a hole running parallel to the pin hole occurs just beyond the sheave slot near one end of the fragment.

R3. Block fragment.        GW (none).
Figure (none).        Lot No.s 1779 N4 LL3 and 1787 N4 LL3.

While still in situ on the seabed, this fragment was identified by R.C.M. Piercy as being part of a block. In very poor condition, it disintegrated into small pieces during excavation. The pieces were retrieved in two separate lots but could not be rejoined.
Sheaves


Figure 53. Lot No. 1105 P4 LL3/4, Item 1.
Pres. D. 0.10. Th. 0.0315. Mid-th. D. 0.094.
D. of pin hole 0.032.

The surface of both faces is eroded, but the original thickness of this sheave appears to be preserved. Only small traces of a rope groove are discernible. Fifty percent of the pin hole is in good condition.

Figure 53: Sheave R4. (Scale 1:2)
R5. Sheave.  GW 544.

Figures 48-49.  Lot No. 913 I4 LR, Item 1.

D. 0.088.  Th. 0.026.  Mid-th. D. 0.088.

D. of pin hole 0.028.

Both faces are in fair condition. The rope groove is well preserved. Fifty percent of the pin hole is in good condition.

GW 256 (A).

Figure 54. Lot No. 1168 P4 UL, Item 1.

Pres. D. 0.084. Th. 0.025. Mid-th. D. 0.077.

D. of pin hole 0.031.

One face is in good condition; most of the other face is eroded. Only small traces of the rope groove are discernible. Seventy-five percent of the pin hole is in good condition. Wood grain is clearly visible.

Figure 54: Sheave R6.
(Scale 1:2)
R7. Sheave. GW 541.

Figure 55. Lot No. 1284 P4 UL3.

Pres. D. 0.084. Th. 0.025. Mid-th. D. 0.077.

D. of pin hole 0.21.

One face in good condition. Only traces of rope groove remain. The pin hole is in good condition throughout. Wood grain is clearly visible.

Figure 55: Sheave R7. (Scale 1:2)
R8. Sheave.  

GW 318 (A).

Figure 56.  Lot No. 1779 N4 LL3/4, Item 2.

Pres. D. 0.078.  Th. 0.025.  Mid-th. D. 0.076.

D. of pin hole 0.0245.

Only one face is in good condition. No traces remain of a rope groove. Surfaces of the pin hole are in only fair condition, but the original diameter seems certain. Possible tool or rotation wear marks are visible on one face.

Figure 56: Sheave R8.  
(Scale 1:2)
R9. Sheave. GW 191

Figure 57. Lot No. 913 I4 LR, Item 2.

Pres. D. 0.076. Pres. Th. 0.023. Mid-th. D. 0.074.

D. of pin hole 0.027.

Half of the original surface on both faces is eroded. Portions of the rope groove remain. Two-thirds of the pin hole is in good condition. Wood grain is clearly visible.

Figure 57: Sheave R9. (Scale 1:2)
R10. Sheave.

GW 536.

Figure 58. Lot No. 1692 06 (not on plan).


One face is completely eroded; half of the original surface on the opposite face remains. One-third of the rope groove remains. The pin hole's original surface is completely eroded. Wood grain is clearly visible.

Figure 58: Sheave R10.
(Scale 1:2)
R11. Sheave.

GW 318 (B).

Lot No. 1779 N4 LL3/4, Item 1.

Figure 59.  

D.  0.064.  D. of pin hole  0.0205.

One face is in fair condition; the other face is completely eroded. No traces remain of a rope groove. The pin hole is in only fair condition, but its original diameter seems certain.

Figure 59: Sheave R11.  
(Scale 1:2)
R12. Sheave. GW 537.

Figure 60. Lot No. 1582 P4 UL4.


One face is in fair condition; the other face is almost completely eroded. Only slight traces of the rope groove remain. Fifty percent of the pin hole is in good condition.

Figure 60: Sheave R12. (Scale 1:2)
R13. Sheave.

GW 538 (A).

Lot No. 41 05 LL2, Item 1.

D. 0.058. Th. 0.024. Mid-th. D. 0.05. D. of pin hole 0.0255.

The original surfaces of both faces are well preserved. The rope groove is in excellent condition; the sides of the groove meet at a sharply-defined angle, suggesting that the sheave saw little or no use. Forty percent of the pin hole is slightly eroded. Wood grain is clearly visible.

Figure 61: Sheave R13.
(Scale 1:2)
RL4. Sheave.  

GW 538 (B).

Figure 62.  
Lot No. 41 O5 LL2, Item 2.

D. 0.055. Th. 0.02. Mid-th. D. 0.05. D. of pin hole 0.019.

Both faces are in excellent condition. The rope groove is well preserved; the sides of the groove meet at a sharply-defined angle, suggesting that the sheave saw little or no use. The pin hole is in good condition but slightly off center. Wood grain is clearly visible. Wear or tool marks are visible on one face.

Figure 62: Sheave RL4.  
(Scale 1:2)
R15. Sheave

GW 540.

Lot No. 1450 P4 LLL.

Pres. D. 0.054. Pres. Th. 0.019.

Pres. Mid-th. D. 0.051.

The sheave is badly eroded; no original surfaces remain. The pin hole's diameter did not exceed 0.021.

Figure 63: Sheave R15.
(Scale 1:2)
R16. Sheave

GW 542.

Figure 64. Lot No. 1170 P4 ULL.

Pres. D. 0.058. Pres. Th. 0.021.

The sheave is badly eroded; no original surfaces remain.

Figure 64: Sheave R16.
(Scale 1:2)
R17. Sheave.  
GW 539.

Figure 65.  Lot No. 1222 P4 LL1.

Pres. Th.  0.02.

The sheave is badly eroded; no original surfaces remain. The pin hole's diameter did not exceed 0.025.

Figure 65: Sheave R17.  
(Scale 1:2)
Rl8. Sheave. GW 590.

Figure 66. Lot No. Axe Complex P4 LR.

Pres. Th. 0.019.

The sheave is badly eroded; no original surfaces remain. The pin hole's diameter did not exceed 0.0185.

Figure 66: Sheave Rl8.
(Scale 1:2)
Miscellaneous


Figure 67. Lot No. 1130 J4 UR4.
Pres. D. 0.062. Pres. Th. 0.025. Pres. Mid-th. D. 0.058. Square hole measures 0.019 x 0.017 on one face and 0.014 x 0.015 on the other.

Subsequent to the drawing and study of this piece, its plastic storage container developed a crack; the piece dried out and no longer possesses its original shape and dimensions. The surface of both faces was in fair condition. The edges of the square hole were slightly eroded. There was no evidence of the existence of a rope groove. The piece also differs from the other sheaves in having a straight rather than a circular grain pattern.

Figure 67: Sheave of uncertain function RL9. (Scale 1:2)
R20. Heart Thimble. GW 256 (B).

Figure 68. Lot No. 1168 P\& UL, Item 2.
Pres. face dimensions 0.115 x 0.109. Th. 0.039.
Pres. dimensions of center hole 0.05 x 0.068.

The surface of one face is in fair condition. The smaller end of the oval-shaped center hole and almost all side surfaces are missing, but slight traces of a rope groove remain.

Figure 68: Heart Thimble R20.
(Scale 1:2)
R21. Pin hole cap or pin fragment. GW 470.

Figure 69.

Lot No. 1105 P4 LL3/4,

Item 2.

Pres. D. of flange 0.032. Ht. 0.024. Pres. D. of cap stem 0.031.

This piece was found lying within the pin hole of sheave R4. Its head appears to have been conical or mushroom-shaped and had an original diameter of c. 0.037. The stem is 0.01 long and had an original diameter of 0.032. The bottom of the stem is flat with a small, centered, conical indentation surrounded by a circular groove. Grain lines indicate that the cap was made from heart wood.

Figure 69: Pin hole cap or pin fragment R21.
(Scale 1:2)
Wood Analysis

A sample taken from sheave R18 has been identified as boxwood. All sheaves appear to have been made from the same type of wood except for R19, which could possibly be of some other, darker-colored wood. A fragment from block R1 was determined to be a ring-porous hardwood belonging to the Ulmeceae family, probably a species of elm.82

Distribution of Rigging Gear

Analysis of the distribution of all the rigging artifacts reveals which were in use and which were spares in storage at the time of the ship's sinking (Figure 9). A large concentration of sheaves of various sizes (R4, R6, R7, R12, R15-18) along with the heart thimble (R20) and pin fragment (R21) were found just aft of Frame 15. The stern area aft of Frame 12 had been in part utilized for the storage of both personal gear and ship's stores. The latter included a variety of tools and materials for shipboard repairs, including carpentry tools and, it would appear, an assortment of wooden spare parts for the rigging. Most material for shipboard repairs was found between Frames 12 and 15; rigging spares were apparently stored separately further aft.

The practice of carrying spare parts for rigging is documented for the late medieval period in the Mediterranean by a contract for the use of the Genoese ship Paradisus in 1268 by Louis IX for the Eighth Crusade. This contract stipulated that eight three-sheave blocks, extra, used blocks,
some sheaves, and some holm-oak wood with which to make small
sheaves be included among the carpenter's stores. 83

In the case of the Serce Liman ship, it would seem that
the rigging spares did not include already-made spare blocks.
Although this is somewhat of a disappointment archaeologi-
cally, the absence of block remains in association with the
rigging remains found just aft of Frame 12, coupled with the
location of these artifacts and their concentration within a
small area, makes it virtually certain that they were spares.

Three other sheaves (R10, R13, R14) and block fragment R2
were raised from an area one meter forward and just downslope
of the storage area. R2 and R10 were surface finds, however,
and thus were not necessarily in situ when found.

In two areas, sheaves were found in association with a
block or block fragments. Just aft of midships in N4 11,
sheaves R8 and R11 and block R3 were recovered. In the bow,
slightly off the wreck site proper, block R1, with sheaves
R5 and R9 still attached, was found concreted to the arm of
the forward port-bower anchor. These blocks and sheaves were
isolated from each other, from the stern storage area, and
from the other rigging remnants. They probably represent
rigging gear in use at the time of sinking.

The location of block R1 suggests that it had fallen from
an area high up in the ship's bow. Block R3 was uncovered
far enough away from this block to suggest that the two blocks
were not being used together but rather were a part of two
different rig systems, very possibly on separate masts.
Sheave R19 was the only sheave found disassociated from any other rigging elements. From its location, it appears that this sheave probably was being used in the forward bow area.

Analysis of Rigging Artifacts

Figure 51 shows a drawing of block R1 as reconstructed. Upon excavation, the block still had two sheaves in place, one of which, R5, was concreted into its slot. Within the slot, or swallow, the gap between the edges of this sheave and the top of its slot, a distance of 0.061, is greater than the 0.051 gap below. This difference is important, since it enables one to distinguish between "top" and "bottom" of the block. The greater gap permitted the rope to pass through the slot and over the sheave.

Although the pin rod of this block was not preserved, there are some interesting points of construction which give clues to a possible malfunctioning of this pin. The sheaves of such a multicourse block should have rotated freely on the pin, since the travel of the separate courses would require a dissimilar rate of rotation of the sheaves. The unevenness of the pin hole on the outer side of block R1 (Figure 48) may have been caused by the binding of the sheaves on the pin and the subsequent rotation of that pin. The use of fixed-axle sheaves might also explain such wear, but such an arrangement for R1 seems unlikely for the reason just mentioned.

Unfortunately, there are no contemporaneous parallels
for this block available. However, one block from the fourth or fifth century A.C. found in the submerged temple at Kenchreai, the eastern port of ancient Corinth (Figure 70)\(^{85}\) and a third-century A.C. block found in the County Hall Ship (Figure 71)\(^{86}\) have features similar to ones possessed by block R1. The central body of the Kenchreai block is of a similar length and thickness, while the sheave slots of both the County Hall Ship and Kenchreai blocks have the same rounded "top" and straight-cut "bottom."

There are no remains of iron bands or strop grooves (scores) along the preserved side of block R1. This accounts for the large conical hole at the upper end of the block. This hole would have been used to lash the block securely to a mast top or deck. The two holes in the notched face at the other end of this block are similar to those on the County Hall ship's block. These would appear to have been used to secure the loose end of the rope before attaching it to the item to be lifted, or before passing it through the sheave of the opposing block in a block-and-tackle rig.

A triple-sheaved block permits more hauling force than does a single-sheaved block and tends to distribute this force more evenly. Consequently, a triple-sheaved block would have been able to lift a larger load than would a single-sheaved block, and a triple-sheaved block-and-tackle rig a far greater load than a single-sheaved one. Such triple-sheaved blocks were frequently used in halyard systems which required greater hauling force than any of the other rigging components.
Figure 70: Fifth-century block found at Kenchreai, Corinth.
(From Joseph W. Shaw, "A Double-Sheaved Pulley Block from Kenchreai," Hesperia 36 (1967) 390, Figure 1. Courtesy of the American School of Classical Studies at Athens.)
Figure 71: Third-century block found on the County Hall ship. (From Joseph W. Shaw, "A Double-Sheaved Pully Block from Kenchreai," Hesperia 36 (1967) 394, Figure 3. Courtesy of the American School of Classical Studies at Athens.)
The deposition of block R1 off the forward end of the wreck indicates that it probably was used as a part of the tackle for a mast set forward in the bow. Furthermore, its large size suggests that it was not used in handling the sails but rather was part of this mast's halyard system.

Earlier examples of wooden sheaves are known and two Roman-period sheaves from Egypt are very similar in design to those found on the Serçe Liman medieval wreck (Figure 72).

Several sheaves from the Athenian Agora dating to the first and third centuries have been found which have square pin holes similar to that in sheave R19 (Figure 73). This feature clearly indicates that this type of sheave was snugly fitted onto a pin which rotated along with the sheave. Although some scholars have suggested that sheaves of this type were used in tackle systems for drawing water rather than as part of a nautical tackle system, no evidence was found on the Serçe Liman wreck to support this idea. Unfortunately, there is no nautical documentation of this type of sheave having been used. This sheave may well have been part of a loading system either carried on board as ship's gear, or as part of the cargo. In any event, the enigmatic square hole of this sheave is a feature not present on any of the other sheaves uncovered and thus probably does indicate that the sheave had a different function.

Heart thimble R20 is very similar in appearance to contemporary heart thimbles. A line would have been fitted into the side groove on the heart and lashed to itself at the
Figure 72: Two Roman sheaves from Egypt. (From Joseph W. Shaw, "A Double-Sheaved Pulley Block from Kencherai," Hesperia 36 (1967) plate 77a and b. Courtesy of the American School of Classical Studies at Athens.)
Figure 73: Sheave W27 from the Athenian Agora. (From Joseph W. Shaw, "A Double-Sheaved Pulley Block from Kenchreai," Hesperia 36 (1967) plate 77d. Courtesy of the American School of Classical Studies at Athens.)
tapered end. In this way, the heart thimble provided protection to reduce the occurrence of friction or wear between the outer line and a line passing through the eye of the heart.

Table 1 shows a division of the sheaves from the Serce Liman wreck into eight general diameter groups based on sheave and pin hole size. Unfortunately, this in itself is not an indication of the number of different-sized blocks represented by the sheaves, since manufacturing tolerances obviously resulted in sheaves of varying diameters within the same block, as seems to have been the case with block R1.
TABLE 1

Chart of sheaves from the Serçe Liman wreck showing general divisions based on sheave and pin hole size.

<table>
<thead>
<tr>
<th>Group</th>
<th>Sheave</th>
<th>Diameter</th>
<th>Axle Hole Diameter</th>
<th>Thickness</th>
<th>Mid-Th. Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R4</td>
<td>0.10</td>
<td>0.032-</td>
<td>0.0315</td>
<td>0.094</td>
</tr>
<tr>
<td>2</td>
<td>R5</td>
<td>0.088+</td>
<td>0.028</td>
<td>0.026</td>
<td>0.088</td>
</tr>
<tr>
<td></td>
<td>R9</td>
<td>0.076+</td>
<td>0.027</td>
<td>0.023</td>
<td>0.074+</td>
</tr>
<tr>
<td>3</td>
<td>R6</td>
<td>0.087</td>
<td>0.024</td>
<td>0.033</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>R7</td>
<td>0.084+</td>
<td>0.021</td>
<td>0.025</td>
<td>0.077</td>
</tr>
<tr>
<td>4</td>
<td>R8</td>
<td>0.078+</td>
<td>0.0245</td>
<td>0.025</td>
<td>0.076</td>
</tr>
<tr>
<td></td>
<td>R10</td>
<td>0.069+</td>
<td>0.0275+</td>
<td>0.023+</td>
<td>0.062+</td>
</tr>
<tr>
<td>5</td>
<td>R11</td>
<td>0.066+</td>
<td>0.0205</td>
<td>0.023+</td>
<td>0.064+</td>
</tr>
<tr>
<td>6</td>
<td>R12</td>
<td>0.063+</td>
<td>0.025</td>
<td>0.02+</td>
<td>0.062</td>
</tr>
<tr>
<td>7</td>
<td>R13</td>
<td>0.058</td>
<td>0.0255</td>
<td>0.024</td>
<td>0.05</td>
</tr>
<tr>
<td>8</td>
<td>R14</td>
<td>0.055</td>
<td>0.019</td>
<td>0.02</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>R15</td>
<td>0.054+</td>
<td>0.021-</td>
<td>0.019+</td>
<td>0.051+</td>
</tr>
</tbody>
</table>
CHAPTER IV

EVIDENCE FOR THE RIG OF THE SERÇE LIMAN SHIP

Hull Design and Tonnage

The rigging remnants described in the preceding chapter offer only scant clues concerning the ship's rig. Despite this problem, conclusions can be reached as to the most probable rig and the number and placement of masts, primarily through an analysis of the hull's design, structure and hydrostatic properties.

The set of hull lines shown in Figure 8 was developed as an aid in determining the ship's size, shape and tonnage. These lines were the result of information acquired from plans and a scale model of the wreck, drawings and photographs of the hull remains, and geometric data projected off the fragment model described in the first chapter. Waterline and buttock lines were placed at intervals which allowed the hull lines to display the maximum amount of architectural information. Station lines were set at idealized centerlines of the frames they represent, since most of the frames were too crooked to be used as true station lines. The heavy, meandering, dashed line through the sheer plan outlines the extent of contiguous hull survival. The bulwark, stem and upper sternpost are represented by dashed lines, since their reconstruction is hypothetical. The hull lines show a deep, broad, full-ended, flat-bottomed vessel with a sharp turn of
bilge and straight sides. Furthermore, the pronounced up-curving of the hull at either end and the incurving stern would have given the hull a very round appearance when afloat. The hull was only 15 m long with a beam of 5.13 m, giving a length to beam ratio of slightly over 3:1.91

The lines drawing, supplemented by hull construction drawings, can be used to calculate tonnage; this vessel displaced about 50 metric tons and had a hold volume tonnage of about 37 metric tons. With an allowance of approximately 15 tons for hull and gear weight, 37 tons of burden would have placed the vessel's draft line at just below waterline 8.92 However, a preliminary evaluation of the hull's construction has indicated that the hull would not have been able to carry 37 tons safely, and a burden of about 27 tons has been calculated as a more practical carrying capacity for this ship. This figure was reached on the basis of a 100 ft³/ton capacity for a hold area extending between Frames P and 12.93 For the purposes of determining the ship's rig and sailing capabilities, an intermediate burden of 30 tons will be used.94 The draft line in this case would have been at about waterline 6 (TWL in Figure 8), and the vessel would have displaced about 43.2 tons of salt water.95

The supposition has been made in calculating the ship's tonnage that extensive areas of the hull were enclosed by decking. Although no deck timbers survived to provide direct archaeological proof of this, the full, rounded shape of the hull would have required a deck or at least strong cross-beams
and clamps for lateral and longitudinal strength. Decking structure would also have provided mast bracing. Further indirect evidence that there was extensive decking is provided by the ship's spare anchors. Their location and disposition on the wreck indicate that they had been stacked together midway between the two sides of the hull with their shanks lying parallel to the keel. The hull's large keelson would have made it necessary to construct a pad over the keelson to provide support and stability had the anchors been stacked in this way within the hold. Such an arrangement would have been quite impractical, and no evidence for such a construction has been detected. It is more likely, therefore, that the spare anchors were stacked on a deck overlying the hold.

The length assigned to the hold in calculating the ship's tonnage is based on archaeological evidence. In the stern, the after extent of the cargo of glass cullet on the wreck abruptly ended at Frame 12. This frame also marked the forward limit of the stern storage area, where the spare rigging and most of the tools, weapons, fishing equipment, animal bones, weighing equipment and currency recovered from the wreck were found. Nail patterns in the hull planking at the point where Frame 12 crossed the keel indicate that this frame was not composed of a single, continuous floor timber but of two relatively robust floor timbers that butted side by side across the keel. The same framing pattern occurs at only one other place within the hull—at Frame P in the bow (Figure 6). Similarly, the after extent of a completely
distinct deposit of artifacts in the bow that included both items of cargo and personal effects (such as a comb, some copper coins, some used pottery, and two glass weights) abruptly ended at this frame. In view of the special construction of Frames P and 12 and the close correspondence of their locations to the distribution extent of certain groups of artifacts on the wreck, it appears likely that these frames gave structural support to a bulkhead or similar divisional structure at either end of the hold. Some cargo was carried in the bow and stern as well, but the primary purpose served by the latter areas was the storage of ship's stores and equipment and personal gear.

It should be noted that an estimate of the total original weight represented by the ballast and cargos recovered from the wreck site could not be utilized in calculating the ship's tonnage. This weight estimate comes to only about eight tons, radically less than the ship had to have carried to achieve even minimal stability. Furthermore, the forward half of the hold was found to contain very little ballast and no cargo. Clearly, a major portion of the ship's cargo, much but not all of it stowed in the forward part of the hold, consisted of perishable substances that have disappeared entirely.

Hydrostatic and Structural Evidence

The hull lines also contribute to an understanding of the general hydrostatic properties of the hull. The propulsion of any sailing vessel is dependent upon the combined forces
exerted by both water and air. The flow of air over the sail creates the driving force necessary to overcome the resistance generated by the hull moving through water. A ship's center of effort is the point at which wind forces are centered in the sails. The center of lateral resistance is the point on the hull where the forces directed at the side of the hull are centered. For ships having the general shape of the Serce Liman ship, this point normally occurs where the hull attains its maximum width. In order for a vessel to sail efficiently, these two forces must theoretically be in balance: the center of effort should be in alignment with the center of lateral resistance (Figure 74). On the Serce Liman ship, the center of lateral resistance falls at about Frame A, at the hull's widest point.

Although one cannot discount the possibility that the Serce Liman ship carried only one mast, an examination of hydrostatic and structural evidence strongly indicates that she was a two-masted vessel.

For a single-masted vessel to sail efficiently, the sail's center of effort should fall directly over or just slightly forward of the hull's center of lateral resistance. Since the center of lateral resistance is represented by Frame A on the Serce Liman ship, the only area in which a single mast could have been stepped to obtain this alignment would have been between Frames C and D. It could not have been placed forward of Frame D since the ship's spare anchors were kept in this area and, whether stacked on a deck or in the
Figure 74: Drawing of a modern boat showing the alignment of its center of effort (CE) with its center of lateral resistance (CLR). (Adapted from C.A. Marchaj, Sailing Theory and Practice (New York 1964) 62, Figure 405.)
hold, would have been a hindrance to any mast emplacement. A single mast stepped aft of Frame N would have placed the vessel's center of effort, particularly in the case of a square sail, too far aft of its center of lateral resistance.

The find spot of halyard block R1 indicates that this block probably belonged to the rig of a mast located somewhere forward of the spare anchors. It would have been impractical, however, to place a single mast this far forward, since the imbalance between the center of effort and the center of lateral resistance would have radically reduced the stability and sailing efficiency of the vessel (Figure 75). Such an imbalance would not have occurred had the mast carried a spritsail, but it will be shown later in this chapter that such a rig would not have been feasible for this hull. For these reasons alone, it is unlikely that the Serce Liman ship carried a single mast.

One can dismiss the possibility of a three-masted rig due to the vessel's small size. Clearly, it would have been impossible for this ship to have accommodated more than two masts without there being interference between the sails and rigging of each mast.

Only two possible general locations emerge for the placement of mast steps in this hull: between Frames D and 2 and Frames L and P. The surviving portion of the keelson show no traces of mast-step remains or fastenings, thus eliminating the area between Frames 2 and 8, while the spare anchors prohibited the placement of any mast between Frames L
Figure 75: Schematic drawings of the Serce Liman hull fitted with single square and lateen sails. The probable offsets of the center of effort (CE) and the center of lateral resistance (CLR) are indicated for each rig.
and D. A mast location aft of Frame 8 also can be eliminated, since the mast would have been too close to the stern. The sail, regardless of the rig, would often have extended back beyond the stern and would therefore have been difficult if not impossible to handle. A mast could not have been stepped forward of Frame P since the keel begins to curve up into the bow at this point.

Although no structural evidence for the presence and location of a mast step amidships between Frames D and 2 has as yet been detected, there does appear to be such evidence for a mast step in the bow. The framing pattern of Frames N and O differs from that found throughout the rest of the hull. They are the only frames not set equidistant to their neighbors at the keel (Figure 6). Although their spacing does approximately match that of the other framing at the turn of the bilge, Frame N curves in toward O as it approaches the keel from either side of the hull. As a result, the spacing of the two frames at the keel is only one-half that of all other floors. This seems to be an intentional anomaly in the framing pattern, probably designed to give added support to a mast step. The bulkhead or divisional structure hypothesized at Frame P is at an adequate distance to have supplied bracing for a canted foremast stepped at Frame N. Similar bracing arrangements for canted foremasts occur on the Logonovo boat dating to about 1400 (Figure 46) and on many modern Arab dhows. 98
An estimate of the sail area necessary for the Serçe Liman ship can be made by comparing her with other, similar-sized vessels.

It has been calculated that the fourth-century B.C. Kyrenia ship, which had a length of just over 14 m, had a sail area of about 700 sq. ft. or 63 sq. m.\(^9\) The Serçe Liman ship, although only slightly longer, had a deeper and fuller shape, resulting in a greater hull resistance and necessitating a somewhat larger sail area.

During the early 1800s, the U.S. Navy built lateen-rigged gunboats designed as harbor and defense craft in Mediterranean waters.\(^10\) A drawing of one of these vessels, Gunboat No. 5, shows its hull design and sail size (Figure 76). The hull dimensions, 50 ft. deck length and 17 ft. beam, are very close to those of the Serçe Liman ship. The sail area used on this vessel was approximately 836 sq. ft. or 77 sq. m.

Although Gunboat No. 5 had only one mast, the sail area it used can be considered as a minimum sail area necessary for the propulsion of the Serçe Liman ship. The more modern hull design of Gunboat No. 5, that included a full bow, more deadrise, a shallow moulded depth, and a stern rudder, served to lessen hull resistance in the water. Thus, the greater displacement and resistance of the flat-bottomed, round-shaped Serçe Liman hull would have required a sail area probably at least 15 to 20 percent larger than 77 sq. m, or something approaching 100 sq. m, for efficient propulsion.\(^101\) The probability of less efficient sail cloth and tackle in the
Figure 76: Gunboat No. 5. (Adapted from H. Chappelle, The History of American Sailing Ships (New York 1935) 99, Figure 13.)
medieval period makes an increase of this order even more likely.

Theoretically, a vessel should have inherent stability, if its centers of effort and lateral resistance are aligned and its center of gravity is not too far above its center of buoyancy. The operating waterline (TWL 6 on Figure 8), wide beam, and flat bottom of the Serçe Liman hull suggest that it would have needed a low center of gravity in order to maintain stability. Figure 77 shows the approximate positions of the hull's centers of gravity and buoyancy. The closeness of these two points gives the hull enough of a coupling distance when heeling for sufficient righting momentum to occur (Figures 77 and 78).

As we have seen, the sail area required to efficiently propel a hull as broad, deep, and flat bottomed as that of the Serçe Liman ship would of necessity have been greater than 77 sq. m. A single sail of such large proportions on this ship, with its round-ship design and light ballast load, would have raised the center of effort and aspect ratio, placing the center of wind force too high for the vessel to have been stable. A two-masted rig, however, would have lowered the center of wind force to an acceptable height.

A double-lateen rig would have been the most plausible and efficient two-masted rig on the Serçe Liman ship. On a two-masted ship, it is the combined center of effort of its two sails which should fall above or just slightly forward of the hull's center of lateral resistance to insure a stable
coupling distance

Figure 77: Relationship of the center of buoyancy (CB) and the center of gravity (CG) on the Serçe Liman hull.

A: the approximate positions of CB and CG.
B: the approximate positions of CB and CG when the ship was heeling and the resulting coupling distance.
Figure 78: Relationship between the positions of the center of gravity (CG) and the center of buoyancy (CB) on modern hulls. (Adapted from C.A. Marchaj, Sailing Theory and Practice (New York 1964) 340, Figure 216.)
vessel (Figure 79). If the Serçe Liman ship had carried two square sails on masts located in the positions established above (between Frames D and 2 and Frames L and P), the combined center of effort would have fallen too far forward of the hull's center of lateral resistance, resulting in an extremely unstable vessel (Figure 80). Moreover, the placement of two such closely set square sails would probably have rendered the vessel unmanageable. Two sprit sails large enough for the ship would have proved too awkward in strong winds and would not have been suitable for long, open-sea voyages.

Sail Plan

A hypothetical sail plan for the Serçe Liman ship is illustrated by Figure 81. A canted foremost is shown stepped over Frame N. Its degree of forward rake is such that it could have been braced by a bulkhead or cross-beam located at Frame P. A vertical mainmast is shown stepped over Frame 1, where it would have been far enough aft so that the spare anchors, if stacked on deck, would not have interfered with the main yard during wearing and tacking. The combination of canted foremost and vertical mainmast is in harmony with late medieval representations of two-masted lateeners, which show a canted foremost and either a straight or only slightly canted mainmast.

Two late medieval wrecks already mentioned offer excellent examples of two-masted lateeners with mast placements
Figure 79: Alignment of combined center of effort (CE) with the center of lateral resistance (CLR) on a modern hull. (Adapted from C.A. Marchaj, *Sailing Theory and Practice* (New York 1964) 195, Figure 123.)
Figure 80: Schematic drawing showing the unstable alignment of the combined center of effort (CCE) with the combined center of lateral resistance (CLR) for the Serçe Liman hull, had she been rigged with two square sails.
Figure 81: Reconstruction of the hypothetical two-masted lateen rig for the Serçe Liman ship.
similar to that proposed for the Serçe Liman ship: the First Contarina ship and the Logonovo boat. The placement of the masts on the First Contarina ship is precisely known, since both mast steps were still present when the wreck was excavated. Similar in hull shape and only about 25 percent larger than the Serçe Liman ship, this vessel also had a foremast stepped well forward in the bow, and the mainmast was stepped only slightly further aft than was the proposed placement of the mainmast on the Serçe Liman ship (Figure 45). The placement of the masts on the Logonovo boat may have been very close to that proposed for the masts on the Serçe Liman ship; the precise location of its mainmast is not known. The boat as reconstructed (Figure 46) has its mainmast stepped somewhat aft of midships. However, if one were to retain the mainsail's position in the reconstruction but straighten the cant of the mainmast by swinging its base forward, the placement of its mast step would be almost identical with that proposed for the mainmast of the Serçe Liman ship.

The combined area of the two sails in the sail plan in Figure 81 is 100 sq. m. This area has been apportioned between the sails so that their combined center of effort is in close alignment with the hull's center of lateral resistance. The sails have been given the shape of right-angled triangles, since it is known that this shape was used in the thirteenth century.105 The luff of the mainsail has a length of 14 m; the luff of the foresail, a length of 11 m. The size and position of the mainsail is such that there would not have
been deck interference when wearing ship, and the sail would not have extended beyond the stern. The foresail extends somewhat beyond the stem, as is the case in medieval representations of two-masted lateeners. The yards are schematically shown as having the same length as the luffs of the sails but probably would have been a bit longer. The masts have been given heights sufficient to insure efficient handling of the sails.

Although the proposed sail area for the ship might at first appear to be overly large, particularly when compared with the 77 sq. m sail area of the similarly sized, lateen-rigged Gunboat No. 5, it must be remembered that the Serçe Liman ship's wide, broad, tubby hull would have required a larger sail area to efficiently utilize the wind force. By dividing this sail area into two sails, the center of effort is lowered, preventing large heeling motions and allowing greater hull stability. Moreover, by the nineteenth century, naval architecture had reached a higher level of expertise, embodying such structural features as exhibited by Gunboat No. 5, along with more efficient sails and rigging. Advancements in hydrodynamic principles led to reduced hull resistance and produced more stable hull designs. None of these features or architectural knowledge were available to ancient shipbuilders. The medieval shipwright did not understand naval architecture as a scientific discipline, but rather used only his inherent
knowledge of ship construction and copied successful traits off of other ships.
CHAPTER V

SUMMARY

Although only a small number of rigging elements were found on the Serçe Liman wreck, an analysis of their distribution on the site does give some notion of the purposes they served. The different-sized sheaves and the pin or pin cap recovered from a storage area in the stern of the ship must have been spare parts for the ship's rigging that were not in use when she sank. Block R3 and sheaves R8 and R11 probably belonged to rigging located somewhere within the central part of the ship, while block R1 belonged to rigging located within the forward part of the ship.

Hull analysis indicates that the Serçe Liman ship carried two masts. The possibility of a single-masted vessel must be eliminated, since the total sail area needed to propel this ship, approximately 100 sq. m, would have been more than a single sail could efficiently handle. The ship so rigged would have been extremely unstable, since the hydrostatic properties exhibited by its broad, tubby, flat-bottomed hull demanded a low center of effort and gravity not attainable with a single large sail.

An overview of sources on medieval ships in the eastern Mediterranean has shown that the lateen rig was the most prevalent rig used during medieval times and that some ships carried more than one mast at least as early as the tenth
century. Evidence for the employment of the square and sprit rigs, although scarce, is sufficient to suggest that both rigs may have seen some use but perhaps only on relatively small craft.

Neither a square rig nor a sprit rig would have been satisfactory on the two-masted Serçe Liman ship with the sail area required by its tonnage, draft and hull shape. On a two-masted ship, the combined center of effort of its sails must fall above or just slightly forward of the hull’s center of lateral resistance for the vessel to be stable. If the masts of the Serçe Liman ship, stepped between Frames D and 2 and between Frames L and P, had carried square sails, the combined center of effort would have fallen too far forward of the hull’s center of lateral resistance, resulting in an unmanageable vessel. Sprit sails large enough for this two-masted ship would have proved too awkward in strong winds and would not have been suitable for long, open-sea voyages. Thus, the most plausible and efficient rig for the Serçe Liman ship would have been a two-masted lateen rig.

No remains of mast steps survived in the Serçe Liman hull. Nevertheless, evidence for the placement of the ship’s masts is not entirely lacking. The masts could only have been stepped somewhere between Frames D and 2 and between Frames L and P because of the location of the ship’s spare anchors and the absence of mast-step remains within the extent of the surviving portion of the keelson.

The foremast was most probably stepped over Frame N,
where an anomaly in the framing pattern appears to have been intentionally devised to give support to a mast step. It has been assumed that the foremast had a forward cant, since this is universally the case in medieval representations of lateen-rigged ships with more than one mast. The specific degree of cant assigned to the foremast in the proposed sail plan is such that the mast could have been braced by a bulkhead or cross-beam at Frame P, where some kind of structure separating the hold from the bow can be hypothesized. Modern dhows and the late medieval Logonovo boat offer examples of canted foremasts braced in this way.

The size, design and location of block R1 indicate that it very probably served as a halyard block for the foremast. It would appear that its location on the seabed corresponds with the area in which this block would have landed had it fallen vertically from its placement in the rigging on a forward-raking foremast stepped at Frame N.

A vertical mainmast has been assumed for the ship, since the after masts in medieval representations are shown with little or no cant. If the ship's spare anchors were stacked on deck, as was probable, this mast must have been stepped very near or over Frame 1 for the anchors not to have interfered with the mainsail during wearing and tacking.

The sail area needed for efficient propulsion of the ship has been apportioned between the two sails so that there is balance between their combined centers of effort and the center of lateral resistance in the hull. Although this
cannot be done with complete precision without the benefit of tank tests, the proposed sail plan represents an attempt to position the combined center of effort just slightly forward of the theoretical center of lateral resistance at Frame A. This slight imbalance might well have made for better sailing. The hull would then have had a tendency to push against the water and air forces, taking some of the stress and sensitivity off the steering oars and helmsman.

The sailing qualities of merchant ships—their speed, maneuverability and safety—have always been important factors in maritime commerce, but this was particularly so in the Mediterranean during the medieval period. In the wake of the Arab conquests, the stable conditions and set routes of Roman times gave way to instability and trading patterns that were of necessity more flexible and complex. The dangers and uncertainties of long, open-sea voyages were numerous, and the ability of ships to surmount these dangers and uncertainties directly affected the markets and values of the merchandise they carried.

As had been the case in antiquity, medieval merchant ships did not normally embark before early spring, with May to September being considered as the most favorable sailing season. On the whole, the seas were considered closed or too dangerous by most merchants throughout the winter season. This seasonal aspect of maritime trade resulted in annual fluctuations in the demand for and thus the market
value of the goods involved. Consequently, the success of a merchant's venture often depended on the arrival of his goods at an overseas market before the new sailing season had brought on a decline in their value. Ships better able to handle poor weather conditions would sometimes successfully negotiate the seas during the closed season or at its end. In this way, the merchants on them eclipsed their competition by selling early and thereby lowering the value of merchandise that arrived later.\textsuperscript{108}

The almost constant danger of pirate attack and frequently shifting alignments in the politically fragmented and unstable medieval Mediterranean world accentuated the need for fast, maneuverable and dependable vessels for maritime commerce. Obviously, it was desirable that merchant ships be able to elude or escape pirate craft, but merchants also needed ships that would serve them well even when schedules and routes were altered due to the circumstances of the moment. Departures could be delayed, if not cancelled, due to reports of piracy in the vicinity,\textsuperscript{109} or destinations could be changed even after departure when news of piratical activity along the planned route or a changing political situation was obtained at an early port of call.\textsuperscript{110}

These requirements of maritime commerce in the medieval Mediterranean were undoubtedly a major factor in the emergence during this period of the lateen rig as the dominant Mediterranean rig. While the square rig was more efficient when running before the wind, the lateen rig
enabled vessels to sail closer into the wind and was more efficient in utilizing changing wind conditions. Lateen-rigged ships could maneuver more safely and at greater average speed close in to shore and the protection it might afford than could a square-rigged vessel.\textsuperscript{111} They also could more readily and safely gain the protection of harbors, particularly harbors like the one at Serçe Liman with its narrow entrance and dangerous local wind conditions.\textsuperscript{112} The success of the lateen rig in meeting the requirements of maritime commerce in the medieval Mediterranean is evidenced by the long-term popularity it enjoyed, and even when the square rig once again became the dominant rig in the Mediterranean at the close of the medieval period, the lateen sail continued to be used on the mizzen masts of square-rigged ships as an aid in maneuvering and by oared ships and many smaller and local craft down into modern times.

The Serçe Liman ship is presently the earliest lateen-rigged vessel known whose sailing qualities can be profitably assessed. Although quite small in size, this merchant ship was capable of making long-distance voyages, as is clear from the nature and origins of the cargos, currencies and equipment she was carrying when she sank. Her round-shaped hull with box-like hold was designed for maximum cargo capacity. The hydrostatic properties of this hull were such that it could retain sufficient righting ability as long as its angle of heel remained small. This inherent stability coupled with a generous freeboard insured the safety and stability of her
cargo and crew, providing the rig's center of effort was low enough to keep heeling to a minimum. Nor was the hull designed to sail well when heeled over, as are modern racing yachts. Thus, the ship's two-masted lateen rig maximized not only her maneuverability, but also her speed and safety. It gave assurance to merchants that the ship would carry their cargos safely and in sufficient time for profit. Ironically, her failure to do so on her last voyage is now contributing to a fuller understanding and appreciation of the vital role played by the lateen rig in meeting the needs of maritime commerce in the medieval Mediterranean world.
END NOTES


2. George F. Bass and Frederick van Doorninck, Jr., "An 11th century shipwreck at Serçe Liman, Turkey," JNautArch 7 (1978) 119. In a communication from Dr. Bass, it was stated that Virginia Grace had accurately dated the amphoras to the eleventh century for Dr. Bass shortly after the wreck's discovery, but this information was overlooked until after the excavation had begun some years later.

3. Bass and van Doorninck (supra n. 2) 119 and 123.

4. For more information concerning the site and excavation see Bass and van Doorninck (supra n. 2) 119-132.

5. The cleaning, recording and conservation of the Serçe Liman hull remains has been described in greater detail by Frederick van Doorninck, Jr., "An 11th century shipwreck at Serçe Liman, Turkey: 1978-81," JNautArch 11 (1982) 7-11.


7. Steffy (supra n. 6) 32.

8. These two bower anchors were studied in 1981-82. Replicas were cast from the moulds left by the iron concretion which had formed around the iron as it oxidized.


10. The glass weights have been identified by Michael Bates. See Bass (supra n. 9) 91.


12. Bass and van Doorninck (supra n. 2) 126.

13. M. Morden, "The Glass Lamps from the 11th-century
shipwreck at Serçe Liman, Turkey" (M.A. Thesis, Texas A&M Univ. 1982) 54.

14. Bass and van Doorninck (supra n. 2) 126.

15. V. Biringuccio, Pirotechnia (Cambridge 1966) 106.

16. Millstones appear to have been a common item of cargo during this period in the Mediterranean. Three medieval Islamic ships that sank off the southern coast of France and have been partially excavated were all carrying millstones. See A.G. Visquis, "Premier inventaire du mobilier de l'épave des jarres à Agay," Cahiers d'archéologie Subaquatique 2 (1973) 157-166; J. Joncheray, "1974 Excavations at the wreck of Bataïguier," JNautArch 5 (1976) 87-88; S. Ximenes, "Etude préliminaire de l'épave sarrasine du Rocher de l'Estéou," Cahiers d'archéologie Subaquatique 5 (1976) 139-150.


18. Visquis (supra n. 16) 158.


20. Bass (supra n. 9) 92-93.


22. Lewis (supra n. 21) 213.

23. G.L. Udovitch, "Time, the Sea and Society: Duration of Commercial Voyages on the Southern Shores of the Mediterranean during the High Middle Ages," La Navagzione Mediterranea Nell'Alto Medioevo (Spoleto 1978) 503.

24. Udovitch (supra n. 23) 525.


26. An interim report on the excavation and study of this wreck will be published in the near future.


32. Casson (supra n. 28) 244 and Figure 180.

33. Casson (supra n. 28) 244 and Figure 182.

34. Casson (supra n. 28) 244–245.


36. Anderson (supra n. 31) 40.

37. Casson (supra n. 28) 245; Kreutz (supra n. 28) 83; Sottas (supra n. 35) 229.

38. Dolley (supra n. 28) 52.


42. W. Arnold Thomas, Painting in Islam (New York 1965) 115, Plate LI. A fifteenth, possible sixteenth, century painting shows numerous vessels sailing in the harbor of Constantinople, several of the vessels carry a sprit sail.


44. Casson (supra n. 41) 3.
45. Casson (supra n. 28) 244-245.


47. Marco Bonino, Archelogia e Tradizione Navale Tra La Romagna e il Po (Ravenna, Italy 1978) 52. Although Bonino believes that Figure 12 (B) is a lateen-rigged craft, there are enough stylistic similarities between the relief and other period square-rigged vessels to suggest that this vessel might instead be carrying a square sail.


51. Tzamtzis (supra n. 28) 101.

52. Landström (supra n. 50) 92.


54. Landström (supra n. 50) 92.


56. Kreutz (supra n. 28) 94; Fahmy (supra n. 28) 137; Dotson (supra n. 28) 95.

57. Kreutz (supra n. 28) 99-103; Dotson (supra n. 28) 96; E.H. Byrne, Genoese Shipping in the Twelfth and Thirteenth centuries (Cambridge, Mass 1930) 5.

58. Kreutz (supra n. 28) 94.

59. Kreutz (supra n. 28) 94; Fahmy (supra n. 28) 120.

60. Kreutz (supra n. 28) 94; Fahmy (supra n. 28) 120.


62. Kreutz (supra n. 28) 100.

64. Kreutz (supra n. 28) 99-100; Goitien (supra n. 11) 307.

65. Goitien (supra n. 11) 306.

66. Goitien (supra n. 11) 305.


68. Goitien (supra n. 11) 306.

69. Goitien (supra n. 11) 477, fn. 13.

70. Bonino (supra n. 47) 49 and 56.

71. J. Jewell, Dhows at Mombasa (Nairobi 1969) 27.


74. Alexiad X 8, 2.


77. L. Arenhold, "Ships Earlier than 1500 A.D.," MM 1 (1911) 300.

78. Dotson (supra n. 28) 163.

79. The contracts are published in M. Champollion-Figeac, Documents historiques inédits tirés des collections manuscrites de la Bibliothèque Royale et des archives ou des bibliothèques des départements vol. 1, XXII and vol. 2,B,XXIX.

80. J. Dotson, "Jal's Nef X and Genoese Naval Architecture in the 13th Century," MM 59 (1973) 167-168 and Figure 2. For the standing and running rigging, see Jal (supra n. 28) vol. 2, 392 and 395-402.


82. Wood samples from the hull and rigging remains have been identified by the Center for Wood Anatomy Research, U.S. Forest Products Laboratory, Madison, Wisconsin.

83. Champollion-Figeac (supra n. 79) vol. 1, XXII, no.
IIIId, 532-533.

84. J. Shaw, "A Double-Sheaved Pulley Block from Kenchreai," Hesperia 36 (1967) 391. In his article, Shaw used this method to distinguish between "up" and "down" directions of a fourth- to fifth-century block found at Kenchreai. "Top" and "bottom" are used as relative terms since a block used on the lower part of a block-and-tackle system would have its "top pointing down".

85. Shaw (supra n. 84) 389-404.


87. Shaw (supra n. 84) 393.

88. The hull lines were developed by J.R. Steffy. For a more detailed analysis and discussion of the hull remains, see Steffy (supra n. 6).

89. Steffy (supra n. 6) 31.

90. Steffy (supra n. 6) 30.

91. Steffy (supra n. 6) 30.

92. Steffy (supra n. 6) 32.

93. Steffy (supra n. 6) 32.

94. Steffy (supra n. 6) 32.

95. Steffy (supra n. 6) 32.

96. Steffy (supra n. 6) 25.


98. Jewell (supra n. 71) 27; D.A. Howarth, Dhows (New York 1977) 36 and 86-87. In many modern dhows, the mast is lashed to a stanchion that is set forward of it and rises up through the deck. Many times, additional bracings are built around the mast and stanchion at deck level.

99. M. Katzov, "A Sailing Model of the Kyrenia Ship," INA Newsletter 8:2 (1981) 6. The sail area of this ship was calculated from a model made by J.R. Steffy. The Kyrenia ship carried a single, broad square sail with calculated dimensions of approximately 35 x 20 ft. (10.7 x 6.0 m.) or 700 sq. ft. (64 sq. m.).

101. During the Fall of 1982, after discussions with Prof. Stefy concerning the hull shape and structure of the Serçe Liman ship, it was concluded that this additional sail area would have been needed for adequate propulsion.


103. The calculations for these relative positions were determined according to their definitions and discussions from La Dage (supra n. 94) 2. "Center of gravity is that point at which all the vertically downward forces of weight of the vessel can be considered to act; or it is the center of the mass of the vessel. Center of buoyancy is that point at which all the vertically upward forces of support (buoyancy) can be considered to act; or, it is the center of the immersed portion of the vessel."

104. The effect of the center of effort or wind force on a vessel's sailing and handling ability are discussed in C.A. Marchaj, *Sailing Theory and Practice* (New York 1964) 61-63.

105. Jal (supra n. 28) 433.


107. Goitien (supra n. 11) 316.

108. Udovitch (supra n. 23) 526.

109. Goitien (supra n. 11) 314; Udovitch (supra n. 23) 524 and 537.

110. Byrne (supra n. 57) 35-36.

111. Coastal sailing was particularly prevalent during the medieval period. See Udovitch (supra n. 23) 541-545.

112. The Serçe Liman harbor is surrounded by mountainous shorelines that funnel northern winds through passes in such a way that strong, antagonistic cross-winds are created within the harbor. A square-rigged vessel using this harbor would have had difficulty in safely gaining entry or exit under these conditions and probably would have had to use sweeps or been towed. A lateen-rigged vessel, on the other
hand, could have easily tacked through the harbor's tricky entrance and would have been better able to take counter-measures against sudden wind changes that were encountered.
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APPENDIX

LETTERS OF PERMISSION
February 25, 1983

Sheila D. Matthews
c/o INA
P. O. Drawer AU
College Station, TX 77840

Dear Ms. Matthews,

The reply to your letter of January 19 was sent on January 31, but as your letter of February 18 only reached me today, it may be that our domestic mails are as unreliable as those we complain about abroad. I repeat my earlier reply:

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Journal and date: IJNA (1982) 11.1
Illustrations: Figure 1
Figure 2
Figure 3

J.R. Steffy

Date: 3/5/83
VITA

Sheila Diane Matthews was born in Cedar Rapids, Iowa on April 13, 1953, the daughter of Roy Melvin and Sheila Stryker Matthews. At an early age, her parents moved to Dallas, Texas, where she attended school through high school. In 1971, she entered the University of Kansas to study art, subsequently transferring in 1972 to the University of Texas at Austin and also changing her major to anthropology. She received a bachelor of arts degree from UT in 1975. In the fall of the same year, she worked on the Padre Island Underwater Survey Project in Texas and the Little Salt Spring Project in Florida, which provided the impetus for her interest in nautical archaeology. In the spring of 1976, she held the position of excavation supervisor of the Coatlan Del Rio Project in Mexico, sponsored by the Instituto National de Antropología y Historia. In September 1976, she began graduate studies in nautical archaeology at Texas A&M University. In 1977, she worked on the Defence Project on a Revolutionary War-era shipwreck in Maine, and during spring 1978, she participated in the Mombasa Wreck Excavation in Kenya. From June 1978 to December 1979, she was invited to work on the excavation and conservation of the Serçe Liman Glass Wreck in Bodrum, Turkey; she later returned to continue this work for nine months in 1981. She has worked as a hyperbaric technician at Texas A&M in 1977, 1981-83. Her permanent address is 1732 Willow Point Dr., Shreveport, La. 71119.