



The Kyrenia Ship: An Interim Report on Its Hull Construction

Author(s): J. Richard Steffy

Source: *American Journal of Archaeology*, Vol. 89, No. 1, Centennial Issue (Jan., 1985), pp. 71-101

Published by: Archaeological Institute of America

Stable URL: <http://www.jstor.org/stable/504772>

Accessed: 23-03-2017 18:45 UTC

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at <http://about.jstor.org/terms>



Archaeological Institute of America is collaborating with JSTOR to digitize, preserve and extend access to *American Journal of Archaeology*

The Kyrenia Ship: An Interim Report on its Hull Construction*

J. RICHARD STEFFY

(Pl. 21)

Abstract

The Kyrenia ship was a small Greek merchantman which sank off the north coast of Cyprus late in the fourth century B.C. Its timbers have been reconstructed in Kyrenia, Cyprus, where it is displayed along with cargo and artifacts from the wreck. The hull was preserved extensively, including all of the keel, more than half of the stem, and 22 strakes of outer planking. Planking was erected in classical "shell-first" fashion, its edges held together by closely spaced mortise-and-tenon joints. Two heavy wales girded the sides of the hull above the waterline. Frames, made from naturally curved timber, were not fastened to the keel but were held to the planking by means of clenched copper nails. The surviving internal structure included ceiling, cross-beams, and a mast step. Several repairs have been recorded for this ship: replacement of a frame and several planks, installation of a bilge sump, relocation of the mast step, repair of a cracked keel, wood sheathing in the bow, and a layer of lead sheathing over the entire hull.

The study of this vessel, the only well preserved fourth century B.C. ship, clearly establishes the methodology involved in the fabrication of these complex wooden structures. Important new technical details are revealed, and fresh insights concerning the economics of classical trading ventures can be gleaned from the chronology established for hull maintenance and repairs.

GLOSSARY

batten—a long, flexible strip of wood, here used to determine the smoothness of hull curvatures.
ceiling (ills. 1, 6)—the internal planking of a vessel.
chock [*floor chock*] (ill. 6)—a block of wood used to fill the cavity between keel, planking and floor timbers.
false keel (ill. 3)—the planks attached to the bottom of the keel to protect that surface.
floor timber (ill. 6)—a framing member which was centered over the keel and whose arms spanned both sides of the bottom of the hull.
frame (ills. 6, 10)—an assembly, or grouping, of transverse timbers which supported or reinforced the hull planking.
futtock (ill. 6)—a framing member which extended the line of a floor timber or half-frame.
garboard strake (ills. 6, 10)—the line of outer hull planks laid next to the keel; the first strake of planking.

half-frame (ill. 10)—a timber which commenced near the keel and spanned the bottom and part of the side of a hull. Half-frames were used in pairs, one on each side of the keel.

keelson—an internal keel, mounted on top of the floor timbers and directly above the keel, which provided additional longitudinal strength to the hull.

knee (ill. 3)—a timber with an angular bend.

limber boards (ill. 6)—short internal planks which could be removed to clean bilges and open limber holes.

limber holes (ill. 6)—channels cut into the bottom surfaces of frames to permit the passage of bilge water.

limber ledges (ill. 6)—longitudinal supports for the limber boards.

lines [*hull lines*] (ill. 20)—a set of geometric projections, usually arranged in three views, which illustrates the shape of a ship's hull.

mortise-and-tenon joint (ills. 6, 14, 15)—a connection between two timbers in which a hardwood tenon was inserted into aligned, corresponding mortises in the timbers. The joint could be locked by means of tapered wooden pegs driven transversely through the tenon.

partner beams (ills. 1, 11)—athwartship timbers which supported a collar for steadying the mast.

rabbet (ills. 3, 6)—a groove or channel cut into the edge or surface of a timber, usually to receive the edge of a plank.

scarf (ills. 3, 15)—a type of joint formed by notching, beveling, or angling two timbers so that they interlocked to form a continuous piece.

seam (ill. 2)—the longitudinal line or joint between two planks.

sheer (ill. 20)—the sweeping line of a hull side or plank, as seen from the side.

shelf clamp (ill. 6)—a thick ceiling strake which supported transverse beams.

shim—thin piece of wood which filled a separation or opening between two timbers.

strake (ills. 2, 5)—a continuous line of planks extending from bow to stern.

treenail (ill. 10)—a cylindrical wooden fastening.

wales (ills. 6, 10)—thick strakes of planking located along the sides of a vessel for the purpose of strengthening the hull.

ways—the structure or surface upon which the hull was constructed.

* I am indebted to Michael L. Katzev, director of the Kyrenia Ship Project, for his encouragement and contributions to the reconstruction, and his assistance in the preparation of this article. I am also grateful for the cheerful support of project staff members Su-

san Womer Katzev, Robin C.M. Piercy, Netia Piercy, Francis Talbot Vassiliades, and Robert K. Vincent, Jr. Special recognition is given to Helena Wylde Swiny, whose meticulous recording and elaborate hull catalogue form the basis of this article.

THE SHIP

The Kyrenia shipwreck was discovered about 1 km. off the north coast of Cyprus, near the town of Kyrenia, at a depth of nearly 30 m. It was excavated in 1968 and 1969 by an international team of nautical archaeologists under the direction of Michael L. Katzev.¹ The cargo included approximately 400 amphoras belonging to more than 8 different types. Hopper-type millstones, a large copper cauldron, coarse and fine pottery, fish weights, wooden utensils, tools and coins were but a few of the hundreds of items comprising the cargo and other finds.² Artifactual analysis and laboratory dating methods indicated that the ship sank during the last decade of the fourth century B.C. Interpretation of the excavated material confirmed that both ship and cargo were Greek.

Beneath the overburden and cargo lay a well preserved wooden hull which had been sheathed in lead. Most of the wooden fragments were confined to an area which measured about 6 × 12 m. Like the artifacts, hull members were labelled on the seabed, then brought to the surface and transported to conservation areas. Nearly 6,000 wooden fragments were catalogued, photographed, drawn full-size and preserved in solutions of polyethylene glycol 4000. The vessel was reconstructed in a gallery inside Kyrenia's Crusader Castle, where it is now displayed along with some of the cargo and ship's furnishings.³

The wreck apparently settled gently on the seabed, coming to rest on its port bottom at a list of about 15 degrees. Its amphora cargo on the port side was hardly disturbed. Both sides of the hull separated from the keel, the starboard side swinging outward at its after end (pl. 21, fig. 1). Internally, most of the port ceiling strakes, a few starboard ceiling pieces, a mast step, two stanchion steps, parts of three cross-beams or planks, and some dunnage survived (ill. 1). Externally, about 60% of the hull area and more than 75% of its representative timbers were preserved (ill. 2). Numerous rigging artifacts, a steering oar blade, and scattered fragments and fastenings provided additional information about portions of the vessel which had disappeared.

This article deals only with the extant remains of the hull.

THE HULL REMAINS

The Keel

The keel of the Kyrenia ship was hewn from a single log of Aleppo pine. Its entire length has been preserved, although it was recovered in 16 pieces. For the sake of brevity and clarity, the fragments comprising this timber, and all succeeding timbers or timber grouping, have been graphically reassembled (ill. 3).

Fragments of lead sheathing, planking and a false keel adhered to the keel when it was excavated. Some of its surfaces suffered minor collapse, there were small cracks and broken edges, and shipworm damage was extensive. Nevertheless, the entire timber was in good enough condition to permit accurate measurements and the study of minute details.

The keel was rockered (curved) over a length of 9.33 m. It had an average maximum sided dimension (width) of 12.18 cm. and an average molded dimension (height) of 20.3 cm.

Each of the garboard rabbets contained the lower halves of 78 mortise-and-tenon joints. The average center-to-center spacing of these joints was 11.8 cm. in the starboard rabbet and 11.7 cm. in the port rabbet. Mortise depths sometimes exceeded 10 cm., although the average depth was 8.4 cm. Their widths averaged 4.3 cm.; they were 0.6 cm. thick. The live oak tenons fit tightly, except in their vertical dimension where tenons were about 1 cm. shorter than the combined depths of their mortises. Tapered oak pegs, having a maximum diameter of nearly 1 cm. and an average minimum diameter of 0.6 cm., were driven through each joint about 2 cm. below the rabbet.

Tapered square pegs were wedged into round holes in the sides and bottom of the keel. Side pegs (pl. 21, fig. 2) were driven obliquely downward and trimmed even with the sides of the keel. They averaged 1.6 cm. on each side at the keel surface and had no obvious use. They were so obscure and blended so well with the rest of the keel surface that only five of them could be confirmed. A dozen more were suspected in eroded and worm-infested areas.

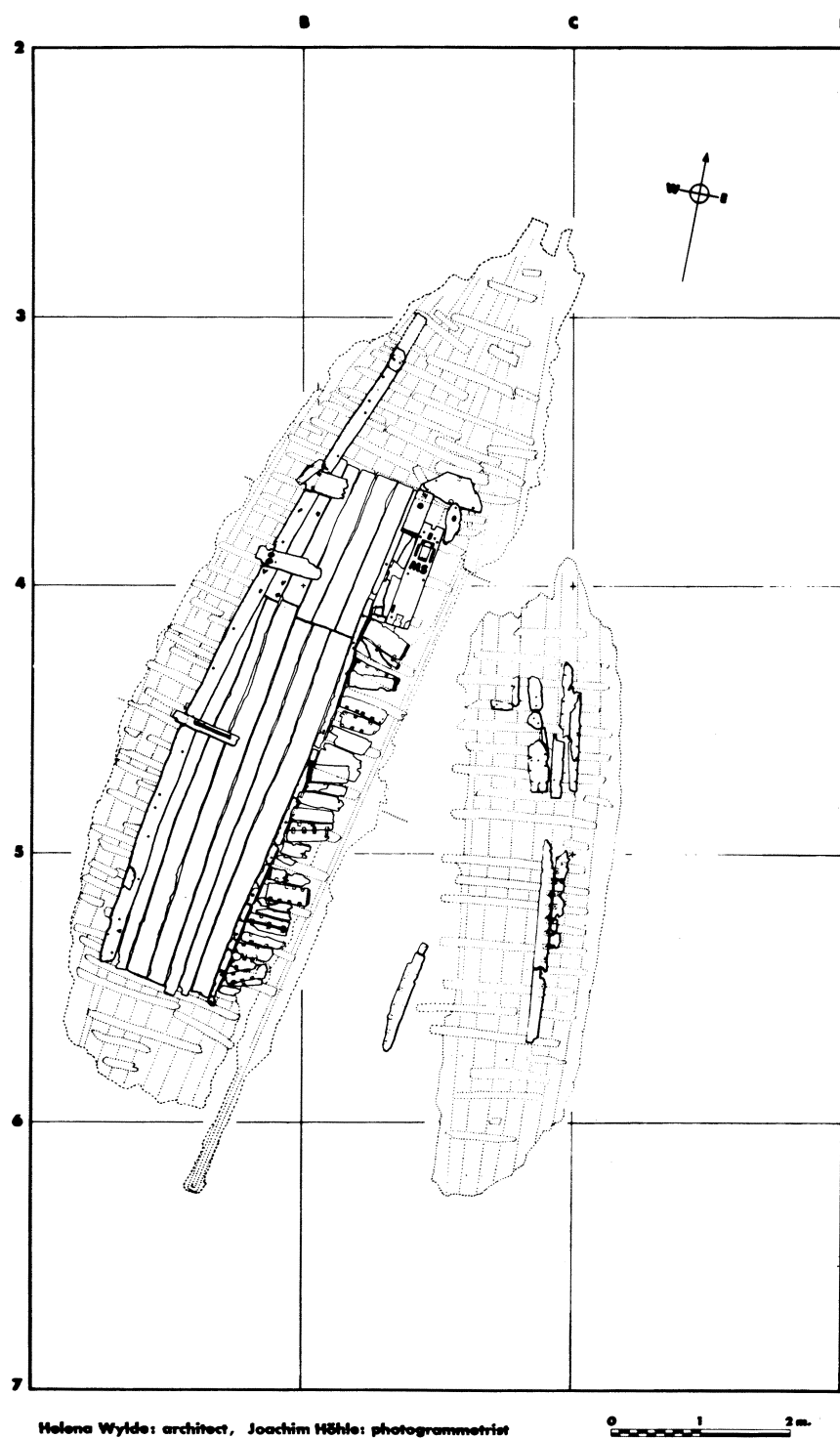
Three treenails and 62 square pegs or peg remnants were found in the bottom of the keel (pl. 21, fig. 2; ill. 3). Most pegs were about 1.5 cm. on a side at the keel surface and tapered to 1.1 cm. on each side at their inner ends where visible. One penetrated the keel to a depth of 5 cm.; another was 6.2 cm. long. Parts of some of these pegs were found in the false keel which they attached to the bottom surface of the keel. The three treenails were 1.2, 1.3, and 1.5 cm. in diameter; they were cut flush with the bottom surface of the keel.

The keel drawings (ill. 3, detail C) show some of the extant false keel fragments directly opposite their original locations. Note that there were many more pegs in the keel

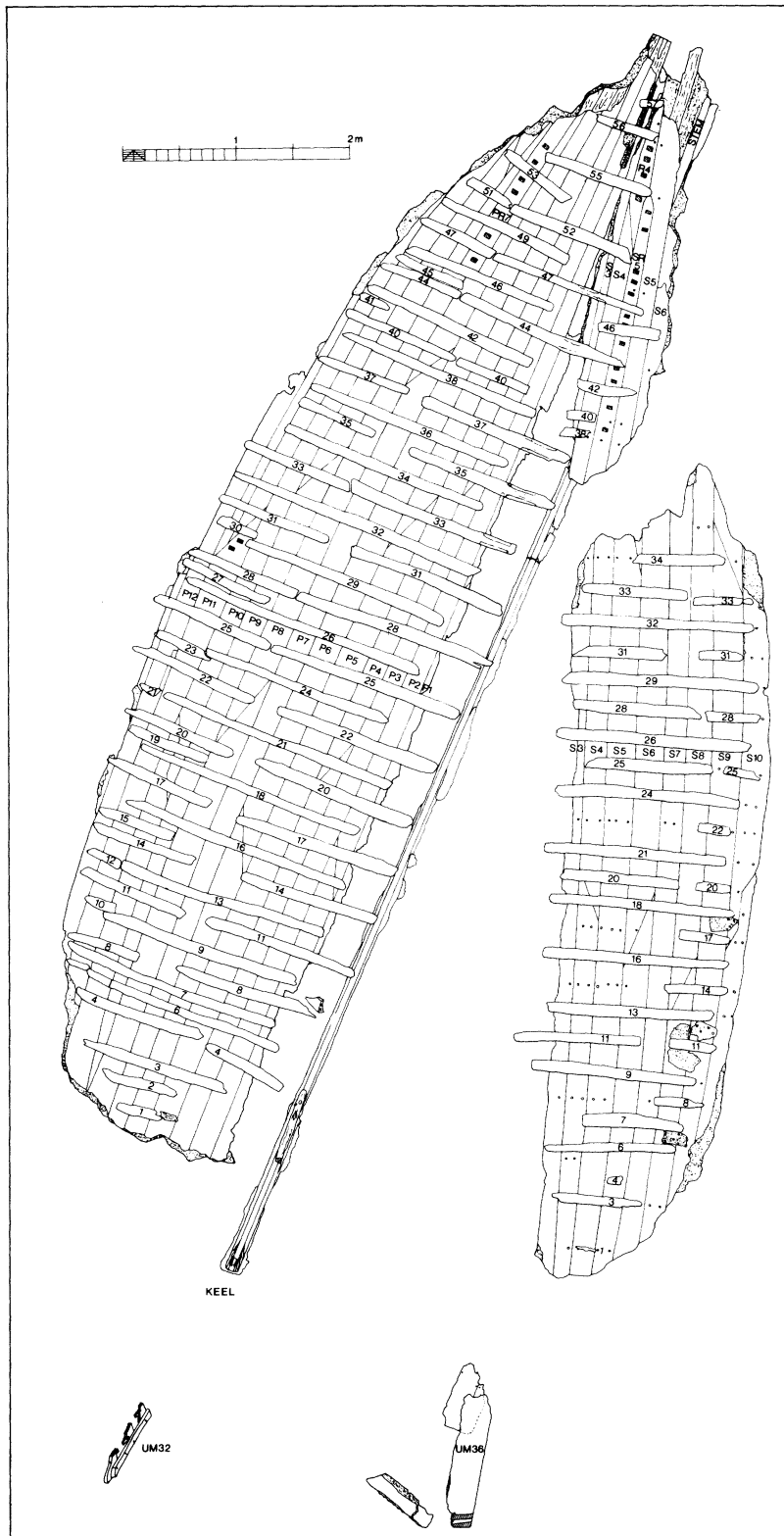
¹ The excavation was sponsored by the University Museum of the University of Pennsylvania; conservation and restoration were conducted under the auspices of Oberlin College and the Institute of Nautical Archaeology. The reconstruction studies resulting in this report were sponsored by the Institute, based at Texas A&M University.

² H.W. Swiny and M.L. Katzev, "The Kyrenia Shipwreck: a Fourth-century B.C. Greek Merchant Ship," in D.J. Blackman ed., *Marine Archaeology* (London 1973) 339-59.

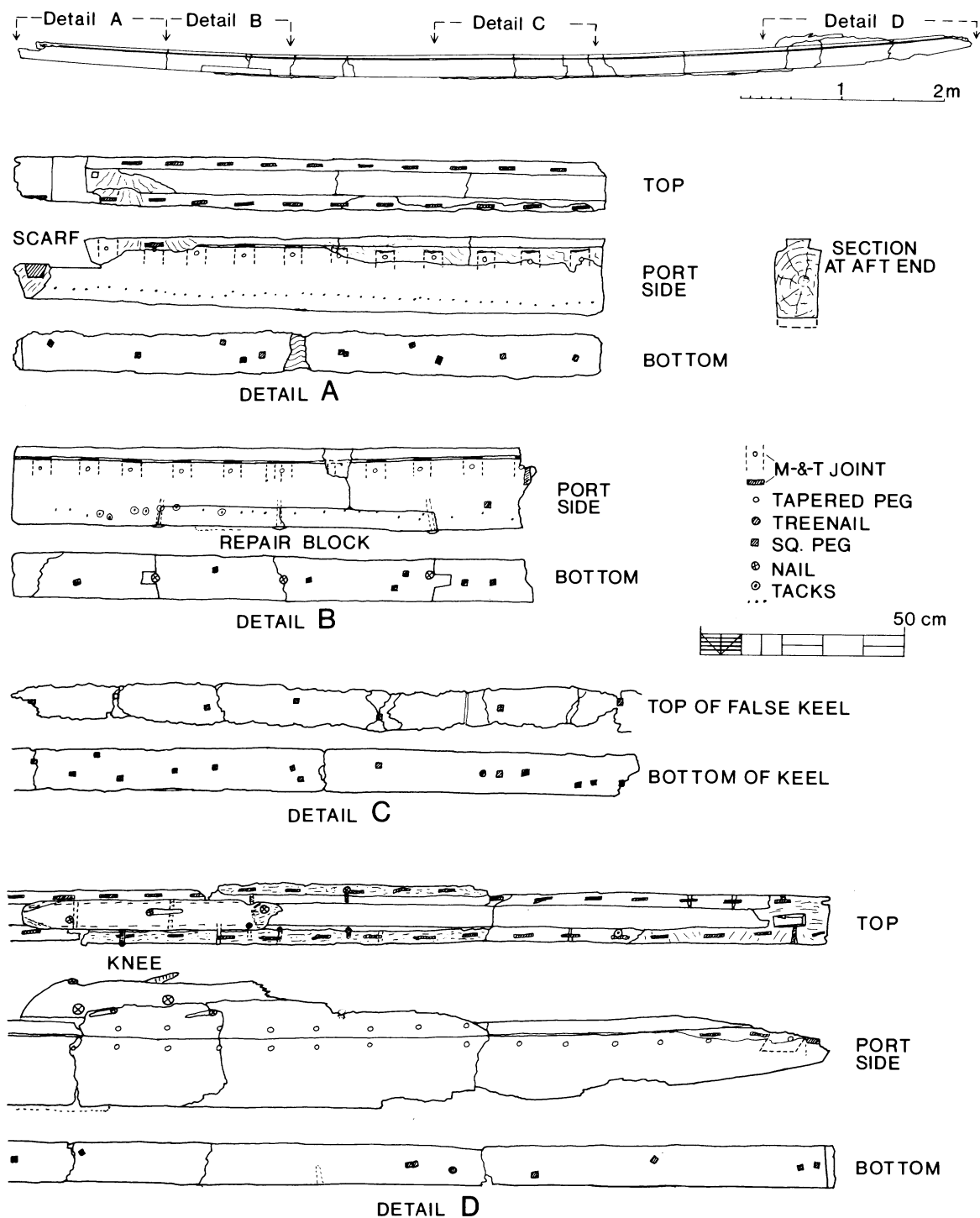
³ M.L. Katzev, Kyrenia project details in K. Muckelroy ed., *Archaeology Under Water* (New York 1980) 40-45.



Ill. 1. Kyrenia ship, the ceiling, beams, and mast step complex. (Drawing Helena Wylde Swiny and Joachim Höhle)



Ill. 2. Kyrenia ship, arrangement of the frames and outer planking. (Revised for reconstruction from an original site plan by Helena Wylde Swiny and Joachim Höhle)



Ill. 3. Kyrenia ship, keel details. The legend applies to all illustrations. (Drawing author)

than were found in the false keel, and that some pegs were installed partially through others. They were driven at random angles into round holes whose diameters were slightly more than 1 cm. in the keel and at least 1.5 cm. in the false keel. Pegs were about 1.8 cm. on a side at the outer false keel surface, where their heads had been flared with a mallet.

A simple hook scarf connected the keel to the stem (ill. 3, detail A). In addition to the mortise-and-tenon joints in the garboard rabbets, the scarf was locked in a fore-and-aft direction by some arrangement of wedges or keys driven within the overlaunch of the two hooks. They left their impressions on the scarf tables and undoubtedly preserved the sharp angles of the hooks.

A small tenon or key, about 1.5 cm. on a side, was driven obliquely into the top of the keel half of the scarf. It may have gone into the after tip of the stem half of the scarf, but preservation was so poor here that its purpose has not been determined. No other fastenings were present in the scarf.

A pine block (ill. 3, detail B), inserted into the bottom of the keel just forward of amidships, was fashioned more crudely than the rest of the keel. Although it was broken into two pieces and its after tongue had disappeared, reassembly indicated that it had an original overall length of 84.3 cm., a forward tongue of 3.5 cm., and an after tongue length of 4.5 cm. Its thickness varied from 3.8 to 4.8 cm.; its width was roughly that of the keel. Three copper nails secured the inserted block to the keel. They had shafts of 1.2 cm. diameter and heads of nearly 3 cm. diameter, but their lengths are unknown. An eroded break in the keel rose vertically above this block.

A 63 cm. long fragment of the forward end of the keel/sternpost knee was still attached to the top of the keel and to pieces of the adjacent garboards (ill. 3, detail D). It was well preserved where it abutted these members, but was broken and eroded elsewhere. Beyond its extent of survival, it had left impressions on the upper keel surface indicating that it originally extended at least as far aft as this keel surface remained intact.

Ten nails or nail holes left evidence for the two methods of fastening the knee to the keel and garboards. Three of these nails were driven through the top of the knee and into the keel. The other nails were driven laterally and in alternating directions, so that their heads held one garboard against the knee while their ends were double-clenched over the opposite garboard. The lateral nails were driven through treenails 2 cm. in diameter; this important fastening method will be described in detail in the section on frame fastenings. All nails were made of copper and had heads averaging 2.5 cm. in diameter and shafts of approximately 1.2 cm. diameter.

Although the top surface of the keel had been torn away at its after end, enough of it survived to permit the recording of several interesting details (ill. 3, detail D). The chamfered end of the keel was preserved from its lower edge to a height of 3.8 cm. A fine-toothed saw had been used to cut it to an angle of 140 degrees with the bottom of the keel. The rabbets continued into the broken upper surface; partial

mortises indicated that originally they extended much farther aft.

A large mortise (8.2 cm. long, 2.8 cm. wide, and about 5 cm. deep) was located in the top of the keel at the stern. Its forward and after ends were cut at nearly the same angle as that of the keel extremity. A small treenail, about the size of the tenon pegs, seems to have been the only device used to lock this joint. The keel surfaces were covered with copper tacks and tack shafts, fragments of lead, coatings of pitch, and tool marks.

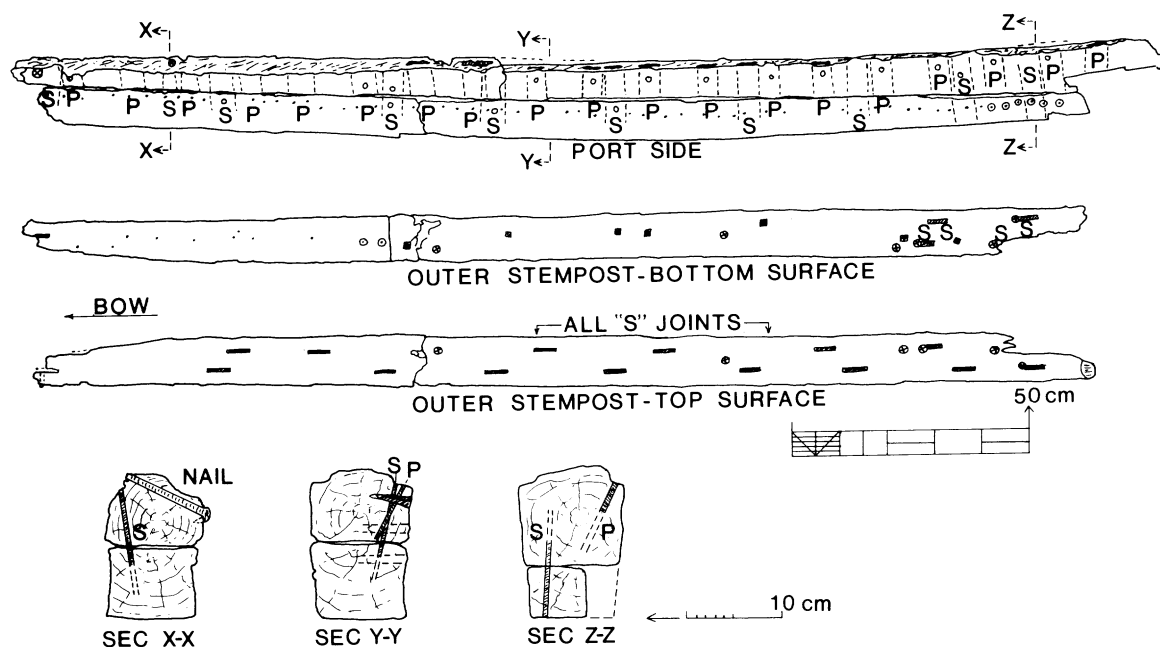
The Stem

The stem survived over a length of 2.46 m. (ill. 4). Its forward end terminated in an eroded break; its after end was scarfed to the keel. Two timbers, hereafter called the inner and outer posts, were joined with nails and mortise-and-tenon joints to form the stem. Together, they maintained approximately the same cross-sectional shape as the keel, whose upward curvature they continued. Top edges were rabbeted to receive the forward ends of the bottom planking. Like the keel, the top surface of the stem was free of fastenings. The false keel, which once continued along the bottom surface of this piece as evidenced by its square pegs and offset, did not survive this far forward. The stem was not as well preserved as the keel, especially along its upper and forward surfaces, where shipworms, rot and distortion obliterated many features.

Drawings of individual fragments have been reassembled in ill. 4; cross-sectional sketches indicate fastening details. Notice that there were two uses for mortise-and-tenon joints in the stem—one group held the strakes to the rabbets, and another joined the two stem posts. There were 38 joints holding strake ends to the surviving lengths of stem rabbets, 19 in each rabbet. These joints were similar to those in the keel and are labelled "P" on the drawings. Their mortises were cut to the depth of the inner post and penetrated through the bottom surface of that member. There were no visible traces of mortise cutting for any of the planking joints in the upper surface of the outer post.

Eighteen post joints survived and are labelled "S" on the drawings. Those which were sufficiently preserved for careful examination were found to be similar to the keel rabbet joints, except for length and spacing. Their average spacing was 25.7 cm., although individual spacing varied greatly. The stem joints ran nearly parallel to the sides of the posts and were necessarily more vertical than the planking joints. In a few cases the two overlapped, so that planking mortises were cut into or through stem tenons. Four of the aftermost stem joints, two on each side, were exposed at the bottom of the outer post and extended upward to about 1 cm. from the inner post rabbets. Forward of the aftermost stem joints there were 7 stem joints on each side which had their upper ends exposed along the rabbet or stem top but did not penetrate the bottom of the outer post.

Six copper nail shafts with diameters of approximately 1 cm. extended vertically through the outer post and into the inner post. They were located only within the limits of the



Ill. 4. Kyrenia ship, the assembled stem fragments. Planking joints are labelled P; joints connecting inner and outer posts are labelled S. (Drawing author)

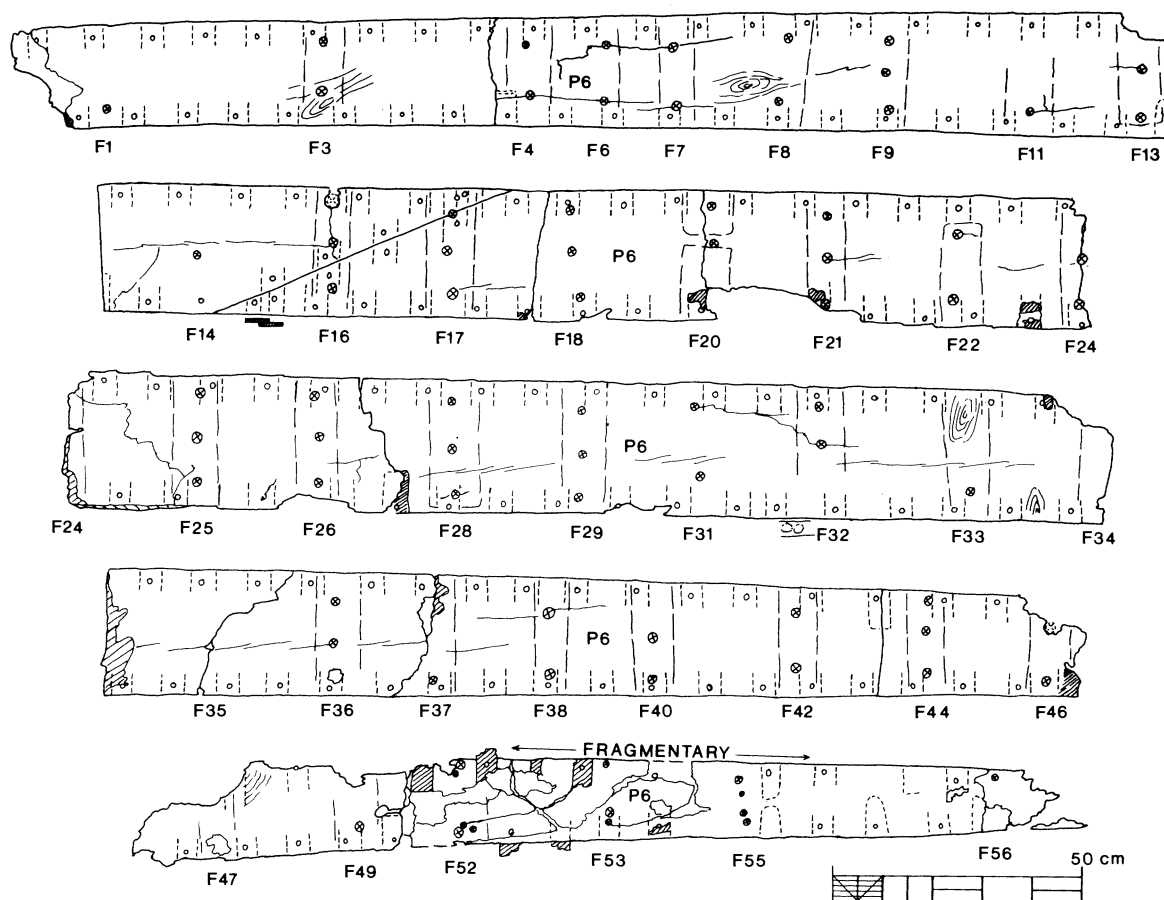
false keel. Two other nails were found in the sides of the inner post, one 34 cm. and another 5.5 cm. from the eroded forward end of that timber. They resembled the planking nails in the sides of the stern knee, although this portion of the stem was so badly decomposed that their function was difficult to interpret. The aftermost nail was clenched aftward along the lower edge of the starboard rabbet. Its shaft crossed through the post at an upward and aftward angle (ill. 4) so that it broke through the existing upper surface of the stem at the top of the port rabbet. The forwardmost nail, surrounded by what appeared to be a treenail, protruded slightly from the port side just below the rabbet. A concretion centered 5.3 cm. aft of the shaft is believed to be the remains of its imbedded clenched tip. The after nail had a clenched length of 5.2 cm. The rest of the forward nail shaft probably is hidden in the mass of teredo tunnels at the stem extremity.

Planking

Most of the planking was concentrated into two contiguous groups (ill. 2). The port group paralleled the keel but was separated from it by a broken garboard whose dozens of small fragments lay scattered in this open area and beneath the hull. The smaller starboard group was angled away from the keel in an aftward direction; its three lowest strakes of planking had shattered and mostly disappeared. A lateral separation of the starboard group was situated aft of the keel/stem scarf. Additional fragments were scattered about and beneath the perimeters of the hull.

There were 9 strakes of bottom planking on each side of the hull between the keel and the lowest wale. Each side also had its lowest (main) wale preserved, although the upper edge of the starboard wale did not survive. Additional port side planking consisted of a broad spacing strake between the main wale and an upper, thinner wale. Fragments of a thirteenth and probably a fourteenth strake also were recovered on the port side. Shapes and dimensions often varied greatly between port and starboard strakes of the same number, and there were frequent variations between port and starboard cross-sectional shapes. All planking was edge-joined with pegged mortise-and-tenon joints, and the frames were fastened to each plank with two or three copper nails. Strakes consisted of two or more planks joined together in diagonal scarfs. In the bow, externally driven tenons secured well preserved sections of planking adjacent to layers of overlaid wooden sheathing. The brittle remains of a resinous pitch and a single layer of lead sheathing covered the entire bottom.

Collectively, the outer hull planking was thoroughly riddled by shipworms; broken edges, except for those made by the excavators to insure safe recovery, were thin and eroded. Nails and tacks were covered with concretion. There were many breaks and cracks, especially in areas of cargo concentration. Inner planking surfaces generally were better preserved than outer surfaces, frequently revealing marks made by tools, frames and cargo. Although starboard planking was not as extensively preserved as port planking, it survived in better condition. The drawings of the inner surfaces



Ill. 5. Kyrenia ship, the inner surface of port strake 6. The vertical, long-dashed lines indicate impressions made by frame edges. Damage from rot and shipworms is not shown. (Drawing author)

of fragments comprising a typical planking strake have been assembled in ill. 5. All strakes can be seen in cross-section in ill. 6 and 10.

The planking catalogues, which contain hundreds of drawings, photographs and pages of descriptive information, must be reduced substantially for presentation in an article such as this. Consequently, I have combined the descriptions of all repetitious details, grouped them graphically where possible, and now present them categorically (Table 1).

Planking widths in Table 1 reflect the greatest dimension across the inner surface of each strake. Inner and outer surface widths varied according to edge angles and plank radii.

Planking thickness values were derived from 1280 points of measurement along strake centers and near edges. Collectively, the lower hollow strakes 1, 2 and 3 were thicker at their centers than at their edges. The opposite was true for strakes 7, 8 and 9, which tended to have thicker edges. Strakes P9 and S9 were about 4.5 cm. thick where they met the main wales, but were nearly a centimeter thinner along

their centers. The rest of the strakes tended to have a fairly constant thickness.

Planking seams were fitted carefully, although their plane was by no means constant. Edges made frequent angular changes, and there were linear humps and hollows. As a general rule, however, the upper or outer strake edges were cut perpendicularly to the sides of their planks; lower or inner edges were angled to reflect lateral directional changes of the strakes.

Scarfs which joined the various planks of a strake sometimes differed from side to side in length, location and even direction. All were diagonal scarfs except for the wales, which had three-planed (Z) scarfs. Table 2 indicates whether the scarf angled upward or downward in its forward direction, the strake width at its after end, its angular length, its approximate location in the hull by frame numbers, and the number of mortise-and-tenon joints used to secure it. Port and starboard strakes are grouped together for comparison. All dimensions are in centimeters.

At least four scarf tips were nailed down with 8.5 cm.

TABLE 1: Outer Planking Dimensions

strake no.	preserved length (m.)	maximum width (cm.)	average thickness (cm.)
P1	6.8 ^a	ca. 20	3.6
S1	9.07 ^b	ca. 20	3.7
P2	9.64	18.5	3.5
S2	7.65 ^b	17 remaining	3.8
P3	10.55	21.7	3.5
S3	9.95 ^b	18.5	3.8
P4	10.43	19.7	3.6
S4	10.4	19.1	3.8
P5	10.27	26.8	3.6
S5	10.07	26.3	3.8
P6	10.22	26.7	3.8
S6	6.4	24.3	3.7
P7	9.9	22.2	3.8
S7	6.24	21.5	3.6
P8	9.8	26.5	3.8
S8	6.35	22.9	3.8
P9	9.34	24.0	3.8
S9	5.71	28.1	4.1
P10	9.32	21.5 ^c	8.0
S10	4.83	21.8	7.9
P11	8.38	31.5 ^d	3.9
P12	5.73	22.7	6.1
P13	1.95	8.4 remaining	3.2

a—there were an additional 2 m. of scattered fragments in the stern area

b—fragmentary and intermittent preservation

c—indicates width of 8 cm. thick area; aft section is 25 cm. wide at junction with strakes 8 and 9 (see below)

d—indicates width of combined strake sections at frame 40

TABLE 2: Planking Scarf Joints

strake no.	boward angle	width, aft end	diagonal length	location	no. of joints
P1 S1	down	17 ----did not survive----	49	F31-F33	3
P2 S2	up up	16.5 --partial survival--	60	F14-F17 F14-F18	3 ?
P3 S3	down	16 ----did not survive----	52	F34-F36	4
P4 S4 P4 S4	down down down	19 18.3 ----no evidence for forward scarf ---- 14.8	56.5 54 42.5	F20-F22 F17-F20 F52-F55	4 3 2
P5 S5	down down	25.7 --partial survival--	68.3	F32-F34 ? -F34	6 ?
P6 S6	up up	25.5 22.8	65.1 70	F14-F17 F16-F18	4 4
P7 S7	down	22 ----did not survive----	61	F37-F40	4
P8 S8	down up	26.6 21	80 63	F20-F24 F13-F16	8 4
P9 S9 P9 S9	down down up	23.2 27 15.7 ----forward scarf did not survive----	67 69.5 54	F32-F34 F33-F35 F52-F55	4 5 3
P10 S10	up up	20.7 --partial survival--	81	F16-F20 F16-F21	11 11
P11 P12 P13	down	28.2 ----none found---- ----none found----	71.5	F27-F31	5

long copper nails having shaft diameters of 0.5 cm. and head diameters of about 1.5 cm. This feature was found on the lower tip of the after scarf of S4, on the lower tip of P11, and on the upper tip of the port main wale (P10). On the upper tip of P5, two nails were used. Hollows were cut into the adjacent strakes to prevent the nail heads from causing a separation of the seam at these locations.

There was a wide variety of shapes for mortises and tenons ranging from precisely rectangular to semi-round configurations. The joints usually were located at constant intervals, although spacing was varied to avoid knots, grain checks or scarf tips. Table 3 gives the reader an understanding of the overall distribution of edge fastenings on the Kyrenia ship. For each seam on each side of the hull, it lists the number of spaces between all mortise-and-tenon joints which could be accurately measured. The second double column shows the preserved lengths of those seams in meters. Spacing, the linear distance from the center of one mortise to the center of the next one, is averaged for each seam and is given in centimeters. The last column lists the number of joints which were in good enough condition to provide at least limited information for the catalogue. The number of joints recorded is usually greater than the number of spaces measured, since broken areas eliminated consecutive spaces.

Mortises had an average depth of about 8 cm. and an average width of 4.5 cm., although perhaps only half of them actually were cut to these dimensions. Depths of mortises varied between extremes of 10.5 and 4.4 cm., but most of them were cut within 1 cm. of the average. Almost all the mortise widths were within the 4–5 cm. width range, except in a few cases where alignments obviously were altered and widths reached 6 cm. or more (as in the upper edge of P5 between F52 and F53). In such instances, narrow slips of wood were inserted alongside the tenons to fill the empty spaces. Tenons almost always fit their mortises snugly, both

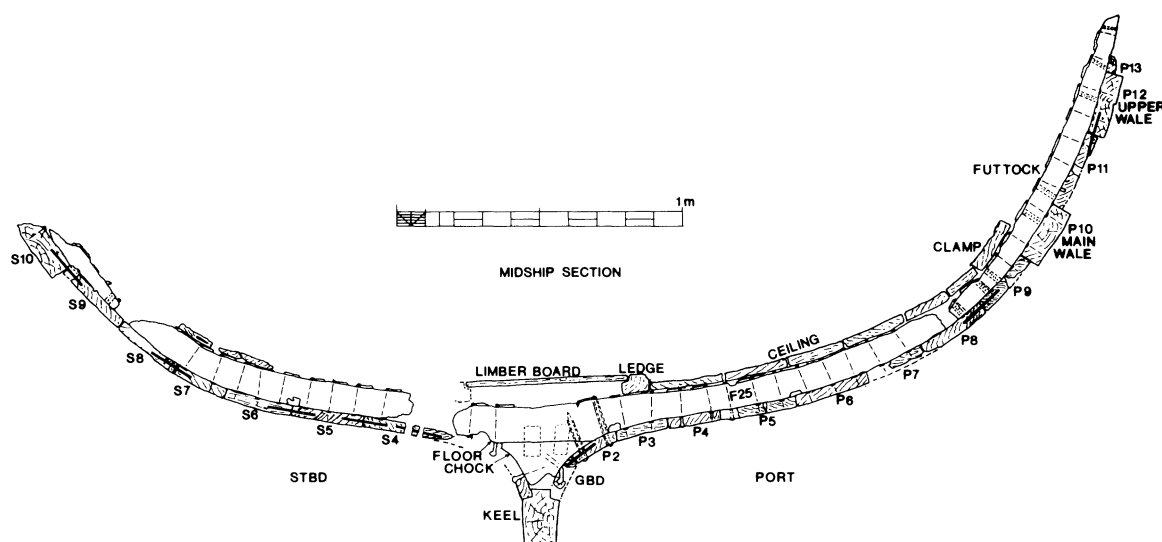
having an average thickness of 0.55 cm. Their widths matched well, and even the end shapes of the tenons somewhat resembled the bottom configurations of their mortises. In a few cases, tenons were exactly as long as the sum of their two mortises, although most of them were 0.5 to 1.0 cm. shorter than the sum of their mortise depths.

Where strakes were extremely narrow, as in the ends of the ship or near scarf tips, mortises and tenons extended into the third plank. For instance, at the lower scarf tip of port strake 6, the aftermost joint of the scarf extends deeply into strake 5 (ill. 5). Only two pegs were ever used in such cases, however, and the pegs always locked the two pieces for which the joint was intended.

All mortise-and-tenon joints had approximately the same vertical attitude, including those in the scarfs, with one exception. An unpegged joint, only 1.8 cm. wide and 4 cm. deep on each side of the seam, was inserted perpendicularly to the scarf on P9 at F33.

Pegs were tapered about 1 mm. for each 1 cm. of length. Most were driven from inside the hull so that their smaller diameters were on the outer planking surfaces. Those driven from outside the hull were found in the keel, stem, lower garboard edges, main wale scarfs (outer joints, ill. 7), some repair plank joints, and at widely scattered locations elsewhere. The latter were found mostly on the starboard side. The pegs in the wales did not penetrate the opposite surface. One joint in the upper edge of P4, between F33 and F34, had no peg at all.

Generally, there were two nails per frame where strake width was less than 20 cm. and three nails per frame where that width was exceeded. In addition to the nails, several wooden plugs penetrated the planking where nail holes had been abandoned. Most of these were found in areas which had been repaired or altered. Fifteen tapered pegs, identical to those used in the mortise-and-tenon joints, were situated



Ill. 6. Kyrenia ship, hull section along the forward face of frame 25. (Drawing author)

TABLE 3: Mortise-and-Tenon Joints

seam	no. of spaces measured		length of seam (m.)		avg. joint spacing (cm.)		no. of joints recorded	
	port	stbd	port	stbd	port	stbd	port	stbd
K/1	84	84	9.9	9.84	11.8	11.7	85	85
1/2	80	§	9.41	x	11.8	x	81	31*
2/3	77	21	9.31	2.54	11.9	12.1	79	46*
3/4	81	67	9.54	8.11	11.8	12.1	87	70
4/5	87	57	9.2	7.94	10.6	14.0	93	59
5/6	92	51	9.92	6.31	10.8	12.4	94	52
6/7	88	67	9.84	7.67	11.2	11.5	91	68
7/8	73	55	8.18	6.25	11.2	11.4	75	59
8/9	78	49	9.01	5.63	11.6	11.5	80	50
9/10	79	45	9.0	5.2	11.4	11.6	82	49
10/11	74	§	8.41	—	11.5	—	77	28
11/11A	20	x	2.64	x	13.2	x	21	x
11/12	51	x	6.54	x	12.9	x	55	x
12/13	37	x	4.63	x	12.5	x	38	x
Total	1,001	496	115.53	59.49	11.5	12		
					stem: post joinery		10	9
					stem: unmeasured planks		4	11
					bow repair strakes		14	51
					P8/P9/P10 scarf		11	x
					scarf joinery		60	30
					unassigned fragments		31*	
							1137	729

§—unreliable

x—did not survive

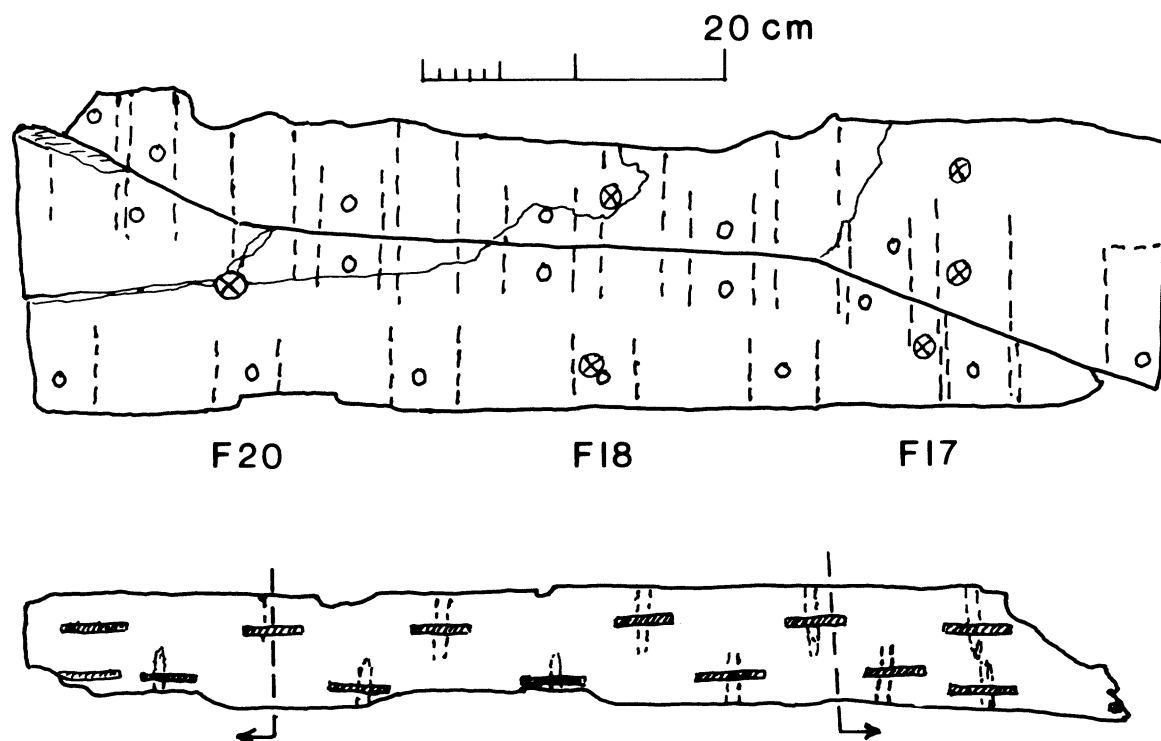
*—estimated; several partial joints may belong to the same unit

Mortise-and-Tenon Joints; Unit Totals for Entire Hull

1. Total number of mortises recorded	3351†
2. Total number of pegs or peg holes recorded	2488†
3. Total number of spaces measured	1497
4. Total number of joints recorded	1866‡
5. Total seam length for spacing measurements	175.02 m.
6. Average joint spacing for entire hull	11.7 cm.

† Some partial joints on small fragments may combine with others; peg count may be higher, since shipworm holes and other suspect areas were not included in the tabulations where they obliterated peg locations.

‡ Includes partial joints



Ill. 7. Kyrenia ship, the inner surface and lower scarf table of the starboard main wale, showing the staggered arrangement of mortise-and-tenon joints in the scarf. A similar scarf was found on the port side. (Drawing author)

under or near frames on the upper strakes of each side of the hull. Only two of them passed through tenons.

Cross-sectional shapes and surfaces of pieces of strake P11 and the upper wale (P12) are shown in ill. 8. Note that there are rabbets in the outer surfaces of both these strakes. On P11, the rabbet extends the length of the strake and is 7.5 cm. from the P11/P12 seam. On P12, the rabbet is more difficult to define because of poor surface condition, but it seems to extend about as far aft as the one on P11 and is centrally located in the strake at amidships. The rabbets were unoccupied, but several tenon ends were visible in the P11 rabbet.

Three vertical nail shafts entered the upper edge of P12 through a thin line of P13 fragments. They were approximately 1 cm. in diameter.

In the bow there was an odd-looking strake centered along what should have been the P7/P8 seam from F46 forward (ills. 2, 9). Two similar pieces of planking were situated among a complex system of scarfs in the starboard bow. While the rest of the hull planking was colored black and was cracked and teredo-riddled, these planks—PR7, SR4 and SR5—were yellow and had the appearance of new wood. The curious tenons, which were visible from the inside of the strakes between frames and from the outside where their presence coincided with frames, are shown in ill. 9. Two similar tenons, which we called patch tenons be-

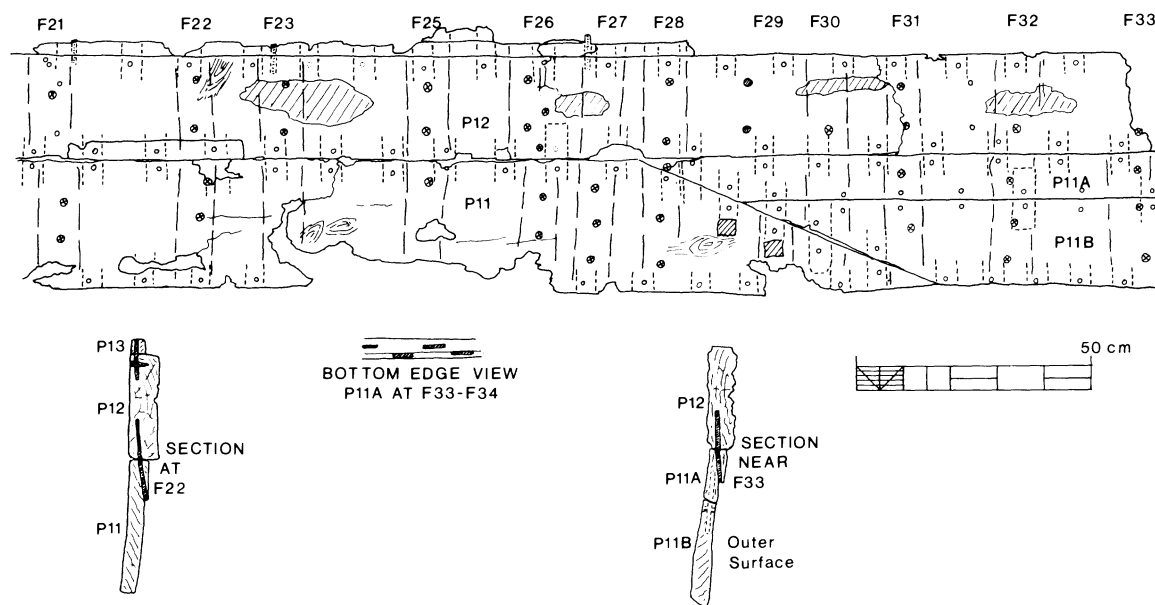
cause of their exterior appearance, can be seen at the scarf on the inside surface of P11 (ill. 8).

A sheathing of wooden planks was fastened to the outer surfaces of the lower port bow planking, except where the above strakes occurred. A single sheathing plank and a few fragments were found beneath the starboard bow. Sheathing planks were 1.1 cm. thick and 11 to 13.5 cm. wide. They were fastened alongside planking nails with copper nails averaging 10 cm. in length and having a shaft diameter of 0.7 cm. All wooden sheathing was relatively free of teredo tunnels and rot, but had become extremely hard and brittle. Ill. 18 shows the sheathing arrangement over the port bow planking. The alignment of sheathing and planking seams in this drawing could be inaccurate by as much as 3 cm. The poor condition of the bow fragments below P7 prevented reliable seam definition, especially for the planking.

The entire surface of the outer hull was covered with sheets of lead which were 1 mm. thick and 1.05 to 1.23 m. wide.⁴ The lead did not survive in good condition. The sheets followed the hull contours closely, starting at the upper extent of hull preservation, passing tightly over the protruding wales, and continuing around the bilge. Rectangular sheets along the bottom were overlapped by separate pieces which passed between the keel and the false keel (ill. 19). They were held in place by copper tacks which had shaft diameters of 0.5 cm. and shaft lengths of 1.5 to 2.5 cm.;

the lead was of very high purity.

⁴ Five different samples from the lead sheets have been analyzed. The results, which ranged from 99.5 to 99.945% Pb, indicate that



Ill. 8. Kyrenia ship, port strakes P11 and P12 (upper wale) along the midships area. Inside surfaces are shown.
(Drawing author)

heads were 2 cm. in diameter. The lead seemed to be consistent in thickness. Rectangular impressions could be seen on the inside of the sheathing; diamond-shaped striations were present over much of its exterior. There were also traces of agave leaves, simply woven and saturated and in a red-brown resinous pitch, between lead and hull.

A few intact areas of the outer hull surfaces also contained traces of the red-brown residue. Another surface detail of note was the presence of numerous charred areas along the inner surfaces of the starboard main wale and the port upper wale. Charring was widely scattered and seldom exceeded 30 cm. in any direction. It was evident, however, that these surfaces were originally much more extensively scorched and were later trimmed away with surfacing adzes.

Frames

The two types of framing patterns can be observed in ills. 6 and 10. All frame timbers were made from pine, and their curvatures were naturally grown. The Kyrenia hull had a framing sequence in which floor timbers and detached futtocks alternated with half-frames and detached futtocks or top timbers. Intermediate timbers were situated above the turn of the bilge in the hold area. There were 41 frame stations with a room-and-space (center-to-center distance) averaging about 25 cm. over the keel, although the spacing of these timbers varied. Most frames survived in fair condition; those frames crossing the keel were separated near that location on the starboard side, and most of these timbers had broken into several pieces. There was distortion of the frames along the upper port side; port frame 16 suffered the most by being bent 8 cm. inward at its upper end.

⁵ Four different samples of nails and one tack have been analyzed. Their copper content ranged from 88.22 to 91.0%; traces of

Frames were fastened to the planking by means of long copper nails,⁵ which were driven through treenails and clenched over the tops of the frames (for details of this method of fastening, see pl. 21, fig. 3). The nails always were clenched twice as indicated, and usually the clenched ends were angled in herringbone fashion in the direction of the keel. Along the garboards and second strakes, where the distance through chocks and floor timbers sometimes exceeded 30 cm., straight nails remained within the frames (ill. 6).

Floor timbers spanned the keel, their arms extending to or near the turn of the bilge. They were 9 cm. on a side along strake 6 if one averages all the measurements for all the frames. None of them had constant cross-sectional shapes, however, and few of them were straight or exactly perpendicular to the keel. The cavities between the floor timbers and the keel were filled with chocks. Half of them remained attached to their floor timbers and could not be inspected for internal details. Of those chocks which were found detached or could be separated easily, all but two were joined to the floor timbers with mortise-and-tenon joints. The joints were 4.5 to 5 cm. wide, 0.5 to 0.8 cm. thick, and mortises were only about 4 cm. deep. None of these joints was pegged, except for those in floor timber F55, but no pegs were set into the chock of F55. Two mortise-and-tenon joints were used in each frame except F44, which had three. Floor timbers F4 and F56 had their chocks aligned with 1 cm. treenails, although the chock of F56 did not survive. Frame F52, which was in much better condition than the other frames and looked like a new piece of wood, had no chock at all; it was made of a single piece of pine. Chock F57 was preserved

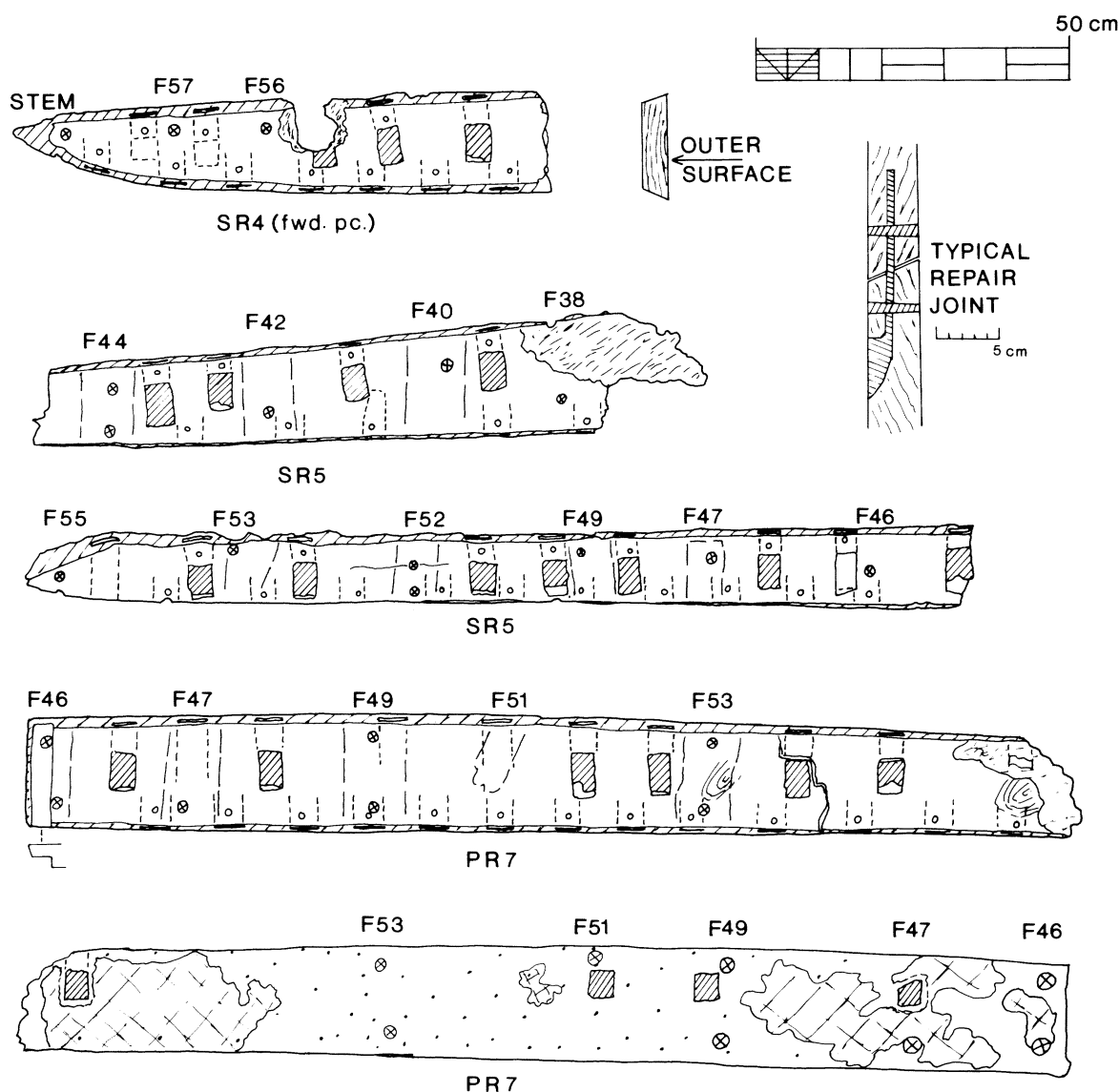
various other elements were identified, but in no case was tin found in concentrations greater than 0.05%.

in good condition, but its floor timber had disappeared. Floor timber F40 consisted of two arms which were separated by a space of 40 cm. over the keel. Both arms apparently were sawn from their central section after installation, as there were saw marks in the planking surfaces at their inboard ends. There were two wooden plugs in the the gar-board next to the port arm of F40.

Floor timbers were fastened only to the planking, never to the keel. In fact, many of their chocks were separated from the keel by several centimeters. Only frames F35 and F37 were close enough to cause discoloration on the upper keel surface. Limber holes were cut centrally into all the chocks to permit the free flow of bilge water. Some of the

floor timbers had additional watercourses at the seams of strakes 2/3 and 5/6; others had none, and there seemed to be no logical pattern to this arrangement. Table 4 lists the location of watercourses (other than limber holes) in each well preserved frame.

Half-frames were always used in pairs. Their heels extended to one of the three lower strakes, while their heads ended at various elevations in the sides of the hull (see wreck plan, ill. 2). A surprising majority of them had grain patterns which faithfully followed the reverse curvatures of these timbers. As was the case for the floor timbers, half-frames were frequently crooked and had varying dimensions, but their cross-sections averaged about 8.5 cm.



Ill. 9. Kyrenia ship, four inner surface drawings of replacement planks and the exterior arrangement (bottom view) of patch tenons and lead tacks on PR7. (Drawing author)

TABLE 4: Watercourse Locations

floor timber	seam no.	half-frame	seam no.
4	none	3	none
8	none	6	none
11	2/3	7	none
14	none	9	5/6
17	2/3; 5/6	13	5/6
20	2/3; 5/6	16	5/6 stbd; none port
22	2/3; 5/6	18	5/6
25	2/3; 5/6	21	5/6
28	2/3; 5/6	24	5/6
31	none	26	5/6
33	2/3	29	5/6
35	none	32	5/6
37	none	34	5/6
40	5/6	36	5/6
44	5/6	38	none
47	5/6	42	none
52	none	46	none
55	none	49	none

square. Half-frames 6 and 42 had mortises with broken, unpegged tenons cut into their upper surfaces (ill. 10).

Futtocks were separated from their floors and half-frames by varying distances; only in the case of F6 was there any connection between a lower frame timber and its futtock. Many futtocks and intermediate timbers had holes plugged with trenails which did not extend through the planking (ill. 6). In a few cases, there were holes with no apparent use or attempt at closure. All these holes and plugs were 1.8 to 2.1 cm. in diameter.

Internal planking and timbers can be seen in ill. 1 and in the midship section drawing (ill. 6). Loose boards, obviously cut from scrapwood, ran athwartships over the keel and provided access to the cavity below. They were seated on limber ledges, longitudinal stringers which were cut to support them. Ceiling planks were laid across the clenched nails on the frame tops and were nailed to the frames at widely separated areas. A few ceiling planks and limber boards were made from previously used planks which had been joined together with pegged mortise-and-tenon joints or dowels. They probably represent parts of three other vessels which had been scrapped, and are therefore being studied and published separately. The ceiling also contained graffiti in the form of Greek capital letters; these are being studied and published by others.

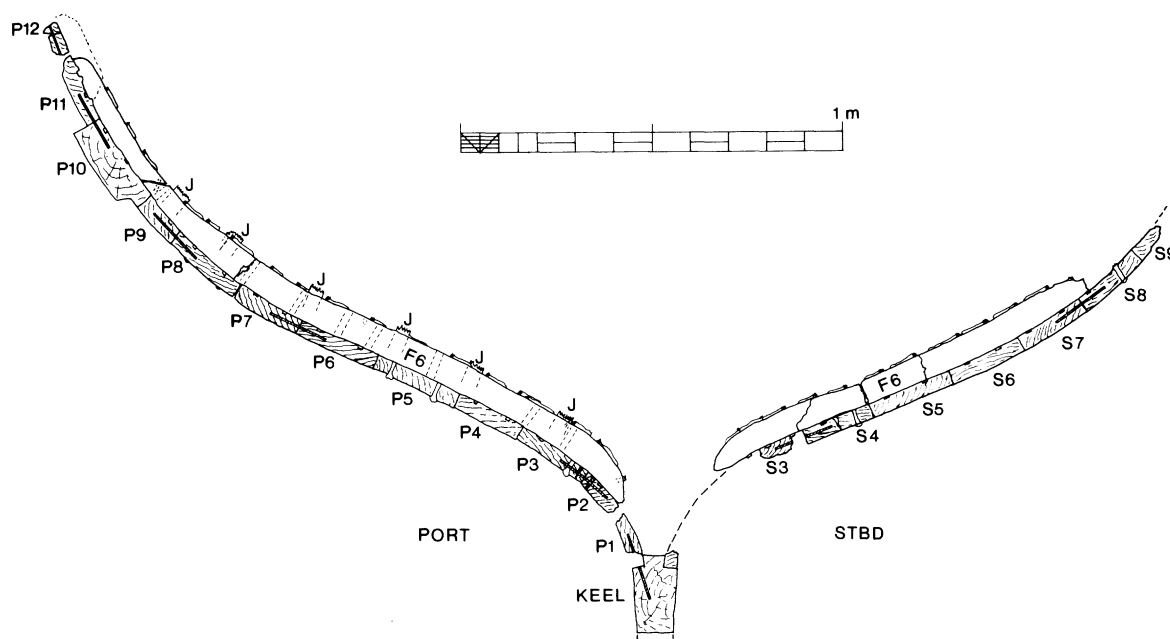
A shelf clamp backed the main wall as shown in the section drawings, but it was not fastened to the wale or even bolted through the frames. It was notched at three places for the beams described below.

Only three cross-beams were found in the wreck. None of them appeared to have great strength, nor were they at-

tached to the hull sides rigidly enough to perform the functions of cross-beaming as we understand it today. Two of these timbers are shown in ill. 11. The central beam was not fastened to the sides of the hull at all, while the forward pair of cross-members (I have dubbed them partner beams) was nailed to the shelf clamp which was itself nailed to upper frame timbers. These partner beams had impressions and discoloration on their upper surfaces next to the hull, which suggested the presence of a longitudinal plank or other timber. Whatever laid atop these beams was not fastened to them, however.

The mast step complex is shown in ill. 12. The piece designated MS1A is a closing device which was found seated in the intricate cutting in the after end of the step. Note that the partner beams do not seem to be in good alignment with the stanchion or mast steps (ill. 1). The mast step was seated in rabbets atop frames 33, 35 and 37; there also was a fourth, unused notch in the bottom of the step. Frame 47 (and perhaps frame 44) was rabbeted for a step, suggesting that the extant step may have occupied one or more different locations before the final voyage of the vessel. Research on mast placement has become quite involved and is still uncompleted.

A few other items related to the hull, which will be published in more detail at a later date, are noted here for the reader's information. The most important unconnected timber was UM36 (ill. 13), believed to be a spare steering oar blade. It was found aft of the stern (ill. 2) and was riddled badly by teredo. A number of timbers were found beneath the hull which are believed to belong to topside construction, as is UM32 in ill. 2. There were lead anchor ingots,



Ill. 10. Kyrenia ship, hull section along the after face of frame 6. Mortise-and-tenon joints atop the port frame are indicated by the letter J. (Drawing author)

lead brailing rings, a single-sheaved block,⁶ and dumbbell-shaped objects thought to be rigging toggles.

Analysis of Timbers⁷

Several groups of wood samples were taken from representative scantling types and hull areas. They were identified as follows:

keel, planking, repair strake PR7, frames, floor chocks, ceiling, beams, mast step, and treenails—pine, probably *Pinus halepensis* Mill.;

tenons, tenon pegs, and false keel—oak, *Quercus cerris* L. type.

Summary of Catalogue

THE KEEL, of pine; sided 12.2 cm. at the rabbet, 10 cm. at the false keel, and molded 20.3 cm.

PLANKING, of pine; edge-joined with pegged oak tenons; planks of each strake joined with diagonal scarfs; bottom planking, 3.7 cm. thick; main wale, 8 cm. thick; upper wale, 6 cm. thick.

FRAMES, of pine; unconnected floors and futtocks alternating with half-frames and futtocks; room and space, ca. 25 cm.; floor timbers sided and molded 9 cm. near the heads, both arms reaching the turn of the bilge; half-frames sided and molded 8.5 cm.; frames attached to planks with 1 cm. double-clenched copper spikes driven through 2 cm. treenails.

INTERIOR SCANTLINGS—keelson, none; thick stuff,

none; clamps, one set inside main wales, of 5 cm. thick pine, not bolted through wales; ceiling, loose pine boards, 2.5 to 3.5 cm. thick.

SURFACES—caulked with a layer of resinous pitch; the bow sheathed in 1.1 cm. thick stakes of pine; the entire hull overlaid with a 1 mm. thick sheathing of lead.

INTERPRETATION OF HULL REMAINS

Angles on frame faces confirm that the keel was rockered and had not sagged to this curvature. Its log was hewn with axes and adzes to a trapezoidal shape; tool marks are evident everywhere. A final trimming of the sides of the keel apparently was done only after the planking was in place, since small adze marks extended across the seam made by the keel and port garboard.

The false keel must have been added to the bottom of the keel later, as it had to be carefully fitted to the outer stem and stern posts. Only one small fragment of the sternpost survived, and we know only that it was trapezoidal in shape like the keel and stem and that a false post was pegged to it. There are half a dozen structural arrangements which fit all the available excavated evidence for the sternpost. The one I have selected seems to fit the hull lines and strake seams better than other arrangements. The angle and

⁶ Swiny and Katzev (supra n. 2) 352–54.

⁷ Wood identification was made by F. Kukachka and R.C. Koepfen of the United States Department of Agriculture, Forest

Products Laboratory, Madison, Wisconsin, and D.F. Cutler of the Royal Botanic Gardens, Kew, Richmond, Surrey, England.

location of the sternpost rabbet are less doubtful, since they were partly established by the distribution of stern artifacts and the dispersion of hull remains.

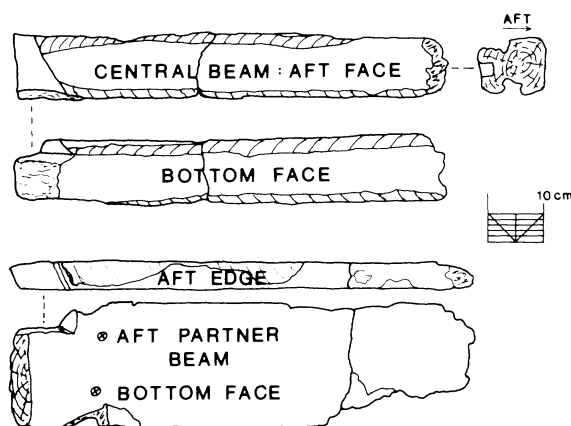
The stem survived only to the point where it began to curve sharply upward, but the bow could be reconstructed accurately to the main wale. We know the stem curved upward beyond the point where it broke off and disappeared, because the forward tip of S4 begins the increased curvature where its lower edge is configured for the stem rabbet. In addition, the existing planking survived far enough into the bow to permit reliable projections of strake seams and hull lines as high as strake 11 on the port side. But this evidence merely tells us where the rabbet was and does not reveal much about the design of the stem. In the lines drawings (ill. 20), the inner stempost has been drawn to continue its known dimensions and curvature. The outer post is completely hypothetical, however, and is based on reasoning which remains open to question. The projected curvature of the inner post has a radius like that of some of the half-frames; indeed, the inner post must have resembled a long half-frame. Because this curvature must have been available to the shipwright in sufficient bulk and length to permit such a small stem to be fashioned from one piece of timber, I assumed that it was fabricated with two pieces for reasons other than timber acquisition. When I built experimental models which followed all the excavated evidence for the bow, but had the inner and outer posts joined together in a regularly curved arc, the

stem seemed to lack sufficient strength to support the bow. Since the grain pattern of the forward end of the outer post is coarse enough to be close to a large knot (or knee), I assumed that the reason for a double post was to shape the outer post in the form of a knee, which would have strengthened the stem. Ancient representations suggest the presence of such a knee⁸ and calculations show that the hull would have handled better with this protuberance than with the rounded bow I had first hypothesized.

Enough of the stem survives to reveal something about its fabrication and attachment to the keel. Probably the two posts were shaped roughly at first, and then joined temporarily while mortises were cut through the inner post and into the outer post. Tenons were inserted next and the two pieces locked together with tapered pegs. At the after end of the stem, however, the inner post was so thick that such a procedure would have resulted in very deep mortises in the inner post and very shallow ones in the outer post. Consequently, the last four joints were cut from the outer surface of the outer post and completed as before.

The post was scarfed to the keel by means of a short hook scarf. Judging from the tool marks left on the scarf, cross cuts were made with a fine saw, while tables and lips were surfaced with chisels. Note that this scarf was not bolted and therefore needed the garboard and false keel fastenings to keep it together. It also did not produce a smooth transition between keel and stem, having a rather angular break in the rabbet. The oblique little tenon atop the keel section of the scarf seemed too light and too far aft to have been intended as a permanent and rigid fastening.

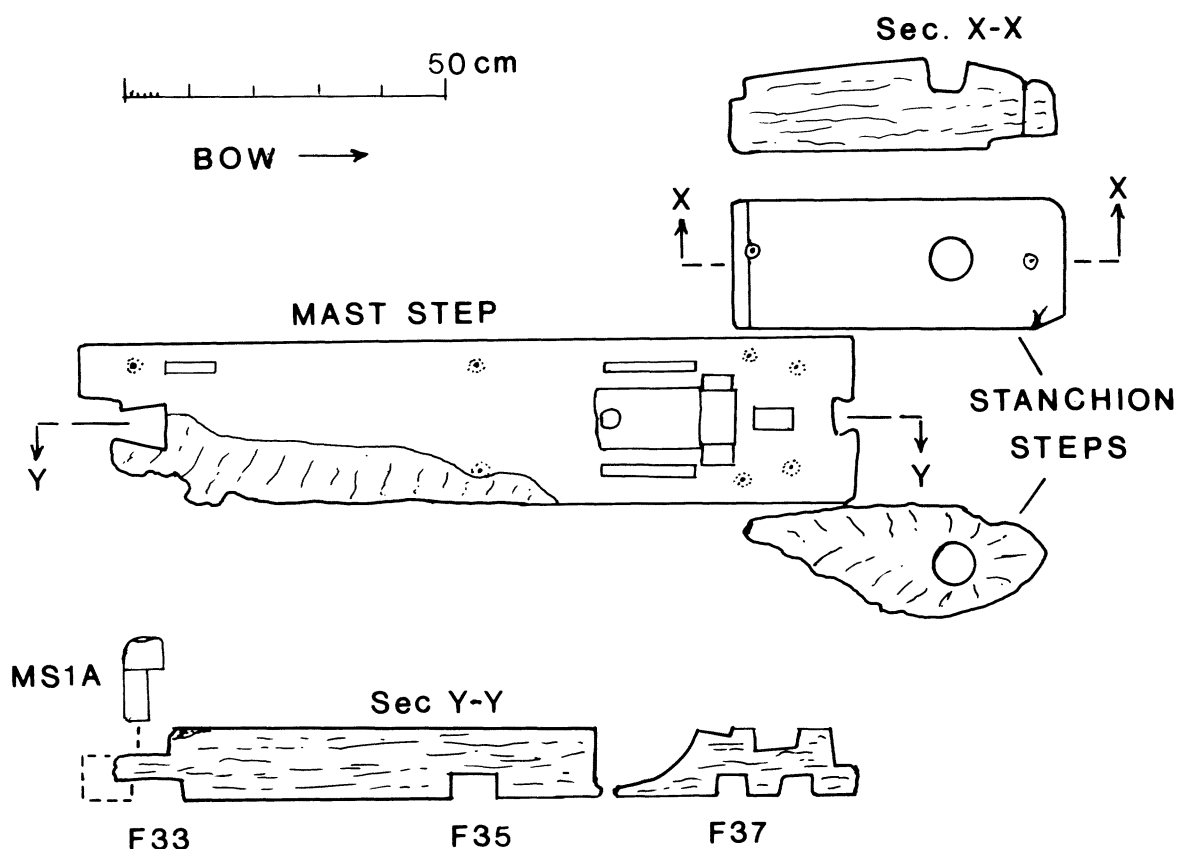
At some convenient time, the false keel was installed. One or more planks had 1.8 cm. holes drilled through them at appropriate locations, while slightly smaller holes were drilled into the keel at the same locations and at varying angles. Tapered wooden pegs, square in cross-section, were driven into these holes to attach the false keel to the bottom of the keel. Heads were formed on the outer ends of these pegs, either by manufacture or by working with a mallet. The builders seemed to use square pegs in round holes wherever a fastening was subject to later removal or abandonment. Such pegs were excellent for this purpose, since they could be worked loose by splitting and side hammering but gripped very well in the direction of the fastening.



Ill. 11. Kyrenia ship, the central and after partner beams. None of the cross-beams penetrated the sides of the hull. (Drawing author)

⁸ A 6th c. B.C. Cypriot clay model, part of the Cesnola collection in the Metropolitan Museum of Art (Inv. No. 74.51.1752), is the closest contemporary parallel for the Kyrenia ship. Hull shape, gently rockered keel, sternpost angle, wale placement, and sheer are all similar to the remains excavated at Kyrenia. Although this

model is sometimes credited with having a ram bow, I believe the coroplast was attempting to portray the type of outer stempost knee construction we have reconstructed; it is merely more pronounced on the model.



Ill. 12. Kyrenia ship, the mast step complex. (Drawing author)

The false keel ran along the stem to above the line where the ship would strike if it ran aground. Here it was gradually tapered and terminated in a 1 cm. thick offset in the bottom of the stem. The false keel that went down with the ship was made up of at least three planks, but this was by no means the one she was launched with. There were plugged holes and abandoned pegged holes in the keel above the existing fragments. Although there is still some doubt, I suspect the pattern of used and unused fastenings on the bottom of the keel represents the existence of at least three false keels during the life of the ship. The nail shafts in the bottom of the stem obviously were used to provide an additional grip on the forward end of the false keel, perhaps because it worked loose along this increased curvature.

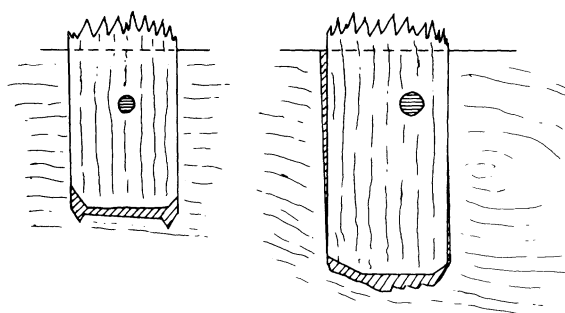
Stem and sternpost might have been steadied on the ways by conventional shoring, but the keel would have been treated differently. Here is where those mysterious unused pegs in the keel sides enter the scene. They were so washed off and obscure—even more obscure than many of the tool marks—that it

was evident they were in an undisturbed state in the keel long before the ship sank. I contend they were used to fasten temporary bracing to hold the keel rigid to the ways until enough of the hull was completed to permit it to be braced elsewhere. The keel braces eventually were split away from the keel and the pegs cut off and abandoned. The keel had to be supported, and rigidly, before work could go further. On modern wooden hulls of this size frames are set on the keel, and they are braced so that the keel needs only to be blocked to the ways. By the time planking goes into a modern hull, the structure is so heavy and rigid that its own bulk resists the efforts. Not so with the Kyrenia ship. Planking began before framing, and the forces resulting from installing strakes onto 50 or more standing tenons must have been enormous. The only way to resist them was to tie down the keel, and the keel could not have been supported above the rabbet line because of the solid shell of planking at this point. Hence a stiff support of side fastenings was necessary, a support which I believe was held in place by many more pegs than we were able to discern.

Installing the Garboards

The keel rabbet and lower garboard edges had to be fitted carefully; the unevenness of this seam suggests that it was quite a task. In the stern, the knee was shaved to the proper side contours and the vertical post rabbet formed. When the fitting was considered adequate, mortise locations were marked on the outside of the garboard strakes and keel. Most of these marks were obliterated by the final trimming of the planks, but enough of them remain to determine how the joints were located. Lines were scribed downward from the garboard to the side of the keel with a sharp awl or other scribing tool. Two lines were struck for each mortise, but their lengths and the distances between them only described the mortise dimensions approximately. Where possible, knots and grain checks were avoided, the mortises being spaced closer or farther apart as was necessary for good distribution of these joints. Overall, the shipwright seemed conscientious about maintaining close and regular spacing. There was the occasional joint cut into a knot or having a bottom cut around a knot because there would have been too much distance between joints otherwise.

As soon as the after garboard plank was shaped at its forward end for a scarf, at its after end for the stern rabbet, and marked for mortise locations, it was removed from the keel; mortises were cut into it and the keel rabbet. Many exposed mortises could be examined at breaks and eroded surfaces. More were probed with wires and drafting film. They seemed to have been cut in two ways. In the starboard ceiling planking, where wood from another hull apparently was converted to this use, holes were drilled to make the outer edges of the mortises, and the wood between the holes was split out (ill. 14). These mortises were squarely bottomed, except for the pointed drill holes at either edge. The mortises of the outer planking ap-



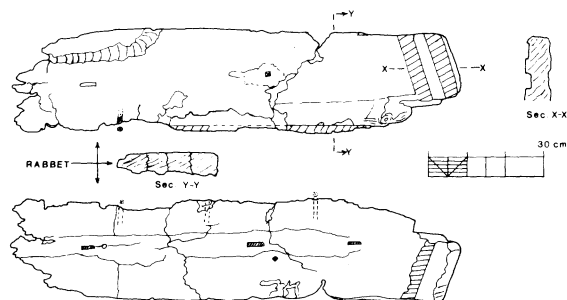
Ill. 14. Kyrenia ship, two types of mortise fabrication. On limber board 2 (left), the mortise was split away between drill holes. On strake 7 (right), the mortise was bottomed with a chisel. Not to scale. (Drawing author)

peared to have been cut with mortising chisels alone. There were no indications of a drill having been used, and the bottoms were shaped irregularly.

Mortises were cut into the keel at angles approximating those which the garboard made with the keel. They were located centrally in the lower garboard edge where possible. Near the stern, this was a relatively simple procedure because the inclination of the angle was almost vertical. Amidships, it was steeper, and the garboard hollow was curved so sharply that deep mortises could not fit safely within the thickness of the plank and still maintain the same angles as the keel mortises. Rather than shorten the depth of the mortise, the builder changed the angle of the mortise in the garboard, which was possible only because the live oak tenons were resilient enough to be bent to the change of angle at the seam (pl. 21, fig. 2). The force required to drive the garboard onto so many of these resisting tenons must have been extreme. This was one of many reasons why the keel had to be braced securely to the ways before planking began.

The fact that the keel and garboard mortises were among the deepest in the ship, despite the problems they created, reveals something about the purpose of mortise-and-tenon joints. So often they are referred to as mere seam connectors. Were they only that, they could have been made much shorter, spaced farther apart, and cut more loosely. As they were used in this hull, these tenons also served as stiffeners—little internal frames—which greatly improved structural integrity. This is probably why the shipwright went to so much extra effort in cutting keel and garboard joints.

At the forward end of the garboards, where the plank width tapered to only a few centimeters, mortises were cut completely through the plank, often



Ill. 13. Kyrenia ship, UM36, believed to be a spare steering oar (quarter rudder) blade. (Drawing author)

where planking was less than 5 cm. wide; frequently the joint was continued into the strake above.

Tenons were then inserted into the rabbet mortises. They may have been cut from long strips of oak, as their surfaces seemed to have been worked smooth. They were made only slightly shorter than the sum of the mortise depths in keel and garboard, which meant that their ends had to be configured somewhat like the bottoms of the mortises they were to occupy. From side to side and edge to edge, they fit precisely. They would have been lubricated at this time, probably with animal fat, to facilitate the joining process. Then the strake was aligned with the protruding tenons and driven home with what must have been a great effort.

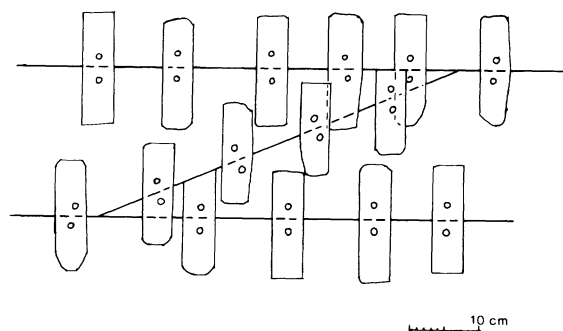
When the seam was considered to be sufficiently watertight, 6 mm. holes were drilled between the scribe marks about 2 cm. from keel and plank edges. Tapered oak pegs were driven into these holes, until they would go no further, and trimmed off even with the surface. As soon as both after garboard planks were so fitted, 2 cm. holes were drilled athwartships through the knee and both garboards at appropriate angles and spacings. Two, or perhaps three, such holes probably were drilled near the after ends of the garboards and through the sternpost. Then treenails were fashioned by splitting strips of pine and rounding them to a diameter of slightly less than 2 cm. Most of these treenails were concreted with copper and were difficult to study, but I think they had to be made from straight-grained wood so that the nails, which would be driven into their centers, would continue through their central axis. They must have fit the holes loosely when inserted, but once the nails penetrated them for a few centimeters, they began to grip the sides of the holes tightly. When the nails had been driven all the way so that their heads were seated firmly in the plank, their ends were double-clenched into the opposite strake (pl. 21, fig. 3). The first clench locked the nail and planks in place like a nut on a bolt; the second clench prevented the first one from turning or being pried upward accidentally. The treenail was important because it applied the pressure from the inserted nail evenly around the circumference of the hole, thereby reducing danger of splitting the plank. It also cushioned any shock of planking movement and filled all gaps around flats on the forged nail shaft, reducing the chances for leakage around the fastening. Note in ill. 3 that cross-nailing of the garboards alternated, one nail being driven from the port side, the next from starboard, etc. The clenched tips were angled away from the line of grain in which the hole

had been drilled, and the holes were drilled at different angles and elevations. Undoubtedly, all this was done to decrease the likelihood of splitting the planks and knee.

After nailing was completed in the stern, forward garboard planks were fashioned in the same manner as the after pieces. Mortise locations again were scribed along the rabbet and also along the seam of the scarf. Scarf mortises were cut to the same attitude as the ones in the rabbet (ill. 15). Within the limits of any single plank, all mortises had to be cut to the same attitude, although that attitude was not always vertical. If a change in attitude were necessary because of a directional change in a seam, an extra scarf had to be inserted. Only if tenons were loose within their mortises could attitudes vary along a single plank edge. On the Kyrenia ship, tenons fit snugly and were arranged as shown in ill. 15. Some scarf mortises were almost side by side with seam mortises, although their angle was slightly different from that of the seams. The forward scarf mortise was cut through the tip of the after garboard and, because tenon length was so important, several centimeters into the keel rabbet. This feature can be seen on the lower scarf tip of P6 (ill. 5), where two joints partially overlap. Although both joints were cut into the upper edge of P5, the scarf joint was pegged only on either side of the scarf seam, not in P5. The shipwright treated all joints which traversed three members in this way; there were always only two pegs to a joint, and they were always located on either side of the seam for which the joint was intended.

Completing the Bottom

When the forward garboard strakes were seated on their tenons and pegged in place, the upper edges of

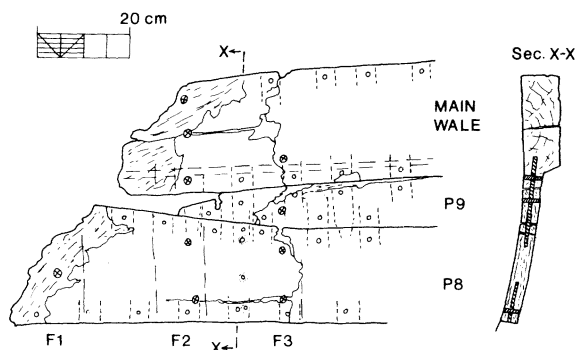


Ill. 15. Kyrenia ship, the attitude of scarf mortises. A few of the various tenon shapes found on this hull are shown here. (Drawing author)

these strakes were trimmed to their final sweep. Strakes 2 and 3 were installed similarly to the garboards. They were cross-nailed to the stem forward, but strake 2 was scarfed in the opposite direction so that its forward planks were set first. Scarf directions were reversed every few strakes to avoid patterns of weakness in the hull. Scarfs also were arranged so that they were not close to each other on adjacent or nearby strakes, just as planking butts are staggered in modern hulls to avoid patterns of structural weakness.

By this time port and starboard body shapes were already quite different. They were too different to have been bent around molds, and the unblemished keel top rules out the presence of pre-erected frames. Strake 4 made the greatest transition from a vertical orientation at the sternpost to about 30 degrees above horizontal at amidships. Although this may seem like a radical transition in which to bend a broad, 4 cm. thick plank without benefit of some sort of framework, this hull was planned to minimize transitional problems. The aftward raking stern rabbet undoubtedly was designed to simplify planking lay, since the angle at which these lower strakes entered it reduced the transition by nearly half. Most ancient models and paintings show hulls with their sternposts at such aftward rakes, and I assume this was a universal feature developed for the reasons just mentioned. There may have been scarfs aft of the surviving planking on some of these strakes, which also would have made the transition easier. But the most noteworthy feature about all this planking (much of the other timber, too) is the shipwright's apparent expertise in the selection and use of grown curvatures. A surprising majority of the half-frames have their grain accurately following the S-shaped sweep of the hull bottom. The forward part of the shelf clamp is a perfect arc, and its grain lines complement that arc all the way. The same situation is found for the curved planking in the bow. It has been stated often that so many of the excavated ancient wrecks have softwood planking because it was easier to cut mortises in them. That may have been one reason, but I suspect that Aleppo pine also was available in plenty of grown curvatures (as it still is) and that it was far more compatible with all phases of planking than were the available hardwoods. Planking in this free form method must have been made much easier by the selection of logs which followed the collective sweep of a strake.

There were two or more scarfs for every strake of planking, and their locations and directions were selected to simplify construction and still maintain structural integrity. Scarf tips had to be nailed down



Ill. 16. Kyrenia ship, arrangement of port strakes 8, 9 and the main wale at the after end of the hull. (Drawing author)

in some locations, which implies that seams may not always have worked out perfectly for the builders. There must have been other areas to hold down or force inward or outward, and probably this was done with temporary bracing methods. The little tenon pegs which were found outside of joints, and were apparently fastening nothing, may have been associated with such bracing. I believe they were used to close nail holes which were left when construction shoring and bracing were removed.

Collectively, planking widths increased with hull area, but this practice changed where the sheer sweep had to be expanded or decreased. It is not the sort of planking diagram one would achieve by bending battens around frame faces; one modern builder called it silly—too broad in the wrong places and too narrow where there should have been stealers, he claimed. In the skeletal forms of construction, that would have been an accurate assessment, but stealers would have been a problem for our builders, and broad planks at the bilge are acceptable if there is no need to warp them around any restrictions. What is seen on the planking plan is a method of controlling the hull shape by the design of the planks themselves, and what is to us a silly arrangement of strakes was probably the norm for its period.

There is a curious arrangement among strakes 8, 9 and the main wale aft of port frame 4 (ills. 2, 16). Its meaning has puzzled us for years and has prompted all sorts of experimentation with models. I can pass along only the solutions suggested by these experiments. By the time port strake 8 was ready to go in, there was quite a difference between the port and starboard sheers. There is plenty of excavated evidence to establish that fact. From all appearances, the port sheer was too deep amidships and too steep astern; the starboard sheer may have been close to

what the shipwright intended. It was important to make the sweep of both sides compatible before installing the main wales, and so he began correcting the port sheer by radically broadening strake 8 near the stern and cutting a scarf angle into its upper edge. Port strake 9 was quite broad amidships, but was made to terminate in the after P8 scarf. Perhaps the shipwright thought this arrangement corrected the sheer. It did not. Additional corrections were necessary when the wale was added and are explained below. The importance of this feature is that it reveals the methods by which ancient builders used planking to form the hull. Both strakes could not have been carried all the way to the sternpost; they would have been impractically narrow. On the starboard side, where planking widths were controlled with more wisdom (or perhaps better wood), this extra work was not necessary within the surviving parts of the hull and probably was not done at all.

When both sides were carried up to the level of the first wale, the planking was smoothed inside and out with small trimming adzes having both curved and straight-edged blades. The inside of the hull was surfaced meticulously, probably to fit the frames better, while the outer surfaces were left more uneven.

It was now time to install the floor timbers. Perhaps a few of them were put in before the bottom was completed in order to stiffen the shell. Now they were certainly needed, so that the sides would be rigid enough to put those heavy wales in place. Actually, the shell alone had a rigidity that one cannot appreciate until he has become familiar with the strength of this edge joinery. But frames would certainly increase hull strength for wale erection, and it would be easier and faster to complete the floor timbers before the higher sides were added. There seems to be no logical reason for postponing this work until the shell was completed.

At first I suspected (and tried to prove) that all the floor chocks were installed as soon as the second or third strakes were in place. It would seem more logical to stiffen this cavity from the start, and it would have been easier to fit the floor chocks to the planking while standing outside the hull next to them. Perhaps a few of them were attached at an early stage, but in at least half the floors, all planking nails went through the chock and either stopped within the floor timber or were clenched over it. A few broke out of the sides of the floor timber because they were drilled crooked; three nails left their treenails and curved along the grain of the floor while two more followed the seam between the chock and the floor. In all these cases, it

was obvious that the floor timber was in place before any of these nails were driven into the chocks.

Had the chocks been installed when only two or three strakes were completed, one also would expect them to be shaped more alike. Their upper surfaces should have been horizontal, their elevations more constant, and their spacing above the keel more consistent. But these chocks looked like afterthoughts, and so they were. It appears that the shipwright shaped the floor curvature on timbers which were readily available; whatever opening was left below was shaped from a piece of scrapwood. The two pieces then were joined by shallow mortise-and-tenon joints. The fact that these tenons were so short, and left unpegged, suggests that the joints were intended only to keep chock and frame properly aligned during fitting and nailing.

Floor arms increased in length as the hull broadened. Most of them were made from straight or slightly curved timber, except at the ends of the hull where sharp curvatures were necessary. Their sides were sawn, and their faces were smoothed with adzes. Some of them were made broader along their upper surfaces than at their planking surfaces, and many had their upper edges chamfered to prevent splitting. Watercourses were cut into most of the planking faces of these floors, sometimes one and sometimes two on each side. A few were found to be free of any such cuts, without apparent reason. The carpenters did not measure the location of these openings. When the floor timber was shaped to the contour of the planking, they held the floors in place and scribed little marks on either side of the 2/3 and 5/6 seams, then cut the recesses at these marks.

Floor timbers were drilled and nailed as described for the garboards and stern knee. Clenched ends were arranged in a herringbone pattern to avoid interference and to distribute stresses. Nails were always clenched downward or inward. Nail holes were drilled from inside, with the workman standing over the frame and drilling downward or outward, as can be inferred from a number of places where holes were abandoned and plugged in the frames; the drill had hit a knot dead center in the planking below or had wandered too close to a seam. Where frames did not contact the planks well, shims were fitted into the gap. They were seldom necessary in the case of floor timbers, but half-frames were frequently shimmed.

Erecting the Sides

The main wales were gracefully curving timbers which were twice as thick as the planking. Z-scarfs

provided more surface for joinery and, therefore, greater strength for the timber. Tenons were pegged from inside the wales, too, but because of the greater thickness of these planks, the pegs did not penetrate their outside surfaces. Scarfs had two rows of staggered mortise-and-tenon joints because the 8 cm. thickness permitted such extra fastening (ill. 7). Outer rows of joints were pegged from the outside of the wale, while inner joints were pegged from the inside surface. As in the seam joints, these pegs did not penetrate the opposite surface of the wales. The starboard wale was not as well preserved as its port counterpart, but enough of it survived to determine that its centerline had virtually the same sweep and angle as the port wale. On both sides of the hull the upper edge of strake 9 was left about a centimeter thicker than the rest of the strake, probably to provide extra bearing surface for the wale.

Now to return to that curious arrangement among port strakes 8, 9 and the wale just aft of port frame 4. Perhaps our shipwright thought he had corrected the faulty sheer in that area, or perhaps he simply had not left enough wood there. Either way, he obviously knew that a big strake like the main wale would not fit the sweep of strake 9 if it had humps and hollows in it; it had to be a fair sweep. When battens were placed across the top of strakes 8 and 9 in this area (as the builder had left them), there was a long, V-shaped hollow which reached a maximum depth of 5 cm. near frame 2 and extended all the way from the scarf at frame 17 to a projected termination near the sternpost. This hollow had to be filled with additional bottom planking.

Wales on ancient ships were more important to the strength of hull structures than they might have been on later vessels because there was such a shortage of strong longitudinal timbers to support them. Wales were like big wooden girdles which clamped the hull and distributed unequal forces caused by poorly placed cargo and the strain of rolling seas. Their ends had to be attached securely to each other, and at least one stronger wale was required to be as close to the waterline as possible. They had to follow the sheer of the shell they were clamping, and they could not be forced or angled away from any fair, mechanically adequate sweep. This is why the port wale should not have been pulled into this hollow in strakes 8 and 9, even if it could have been. Nor would the insertion of a small, filler piece here have been mechanically feasible, because its weakness would have been counter to the strong attachment to the shell which the wale re-

quired. And so the shipwright produced what was, in my opinion, a marvelous example of ship carpentry. He cut the wale much wider aft and, maintaining the required constant wale thickness and breadth, carved the missing planking area into the extra width at the bottom of the wale. The cross-sectional shape of this part of the wale is shown in ill. 16.

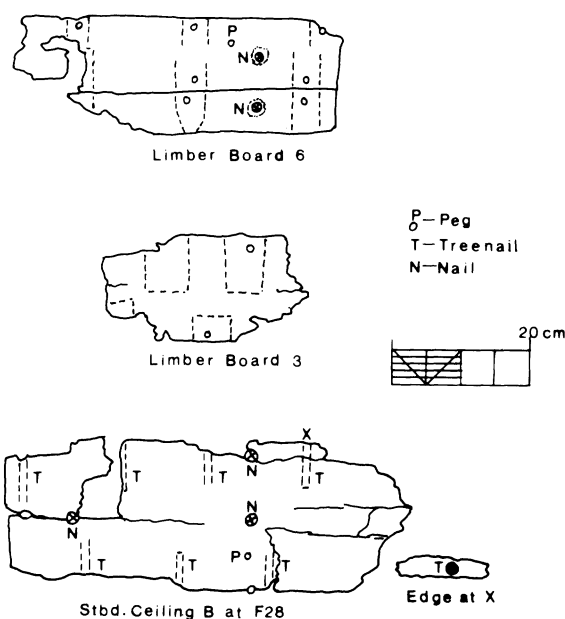
Details become more difficult to interpret above the main wales. Nothing was preserved above this point on the starboard side, and planking above the port main wale survived in poor condition. Strake 11 was not an original strake. It represents a repair which is discussed below. The upper wale, strake 12, was 1.5 times as thick as the bottom planking and performed a similar and complementary function to the main wale. No scarf could be found in the surviving length of this wale, but there may have been one beyond the limits of preservation. Tenon pegs did not penetrate the outer surfaces of this plank. A small wooden insert, about 2 cm. thick, was rabbeted into the lower inner edge of the upper wale between frames 21 and 23. It appears to have been used to patch a void made when part of the strake edge split away. It was held in place only by the three pegs in the adjacent mortise-and-tenon joints. There is no clear explanation for the charred areas on the inner surfaces of the upper port and starboard main wales. Charring might have been used as a wood bending process, or it could represent an attempt at exterminating worms or termites.

The significance of the rabbet in the center of strake P12, of the vertical nails, and of the arrangement of fragments of strake 13 is not yet fully understood. Research continues on these features.

Half-frames and futtocks were made and installed the same way as the floor timbers, although they were somewhat lighter. Many of the futtocks, especially those above the half-frames, probably continued to the top of the hull. Secondhand timbers, perhaps removed from a hull being scrapped, were used for these light upper frames. About one-third of the holes in them were abandoned and plugged with treenails. Being reworked timbers, many of them have strange, non-functional cuttings—remnants of their previous use. A few had recesses in their upper surfaces which once held a stringer, similar to, but smaller than, the shelf clamp of the Kyrenia ship. Some of the intermediate timbers, such as F10, F12, F15 and F30, are believed to have been supports for splashboards or other topside protection. Most of them were fastened only lightly to the existing planking; F10 and F45 were not fastened at all.

Internal Construction

The shelf clamp, the uppermost ceiling strake, was nailed lightly into the inner faces of the frames. Although clamps do not appear to have been fully developed by this time, this one did support the beams and provide some longitudinal strength to the hull. Most of the ceiling planks were simple floorboards, some of them made from scrapwood, which rested atop the clenched nails (see section drawings) along the length of the hold. The hold extended from frame 6 to frame 42; both of them were half-frames which had mortises and broken tenons in their upper surfaces (ill. 10), presumably for some sort of bulkhead support. The starboard ceiling did not survive extensively; what there was of it seemed to be salvaged from another, smaller hull. Some of the starboard ceiling was made by cutting through the centers of what appeared to be two adjacent outer hull planks, so that the old seam remained in the center of the new plank. Other secondhand planks, probably from the same two vessels as those of the ceiling, were used for limber boards. Yet another, still smaller hull was represented in the starboard ceiling; it had planks with treenail-joined edges. All these planking types had nail and frame impressions (ill. 17).



Ill. 17. Kyrenia ship, three examples of reworked ceiling planking. (Drawing author)

⁹ A report on a detailed study of masting and rigging will be available soon.

Where a keelson would be located centuries later, limber ledges supported limber boards. These boards were rectangular planking scraps, laid athwartships to prevent cargo from falling into the keel cavity, and were easily removed to clean bilges and watercourses.

The main beam, located just aft of amidships, hardly deserves that title. It was not large, could not have supported a deck, and was unfastened, yet it was carefully fitted into the shelf clamp and notched around frame 23. It may have offered inward resistance to the wales, but certainly would not have been much help in the other direction. I suspect planks, used for a walkway around the sides of the hull, rested atop this and other beams. The other two beams are partner beams used in conjunction with the mast step complex.⁹

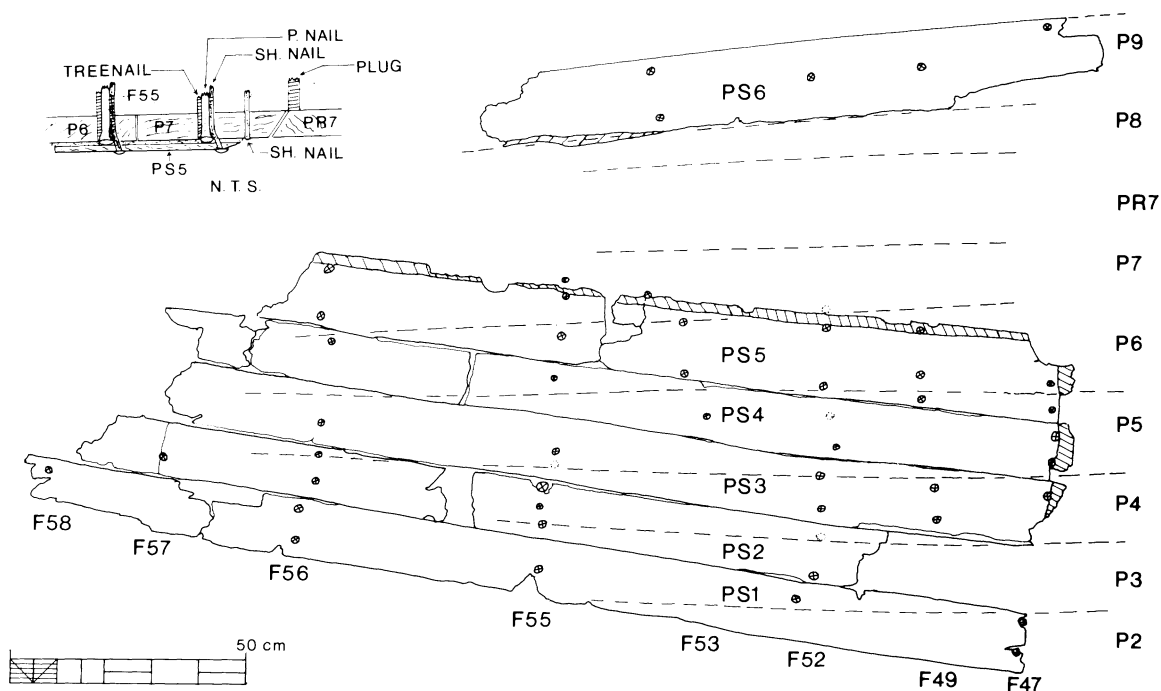
Repairs and Overhaul

One of the great contributions of the Kyrenia hull is the evidence for a series of repairs and alterations. The Kyrenia ship first went to sea without her sheathings of lead and wood and many of the other features outlined in the catalogue section of this article. But this was an old ship and, like all old ships, had undergone maintenance and repairs performed by numerous workmen—some of them, perhaps, belonging to different generations. Here, in what I have reconstructed as the chronological order, are the interpretations of the evidence for these events.

Frame 47 had rabbets cut into its upper surface, similar to those in the frames which supported the mast step. At one time, perhaps, the mast step was this far forward, also spanning frames 44 and 40 in a reversal of its present direction. Extra cuttings in the various timbers would permit the step to be seated in at least three locations, and possibly a fourth. But that is another story.¹⁰ Eventually, a new notch was cut into the bottom of the mast step to permit it to be reversed and placed aft across frames 37, 35, and 33. There may have been other locations for the step, but this is where it was found. Unused limber ledges were cut off and placed around the relocated stanchion steps to close gaps in the ceiling, and the partner beams were readjusted to fit the new mast location. We can only guess whether the mast step was moved to make room for a bilge sump, or whether this move merely permitted the creation of such a convenience. In either case, the aging hull must have begun taking in seawater, and a more accessible means of removing it became necessary.

What happened next is an indication of the lesser

¹⁰ See *supra* n. 9.



Ill. 18. Kyrenia ship, wood sheathing over ghosted port bow planking. Detail shows the method of driving sheathing nails alongside planking nails. (Drawing author)

degree of importance with which ancient ship carpenters regarded frames. Frame 40 was sawed off—not bridged or offset by substitute timbers, but simply eliminated—between the second and third strake seams on either side of the hull (pl. 21, fig. 4). Frame 40 was just aft of the unbolted keel/stem scarf. The entire chock and central floor area then was removed to make room for the sump. The saw marks still remain on the upper edge of port strake 2, where that cut was made (rather clumsily, I feel), and the discoloration and impressions of the once present chock can still be seen. Four frame nails had penetrated the strakes here, and these were removed; tapered wooden plugs wedged with tiny pegs or nail shafts were used to close the holes. The sump (an unwallled opening, really) thus produced was several meters forward of the lowest part of the keel, but with cargo covering the limber boards in the hold, it was as far aft as it could be placed for regular access. A broad piece of scrap-wood was laid across the two frames forward of the sump to serve as a platform for the bilge pump operator who, I assume, used a leather bucket.

There must have been the occasional scraping, a new coat of pitch, or perhaps a replacement for part of the false keel. But eventually the years of service caught up with the old hull; bilges shipped more seepage water, and lead patches were needed here and

there on the starboard side and on port strakes 8 and 9 aft of frame 46. Shipworms must have taken their toll, too, and finally frame 52 was found to be rotten or cracked. It was time for repair. Floor timber 52, which probably was originally made like all the other floor timbers, was removed. It was replaced with one fashioned from a single piece of timber. New treenails and nails were inserted into the original holes in the planking and clenched over the new frame. Frame 52 looked new when excavated—still light in color with chamfered upper edges hardly worn. It also displayed a different form of workmanship; chamfering was more pronounced and the frame was flatter and wider than its neighbors.

After floor 52 was completed, the exterior of the bow was sheathed with strakes of pine which had an average thickness of 1.1 cm. (ill. 18). They were laid parallel to the stem, and while their edges were aligned closely, no attempt was made to assume tight seams. Sheathing strakes terminated aft of frame 47 and extended forward beyond the limits of preservation. Nails averaging 10 cm. in length and having a shaft diameter of 0.7 cm. were used to attach the sheathing through the strakes and into the frames. Usually these nails were driven alongside planking nails, utilizing the existing treenails for passage. Since planking nail heads often extended a centimeter or

more from the surface of the planking, this method of fastening helped to prevent splitting; fastenings between the planking nails would have bent the sheathing over those nail heads, creating tension and an uneven surface.

The wood sheathing probably served a dual purpose. To some extent it helped to stabilize the bow, and it also held some form of caulking material which has now almost totally disappeared. Its upper limits were difficult to determine, but it probably covered the entire bow up to the main wale. The uppermost piece remaining on the hull at the time of excavation was found on port strake 9; a small and a large nail were concreted together in futtock 51 just 2.7 cm. below the main wale. The fact that the ship was not wood sheathed throughout indicates that the rest of the hull was still fairly sound at this time.

Before long the vessel was hauled out again for inspection and repair. What was found was not good news. The old ship had cracked her keel near frame 31; that was probably what necessitated all those internal lead patches along the lower starboard seams. The bow also was in bad shape again because, although the sheathing provided some stiffening and the caulking prevented leakage, rotten plank seams apparently caused mortise-and-tenon joints to lose their grip. When edge joints failed on shell-first hulls, the situation was as serious as when frames were rotten on latter day wooden hulls. This time a major overhaul was necessary.

With the hull blocked up and the bottom accessible, the outer hull surface was scraped and the false keel removed. Saw cuts were made into the bottom of the keel, well on either side of the break. The wood between these cuts was removed, and the new surface smoothed with a small adze. Recesses were cut at the ends of this opening to help lock the piece which would be installed. A pine block was fashioned to fit the new opening, and three holes were drilled through it and into the keel. Resinous pitch, probably pine pitch, was spread around the cut-out portion of the keel, and the block was nailed into place with long copper nails. Treenails were not used here because the nails provided no leakage path into the hull.

That was all; obviously the keel was considered to be strengthened sufficiently. It is impossible to determine how badly the keel had cracked to prompt the repair, but a washed out, serious-looking crack was discovered in the keel top as soon as archaeologists uncovered it. It was then large enough to show up on bottom photographs. By modern standards, such a repair would be inadequate, but considering the lesser

contribution this keel made to the spinal strength of the hull, it was probably acceptable.

The bow required more effort. A rotten seam between port strakes 7 and 8 was removed by making longitudinal cuts down the middle of these two strakes, commencing at frame 46 and extending forward for an undetermined distance. The bad wood between the two cuts was removed and discarded, old nails were pulled out of the frames, and the ends of tenons which had been severed by the cuts were pulled out of their abbreviated mortises. Some of the wooden sheathing above PS5 must have been removed to perform this task; forward of frame 56, PS5 also had to be removed or cut through.

The new strake edges were now dressed, so that their edges were angled to a wider dimension between the outer plank surfaces than that between the inner surfaces (ill. 9). Probably with specially-shaped chisels, the old, now shallow mortises were cut to a depth of 7 or 8 cm. in each new strake edge. A new plank was shaped to fit the present opening, mortise locations were marked on it to coincide with the ones just cut, and nail holes which could be reused in the frames were drilled, possibly by holding the plank against the frames and running the bit through existing frame holes and into the new plank. The bottom edge of the replacement strake was cut for standard mortises. Upper-edge mortises first were cut normally, then a rectangular cut was made into the surface of the plank to expose the bottoms of the mortises. These surface cuttings were made on the inside of the replacement strake except where they coincided with frames, in which case the cut was made from the outside. Standard tenons were inserted into the mortises in the upper edge of strake 7, and the new strake was fitted to them and pushed home. Because the new seam flared outward, this task was accomplished easily. Tenons, which were shaped exactly like the upper mortises (we have named them "patch tenons" because of their distinctive outward appearance), were now pushed upward into the mortises of strake 8 through their openings in the surfaces of the new plank. Then all tenons were pegged in the normal manner, the ones at frames being driven from outside the hull. Nails were driven and clenched as before to complete the repair. Similar procedures were followed for starboard strakes 3, 4 and 5.

Port strake 11 probably was replaced at this time. Here the technique was different—new seams were not cut out, but an entire strake of planks was renewed. The new after plank simply was shaped to fit the opening between wales, but the forward one was so

wide that it had to be made of two pieces of wood. This section apparently was assembled before installation. Peg angles were straight and in nearly perfect alignment, and the edge angles of the seam between the two planks were exactly square. Mortises and tenons were rectangular and consistent in depth and dimension. Nowhere else in the hull was this condition noted.

Existing mortise locations in both wales were marked on the outer surfaces of the new planks. Mortises were cut normally into the bottom edges. About 8 cm. from the upper edges of P11, where the strake was thicker, a rabbet was cut into the outer plank surfaces (ill. 8). Mortises were cut angularly into this rabbet, so that they coincided with the upper wale mortises at the seam. Then the after plank was lowered onto the tenons protruding from the main wale; it was held to the upper wale by new tenons which were pushed into the rabbet mortises until properly seated. The upper tenons really were sprung into place, as there was an angle between the mortises of P11 and those of the upper wale.

At the scarf, only the lowest tenons were in place when the forward piece was installed. The highest scarf tenon was inserted through the rabbet, and the two center ones were cut in the form of inside patch tenons.

There is a mystery about this strake, however. Tenon pegs had to be driven from outside the hull where they coincided with frames. This could not be done in the wales because of their excessive thickness, and yet there were pegs beneath frames along both wales. Only a few joints occurred beneath frames in the upper wale, and here the old pegs may have been abandoned and the new tenons left unpegged. But the pegs in the upper edge of the main wale, many of which were driven beneath frame locations, still grip their tenons. Perhaps the old strake 11 was cut away from these joints and the existing tenons were used again, or perhaps we have missed a detail because preservation is so poor here. Consequently, the interpretation of this repair remains partially in doubt. But the importance of P11 lies in the fact that a rabbet was substituted for patch tenons where great numbers of joints and seam lengths were encountered. The rabbet probably was filled with pitch, although only traces of this material survived.

Other repairs might have been made beyond the limits of hull survival; then the hull was prepared for a covering of metal.

All edges and ends of the wooden sheathing were

feathered, so that they presented a smooth transition from sheathing to planking for the lead sheets which would follow. Wood sheathing covered only original bow planks; the replacement strakes just installed were left exposed.

Next, a thin matting of agave leaves and pitch was put on the hull. Sheets of lead were applied over this layer, some of them reaching lengths of nearly 2 m. within the preserved areas. All were 1 m. or more wide and were fastened to the hull with large-headed copper tacks which were driven in diagonal patterns (ill. 19). At the seams, tacks were spaced more closely, their heads sometimes touching, and sometimes in double rows. Sheets overlapped those immediately aft or below them. The tacks were stopped at the bottom of the keel, where a separate sheet crossed the keel bottom and overlapped the side sheathing.

Most of the lead sheathing was preserved too poorly for us to obtain this information directly. Most of the tack shafts remained in the hull, however, and chalk was applied to the exposed ends of these shafts so that the sheathing pattern could be discerned.¹¹

Careful inspection of the hull has shown that only one application of lead sheathing was put on the planking. A previous layer of lead would have left numerous extra holes and tack shafts imbedded in the wood everywhere, but no such remnants were found. Since no tack shafts or lead fragments were found beneath the wood sheathing, no lead sheathing could have existed on the outside of the hull before this wood sheathing was applied. Nor could the wooden sheathing have been applied when the hull was built; frame 52 could not have been replaced as it was, nor could the fresh, teredo-free appearance of these thin planks be explained.

The replacement strakes PR7, SR4 and SR5 could not have been present at the time of construction, as proved by abandoned nails, mortises and the changes in port strakes 7 and 8. Patch tenons and yellow-colored, teredo-free wood are additional indications of late installation. Yet the replacement strakes may have been installed at a later date than the wood sheathing. At first I thought that all these bow repairs were part of a single overhaul. The argument was that the wood sheathing served as a solid surface for the lead sheathing tacks, which might not have gripped the rotten surfaces of the hull planking sufficiently in this area. But an abandoned nail shaft of the type used to fasten the wood sheathing was found beneath SR5 on starboard frame 46; no wood sheath-

of the tack shafts on the port side.

¹¹ Robin C.M. Piercy, assistant project director, developed the idea of chalking tack shafts. It was he who located and marked most

ing could have been located here when the ship sank. Several more such sheathing nails were suspected on frame 47 above PS5 and beneath P9 on frame 51, although they were so badly concreted that we cannot be certain of their use. Sheathing edges appeared to be feathered while on the hull, especially around nail heads. Some of the nails did not seem to grip the upper edge of PS5 at all, suggesting that this plank was once wider or that another was adjacent to it (ill. 18). Lastly, there was a difference in color between replacement strakes and wood sheathing; the covering of lead kept the replacement strakes looking new, but the wood sheathing had darkened before lead covered it. In my opinion, wood sheathing was applied at an earlier time, some of it was later removed to repair rotten planking seams, and what was left simply was feathered to receive lead sheathing.

Common sense dictates that the lead sheathing must have been installed at the same time as the replacement strakes because of the gaps in the wood sheathing, their feathered edges, and the apparent poor condition of the rest of the planking. I assume the keel was repaired during this last overhaul, since the same red-brown pitch found beneath the lead sheathing was found between the keel and its repair block.

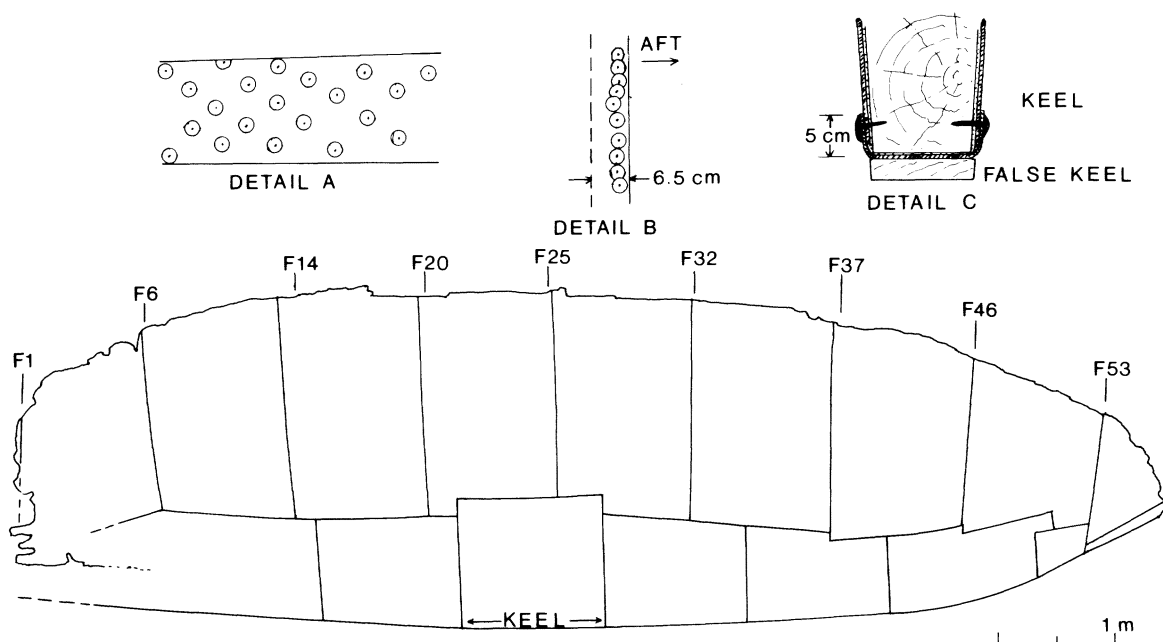
Thus, we have rather firm evidence that the Kyre-

nia ship was altered several times and hauled out at least twice for major repairs. Research continues in the hope that we can establish a precise chronological schedule between launching and sinking.

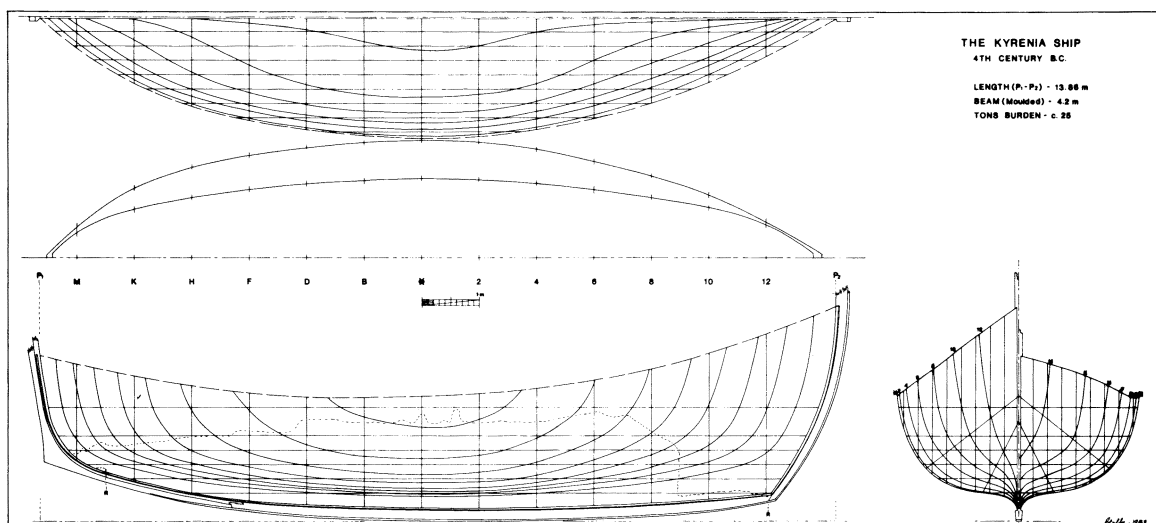
HULL ANALYSIS

Hull lines are shown in ill. 20. Port side lines are illustrated here because that side was preserved more extensively; starboard side lines are somewhat different. Ancient ships do not lend themselves well to modern forms of ship drafting because their humps and hollows, which are so important in interpreting their construction, must be averaged to achieve these multi-dimensional projections. Since our more accurate and revealing research models cannot be published in three-dimensional form, however, these averaged lines are the only means of presenting the hull design.

The wandering, dashed line (line R) in the sheer plan represents the extent of continuous preservation. Above and beyond this line, there is some scattered evidence to determine additional hull shapes. The sheer line was based on the pattern of isolated nails and scattered remote fragments which were recorded during excavation. But this evidence was slim, and research in the topside areas has produced too few safe results for inclusion here.



Ill. 19. Kyrenia ship, schematic diagram of the lead sheets on the port side of the hull. Details illustrate (A) a typical tack pattern, (B) a typical method of overlapping vertical seams, and (C) the method of sheathing the bottom of the keel. Details are not to scale. (Drawing author)



Ill. 20. Kyrenia ship, the hull lines. (Drawing author)

When new, I suspect this hull might have been loaded deep enough to be considered a 25-tonner. Her length has been projected to about 14 m. and her maximum breadth must have been about one-third of her length.

Although the Kyrenia ship may have been considered a small ship, I believe that her design was indicative of most seagoing merchantmen of the period. Like all good hull designs, lines, scantlings and fabrication techniques are complementary to each other. Perhaps most load-bearing hulls of the period had to have that graceful wineglass midsection because it was compatible with construction techniques. I doubt that it had anything to do with lateral resistance or any of the other modern reasons for V-keels. If the sheer seems extreme, it is no more so than that of some wooden hulls still plying the Aegean and Mediterranean. In fact, the entire hull configuration has remained popular there into this century.

The deep V terminating in the keel is intriguing. By itself, the keel had meager backbone strength, although the arc contributed some additional support. Without a keelson, it seems at first to be a structural flaw. But when one added to that long arc a deep, V-shaped trough of planks, reinforced it with locked edge-joints every 12 cm. or so, and braced it laterally with heavy chocks every half-meter, an arched girder evolved which did have sufficient backbone strength. The spine of the ship was there and it was sufficiently strong; it merely does not conform to our own modern practice. A few centuries later, floors were bolted to

keels, which greatly increased the integrity of such a structure.¹² As soon as keelsons were introduced, the V-shaped section could be reduced and eventually eliminated.¹³

CONCLUSIONS

Some difficult decisions had to be made to determine what should be left out of this report in order to keep it within journal size. The catalogue and its interpretation were condensed. I have mentioned nothing about the interesting pieces of wood and metal which were found apart from the main hull, rigging and steering studies, research models, sailing tests, a full-size sectional replica, another complete full-size replica under construction in Greece, nor the reconstructed hull remains in Kyrenia (pl. 21, fig. 5). But the major contributions of the vessel have been documented here.

The most important aspect of the Kyrenia wreck is that it was preserved well enough to reveal construction methods, both for the original hull and later repairs. Essentially, the sequence of construction—keel and posts, bottom planking, floor timbers, side planking, half-frames and futtocks, internal timbers, and topsides—had plenty of excavated evidence to support its formulation. But the means by which that sequence was carried out deserves a few additional comments. Because so many internally driven tenon pegs were located beneath frames, some scholars would surmise they prove that planks were there before frames. I agree that such is the case on this hull, al-

¹² The Madrague de Giens wreck had bolted floors in the 1st c. B.C.: P. Pomey, "La coque," in A. Tchernia et al., *L'épave romaine de la Madrague de Giens (Var)* (Gallia Suppl. 34, 1978).

¹³ The Titan and other wrecks had keelsons and relatively flat floors: J. Taylor, *Marine Archaeology* (London 1965) 88–91.

though this study has also proved that peg directions beneath frames are not always an indicator of shell-first construction. First, one must investigate all surfaces of frames and planks carefully in order to ascertain that none of the timbers in the area has been repaired or replaced.

There are better ways to recognize shell-first construction, some of which have been mentioned previously. Frames did not even touch the keel, port and starboard body shapes varied, and it was not physically possible to bend some of those planking shapes around molds or frames while aligning 50 or more standing tenons. In frame-first construction, flats are often cut on curved frame faces better to seat broad planking such as strakes 7, 8 and 9 at the turn of the bilge. These frames had nicely rounded faces. Nor were the athwartships curvatures of these planks drawn to those shapes. Concave planking surfaces often bore saw marks near their edges, where the original plank thickness was cut, while their centers were shaped with an adze. The reverse was true for the opposite surfaces; saw marks were central, and adze marks were near the seams. It was obvious that these planks were partially shaped to their lateral curvatures, and that the frames were shaped to match those planking contours.

If the reader considers the above details to represent pure shell-first construction, then the Kyrenia ship was so built. But wood is wood; it moves with the slightest change in tensions, and even with changes in humidity. There is no way such a complex structure could be built without some form of control. Part of

this control undoubtedly came in the form of selected grown curvatures and the ingenious use of planking shapes and edge angles. Beyond that, however, there had to be braces, shores and all the other restraints needed to make even the best selected timber behave. In short, this hull was shaped by planks rather than frames or molds, but the constraining advantages which frames and molds normally supply also had to be supplied to the Kyrenia shell during construction, probably in the form of various bracings until the frames were in place.

All this brings to mind the fact that the two resources which the ancient shipwright seems to have had in abundance were the same two which are so restrictive in modern shipbuilding—time and materials. Mortise cutters must have been faster at making joints than we realize, but this entire hull is an example of labor intensity. Whether or not timber was plentiful to our builder, this vessel certainly does not seem to be designed to conserve it. Much more wood had to be cut away as scrap than was the case for later, skeletal-built hulls. Yet there also was a desire to conserve time and materials, as exemplified by the reworked top timbers and ceiling planks. Perhaps this is a reflection of the overall philosophy of the society, rather than an indicator of inefficient construction techniques. Our own fabrication methods may seem just as curious twenty-three centuries hence.

INSTITUTE OF NAUTICAL ARCHAEOLOGY
AT TEXAS A&M UNIVERSITY
DRAWER AU
COLLEGE STATION, TEXAS 77840



FIG. 1. Kyrenia ship, hull in situ. (Photo John Veltri)



FIG. 2. Kyrenia ship, a lateral break in the keel, showing square side pegs and a fragment of garboard attached to the keel by a mortise-and-tenon joint. (Photo Robin C. M. Piercy)

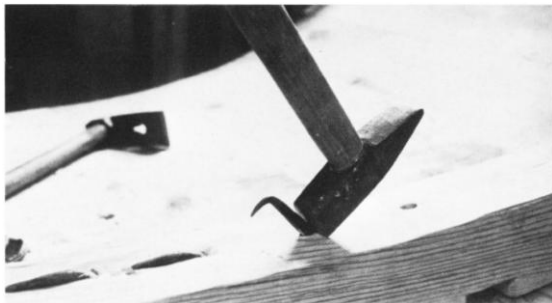


FIG. 3. Kyrenia ship, a planking nail being clenched over a frame top on the sectional replica. (Photo Susan Womer Katzev)



FIG. 4. Kyrenia ship, the mast and stanchion steps before raising; the bilge sump is directly forward of the mast step. (Photo Robin C. M. Piercy)

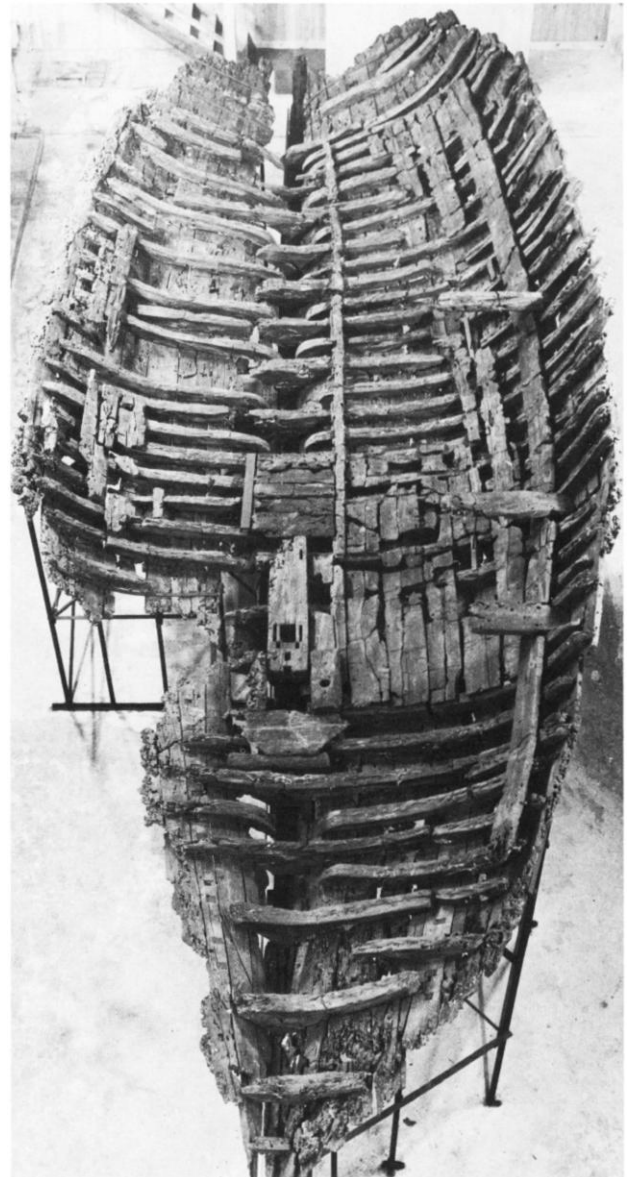


FIG. 5. The reconstructed hull in the castle at Kyrenia, Cyprus. (Photo Michael L. Katzev)