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The 4th century wreck at Yassi Ada An interim report on the hull

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Excavation of a 4th century wreck at Yassi Ada (Turkey) was undertaken by the University Museum of the University of Pennsylvania in the summers of 1967 and 1969. The excavation report (Bass & van Doorninck, 1971) includes a preliminary description of the hull remains uncovered and recorded by the end of the 1969 season. The excavation was resumed during the summer of 1974 by the American Institute of Nautical Archaeology but was abruptly terminated by the tragic events on Cyprus after less than three weeks of diving. The 1974 season, although brief, permitted the staff to complete excavation of all the hull remaining below the level of the waterline. A detailed recording of all these remains would also have been completed had the work been permitted to continue just a few more days. New data acquired has sufficiently augmented and clarified what was previously known about the hull's configuration and construction so that a full, revised description of the hull remains seems desirable.

Plan of reassembled hull remains

A tentative, graphic reassembly of the surviving hull remains up to the lowermost, waterline wale has been made as a first step in reconstructing the hull. Figure 1 gives a plan of the reassembly. The hull has been reassembled in conformity with its original shape. Thus, for example, the sternpost is shown curving upward at its after end and the planking is shown rising out from the keel, at first in a convex curve (as seen from above) and then, as it reaches the bilge, in a concave curve. Frame remnants in Fig. 1 appear in outline only so that the under-

lying areas of planking are visible. An exception is the remnant of frame B-20. This is the only frame remnant in the reassembly that still remains *in situ* on the wreck.

The A and B series of frame labels in Fig. 1 (the A series running forward and the B series aft from a point about 1.8 m forward of midships) is purely arbitrary. A P series of labels running out from the keel has been assigned to the port planking; an S series, to the starboard planking.

The remnants of keel, sternpost, wale, and outlined frames in Fig. 1 have been raised, measured and drawn. One exception is the forward remnant of the keel timber located at A-5 which has not yet been drawn. A series of photographs were taken of the sternpost, wale and frame remnants lying on a grid (Bass & van Doorninck, 1971: fig. 2). Small, white plastic arrows placed directly on the grid were used both to control parallax distortions and to mark the locations of structural features. These grid photographs, when supplemented by recorded measurements, provided the data necessary for accurate drawings to scale. The remnants of A-10 and 15 and B-29 also have been raised, photographed and drawn, but their precise original locations within the hull are not as yet known. Thus they do not appear in outline in Fig. 1. All other frame remnants were too poorly preserved to assist in any way in reconstructing the hull.

The only planking remnants in Fig. 1 that have been raised and drawn in detail are S-1 through 4, the fragments of P-3 and 4 attached to the sternpost, and a few small fragments that

were collected after breaking loose during the course of the excavation. The other planking remnants have been left *in situ*, but structural features visible on their exposed inner face were recorded by numerous close-up photographs (such as Fig. 2) taken in 1969 and again in 1974. The photographic coverage of about 80% of this planking has proven to be excellent. Extensive overlapping has produced stereoscopic views in which details are often more clearly seen than they were on the wreck itself. On the other hand, photo coverage of the planking forward of A-3, of P-1 through 5 aft of B-8, and of P-9 through 20 aft of B-14 is often not as complete, since the photographing of these areas was still in progress when the 1974 season was terminated. Some structural details in these areas certainly have not been recorded.

Features visible in the close-up photographs of the planking that appear in Fig. 1 are planking edges and scarfs, holes for treenails fastening framing to planking, nail holes, pegs securing mortise-and-tenon joints employed in edge-joining the planking together, major splits in the planking, and notable score lines. Treenail holes occur, of course, only where frames were located and are larger than the joint pegs, which normally appear on the plan in pairs, one on either side of abutting planking edges. The seven large holes in the sternpost and keel are bolt holes. Treenail and nail holes visible in close-up photographs are shown in solid black, while treenail and nail holes whose existence and location are documented solely by frame remnants are shown in outline. Most of the latter occur in areas where the planking did not survive. A few nail holes and joint pegs not visible in any photographs were detected and located on drawings of the planking by divers while working on the wreck. The drawings were used to assist in mapping the planking as systematically and completely as possible. These nail holes and pegs, whose exact positions cannot be verified, are denoted on the plan by the letters N and P respectively. A question mark beside a peg, treenail hole, or nail hole indicates that the feature's identification is not entirely certain. The letter M appears on the plan where a mortise occurs but without a peg to mark conveniently its presence and location.

Method of reassembly

The graphic reassembly was begun by rejoining keel, sternpost and S-1 (the starboard garboard) on paper. Although none of the keel or a keel-sternpost scarf had survived, well-preserved, S-1 made possible a completely accurate reassembly of the three members. S-1 and keel were reassembled by aligning the two halves of mortise-and-tenon joints that had fastened these two members together. S-1 and sternpost were in turn reassembled by setting S-1's inner edge within a rabbet cut for it on the sternpost's starboard side. Nail holes in the two members made by nails fastening garboard to rabbet were aligned. All these nail holes were completely preserved, and the rabbet for the garboard was well-preserved throughout.

The floor remnants of B-8, 11, 23 and 27 were next added to the assembly. Only in the case of these four frames were the remnants' positions and attitudes relative to a vertical centre line bisecting keel or sternpost (the vertical broken line in Figs 3 and 4), as well as their longitudinal locations within the hull, known at the outset within very minimal parameters of possible error. Well-preserved holes for bolts fastening floor to keel or sternpost fixed the positions and attitudes of the B-11, 23 and 27 floor remnants. The position and attitude of the B-8 floor remnant was fixed by a treenail hole for this floor in S-1 plus excellent preservation of the floor's under face where it overlay S-1 (Bass & van Doorninck, 1971: fig. 5). Addition of these floor remnants to the assembly now made it possible to begin the development of tentative lines plans of the hull up to the waterline wale.

The locations of the treenails in the B-8 and 11 floors were plotted on the reassembly plan. Then the locations of the plank edges running beneath these floors were marked on the plan. These edge locations were determined through reference to close-up photographs of the planking showing both the edges and adjacent holes for treenails that were in the B-8 or 11 floors. The run of the P-1 through 15 edges from floor B-8 to floor B-11 could now be tentatively drawn in on the plan. The frame remnants of B-9 and 10 were next added to the reassembly. A stereophotogrammetric map of the planking (Bass & van Doorninck, 1971: 28) gave the longitudinal positions of these remnants within



Figure 2. Close-up photograph of planking. Frame remnant of B-4 appears *in situ* along right edge of photograph. White T and triangle are targets used in photogrammetric mapping of hull remains.

the hull. Their latitudinal positions relative to the edges of P-1 through 15 were shown by close-up photographs of the planking. The remnants were given attitudes relative to a vertical centre line bisecting the keel so that the curvature of each co-ordinated with the developing hull body plan. Placement of the B-7 and 12 remnants followed, making it possible to extend the evolving planking plan out through P-20 and to add the futtock remnants of B-8 and 11 to the reassembly.

The reassembly was gradually and systematically extended toward either hull extremity through employment of the general techniques just described. As each new frame remnant was added, the augmented lines plans and planking edge runs were checked to see that they remained fair and in full accord with all available evidence. Since the below waterline shape of the hull was not initially fixed at any point forward of B-8, recovery of the forward hull lines was particularly difficult and was partially dependent on co-ordination with the fairly fixed lines aft of B-8.

It proved possible to determine the precise longitudinal position within the hull of each

frame from A-5 to B-14 through co-ordinating evidence afforded by treenail holes in S-1, bolt holes in the keel, the photogrammetric map of the planking, and close-up photographs. The surviving planking aft of B-14 was not photogrammetrically mapped, but the original spacing between B-13, 15, 16, 18 and 20 along P-13 is known through direct, underwater measurements, and the general longitudinal position of B-17 is indicated by the keel bolt hole at this frame. This evidence coupled with close-up photographs of the planking made possible a precise longitudinal placement of remnants B-15 through 20. Longitudinal placement of the A-6 and 7 and B-21 and 22 remnants is in accordance with their positions on the photogrammetric map made of the hull remains (Bass & van Doorninck, 1971: fig. 4).

The precise latitudinal position within the hull of about half the frame remnants from B-4 to 11 was fixed by treenail holes in S-1 and/or by bolt holes in the keel. However, such direct evidence fixing the latitudinal positions of frame remnants forward of B-4 and between B-11 and 23 was totally lacking. In these areas, determination of each remnant's position and

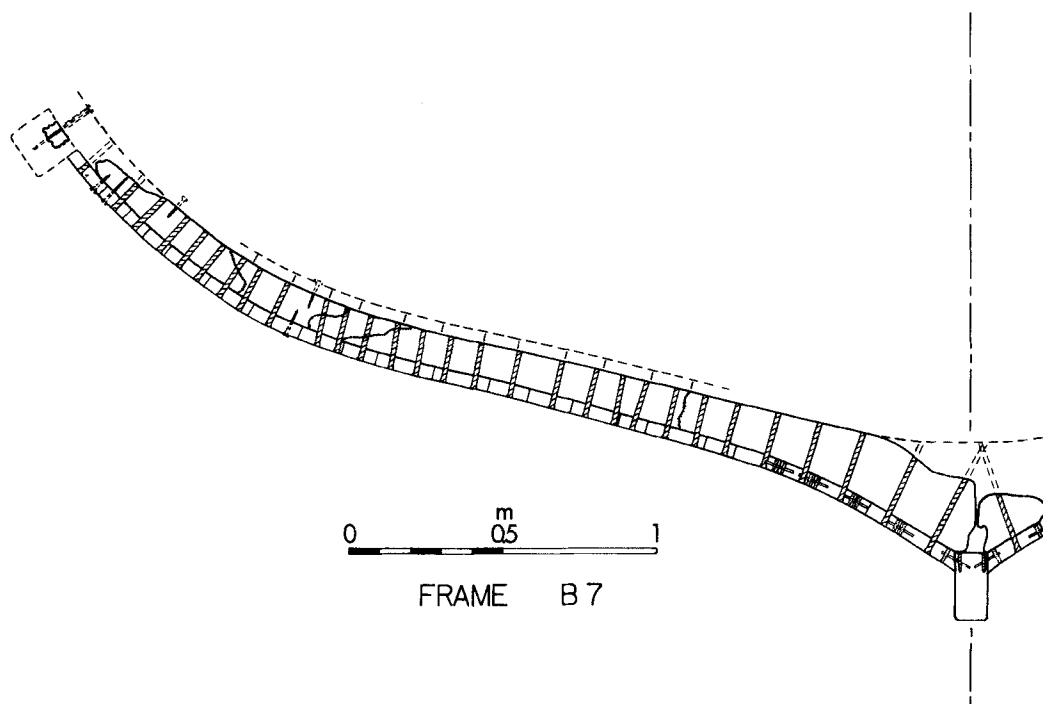


Figure 3. Hull section at B-7 (midships).

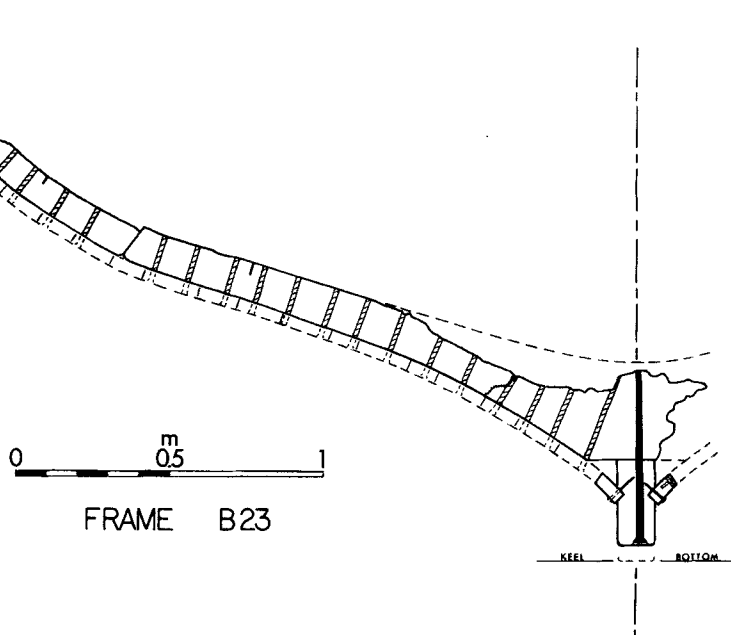


Figure 4. Hull section at B-23.

attitude relative to a vertical centre line bisecting keel, sternpost or stem had to be based on co-ordination of the remnant's curvature with the developing hull body plan and on maintenance of fair planking runs.

The reassembly was not easily accomplished. Every error made, even when slight, soon became compounded to the point where further progress was impossible without in some way doing clear violence to the evidence. Once the source of error was determined, a fresh start from that point was made. Much of the reassembly had to be redone many times over before the work could be brought to a successful conclusion. The trial and error process was much like that required in building a model of the Pantano Longarini ship (Throckmorton, 1973: 257). The task was a long and often frustrating one, but the fact that there proved only one way in which the remains could be successfully reassembled suggests that the reassembly is quite accurate. A model will be made in the near future to check and further refine the results. There would appear to be sufficient evidence for an accurate determination and verification of a complete set of hull lines at least up to the waterline wale.

The tentative lines plans

The tentative hull lines developed by the reassembly process are schematically illustrated by Fig. 5. The lines were solidly rendered

should not undergo any real changes when a model is made, but some adjustments may well occur where they are broken. These tentative lines give the hull at the level of the waterline wale an overall length of 16 m. and a moulded beam of 5.9 m. I, at present, estimate the ship's overall length at just about 20 m and her moulded beam at just under 8 m¹¹. The maximum beam at the level of the waterline wale occurred amidships at B-7. The length of keel was no more than 7 m. Thus both bow and stern possessed considerable overhang, the bow's being somewhat greater than the stern's. One often encounters representations of hulls so shaped in Roman art. The waterline wales curved up but slightly at either extremity and were raked so that their after rise was a bit steeper than their forward rise. The V-shaped hull bottom had moderately developed hollows and was a bit steeper at the forward end of the keel (A-7) than at the after end (B-21).

Keel, sternpost and stem

We will begin a description of hull members and construction with the longitudinal spine of keel, sternpost and stem.

The keel had a moulded height of 0.22 m and a simple, rectangular cross-section. There were no rabbets for the seating of the garboards. Instead, the garboards' upper face at the inner edge was set flush to the keel's upper face, and

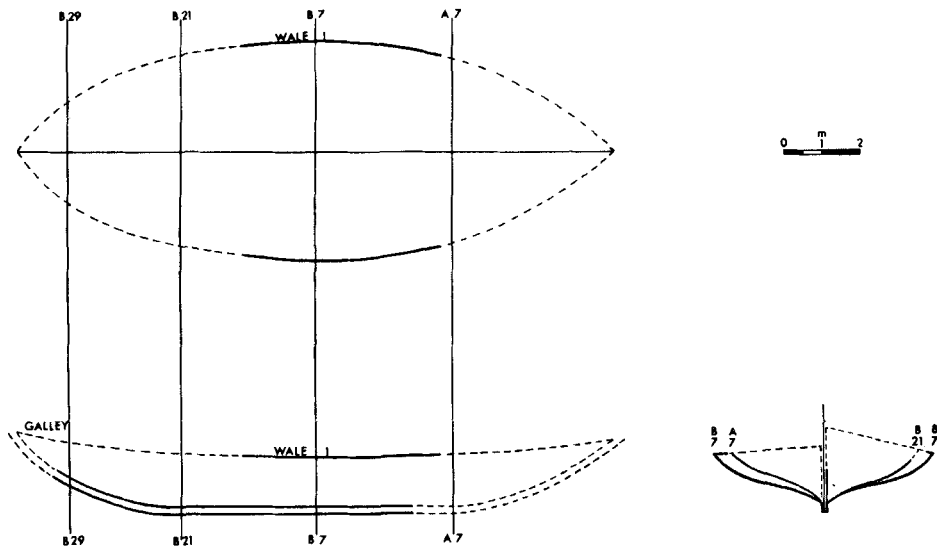


Figure 5. Schematic drawing showing tentative hull lines up to waterline wale.

the garboards were edge-joined to the keel by mortise-and-tenon joints of the same size as those used throughout the hull planking (Fig. 3). Reference to Fig. 1 will show that many of the joints fastening P-1 to the keel have undoubtedly not been recorded. This is due to stretches of poor preservation on the keel's port side and to the fact that a thick deposit of bilge sludge covering much of P-1 often prevented detection of the pegs for these joints in the garboard. The builders in fastening S-1 to the keel neglected, for some reason, to peg two of the joints (marked M on Fig. 1).

A hook scarf had joined keel and sternpost. The upper half of the keel's after end and the lower half of the sternpost's forward end were cut back about 0.35 m to form the scarf. The sternpost's upper face at the scarf's forward end was dovetailed into the keel's upper face (Fig. 1). A second dovetail presumably occurred on the under face at the scarf's after end, but it did not survive. The builders must have lowered the sternpost vertically into place from above when joining it to the keel. They did not deem it necessary to secure the sternpost in place with a bolt, treenail or other fastener running vertically through the two halves of the scarf.

The garboards' upper face at the inner edge remained flush with the spine's (keel's) upper face as far aft as the dovetail in the upper face of the keel-sternpost scarf. At this point, the spine's (sternpost's) upper face began to rise above the garboards' inner edge. Beginning 0.04 m further aft, the garboards were seated in 0.02–0.03 m deep rabbets cut into the sternpost sides and were fastened in place by iron nails at 0.1–0.2 m intervals (Fig. 4). The bearding line of the rabbets attained a c. 0.08 m maximum distance below the sternpost's upper face around B-23. The sternpost had a moulded height of 0.28 m where this dimension was fully preserved at B-23 and a maximum width, again at B-23, of 0.127 m.

The keel at its after end had a width of 0.095 m, but it widened toward the bow at a uniform rate, attaining a 0.122 m width at A-1, 5.2 m^[2] forward of the keel-sternpost juncture. The keel and immediately adjacent timbers beyond this point had been badly shattered into many small pieces that often had been violently dislocated. This dislocation clearly had taken place prior to the process of wreck formation and quite prob-

ably occurred as the result of the ship striking the Yassi Ada reef.

One substantial piece of the keel timber did survive at A-5, where an iron bolt had fastened the timber and frame together. This piece has revealed that the keel timber here attained a width of 0.125 m and that the timber's upper face began to rise above the garboards' inner edge at some point between A-3 and 4. The keel's upper face was still flush with the garboards' inner edge at A-3, where a mortise-and-tenon joint fastened S-1 and the keel together. However, at A-4 the garboards were seated in rabbets in the timber's sides whose bearding line was already approaching a distance of 0.04 m below the timber's upper face. The timber remnant at A-5 bore no trace of a keel-stem scarf, nor would there have been room for a scarf of even minimal size between this remnant and A-3, where the garboards' inner edge was still flush with the keel's upper face. It would appear then that the keel timber curved upward at its forward end. How far the keel timber continued into the bow is not known.

The bow's initial rise was not as abrupt or steep as was the stern's. As a result, the planking had longer runs into the bow than into the stern. The graphic reassembly indicates that this greater distance was at least 0.4 m in the case of the garboard and second plank on either side of the keel. The placement of the forward tip of P-2 in Fig. 1 is in accordance with its location on the photogrammetric map made of the hull remains, and its placement has been in turn the primary factor determining the placement of the forwardmost remnant of S-1^[3]. There may, of course, be some error in the placement of these remnants, but the error cannot be substantial.

Planking

Apart from the garboards, which attained a thickness of 0.053 m along their inner edge, the planking had a thickness of 0.042 m. There were 20 planking strakes in all between the keel and the first wale. The maximum width of the individual strakes ranged from as little as 0.1 to 0.25 m.

The garboards were in either case made of a single piece of planking; all the other planking strakes apparently consisted of either two or

three sections scarfed together. The scarfs were S-shaped and varied greatly in length. In configuration the shorter ones were very like the planking scarfs of the Punic ship in Sicily (Frost, 1974: fig. 1). The longer scarfs occurred in the narrower planks. The longest scarf fully preserved, the after scarf in P-14, was just over 2.3 m long. Another noteworthy scarf was the one in P-19, where the inner half of the scarf had a secondary scarf at B-6. It was rather surprising to find many of the scarfs concentrated within small areas of the hull, such as around A-3 and B-13. Certainly this was not a very good practice from a structural standpoint. The shortest scarfs were normally fastened together by two mortise-and-tenon joints; the long after scarf in P-14, by at least seven and perhaps as many as nine joints. A fragment of a scarf feather tip raised has revealed that outer feather tips in scarfs were secured in place by an iron nail driven laterally through the tip into the adjoining section of the plank already in place.

Wales

Remnants of four wales survived on the hull's port side; they appear in the photogrammetric map of the hull remains (Bass & van Doorninck, 1971: fig. 4). Only wale 1, the waterline wale, has been included in the graphic reassembly. Wale 2 ran parallel to wale 1; an intervening

planking strake was roughly 0.25 m wide. Wale 3 was closely set or even tangent to wale 2 amidships but had a steeper rise than the lower wales both fore and aft, perhaps paralleling the sheer of the deck. Wale 4 was probably located at deck level. The wales had the following cross-sectional (width $\times$ thickness) dimensions amidships: wale 1, 0.16 $\times$ 0.16 m; wale 2, 0.17 $\times$ 0.1 m; wale 3, 0.12 $\times$ 0.16 m; wale 4, ? $\times$ 0.16 m. A diagonal scarf fastened with a single, centrally-located iron nail running vertically through the scarf's two halves occurred in wale 3 at B-11. In a side view of the hull, the scarf would appear as a straight, diagonal cut with the after wale section overhanging the forward section.

While the planking strake extremities were fastened to the stem and sternpost rabbets with iron nails as were the garboards, a different method appears to have been employed in fastening the wale ends. An upper portion of the sternpost that survived (it appears in fig. 4 of Bass & van Doorninck, 1971) had a hole for an iron bolt running through its width near the remnant's upper end. This hole emerged at either side within the confines of the sternpost rabbets. It is likely that the iron bolt was used to fasten the stern ends of a pair of wales to the sternpost. In all probability the wale involved was wale 3.

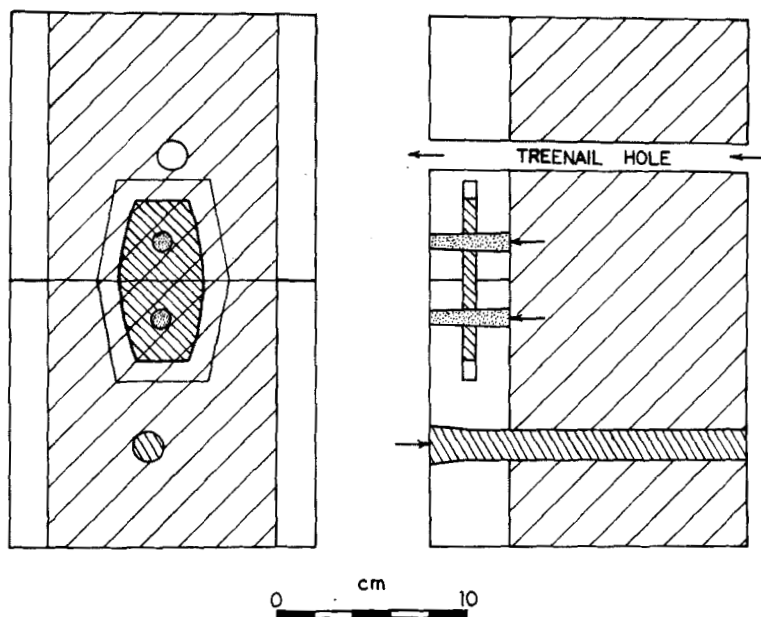


Figure 6. Schematic drawings showing typical joint and frame-planking assemblies.

Mortise-and-tenon joints

There is certain evidence that all of the outer hull strakes up to and including wale 3 were edge-joined together. Pertinent evidence is as yet lacking for higher strakes.

Mortises that have been examined in keel, planking and wales were with few exceptions 0.07–0.09 m wide at the surface, penetrated to a depth of 0.05–0.055 m, were 0.007 m thick, and markedly decreased in width as they penetrated into the strake's side (Fig. 6). The tenons, normally about 0.045 m wide and 0.085 m long, were much smaller than the mortises into which they were inserted and were strongly tapered at the ends. The looseness of the tenons is a notable departure from the normal practice in Graeco-Roman hull construction, where tenons had pretty much the same dimensions as their mortises. Graeco-Roman shipwrights had to exercise considerable care in aligning and cutting the many closely-spaced mortises in their hull shells to succeed in driving long sections of hull strake down on the numerous, tight-fitting tenons of adjoining strakes already in place. Even then, one imagines that much effort and occasional frustration were involved. In the present instance, on the other hand, the builders had plenty of play when fitting one strake to another; time and manpower required in cutting mortises and fitting strakes must have been significantly reduced. Interestingly, we found the same degree of tenon play in the 7th century Yassi Ada ship (Fig. 7).

Once a strake had been properly fitted to the strake below, each tenon joining the strakes was permanently fixed in place by a pair of wooden pegs (Fig. 6). These pegs had a maximum diameter of 0.01–0.011 m on the inner face of the strakes but tapered to a diameter of 0.007–0.009 m on the outer face. A total of 15 pegs have been extracted from planking joints. Twelve of the pegs appear in Fig. 1; they are circled. Five of these are illustrated in Fig. 8. All 15 pegs were tapered, and all had been driven in from inside the hull. All pegs driven into the keel and wales were also driven from the inside; these pegs did not extend all the way through these timbers to their outside face. Figure 3 illustrates this in the case of the keel. Not one example of a peg driven from outside the hull has been found, while the many pegs

known to have been driven from the inside were rather widely distributed throughout the surviving hull remains up through wale 3. Clearly the driving of joint pegs from the outside was at best a rare exception.

We made every effort to find and accurately map all surviving joint pegs. Every peg detected was marked with a white thumbtack that would

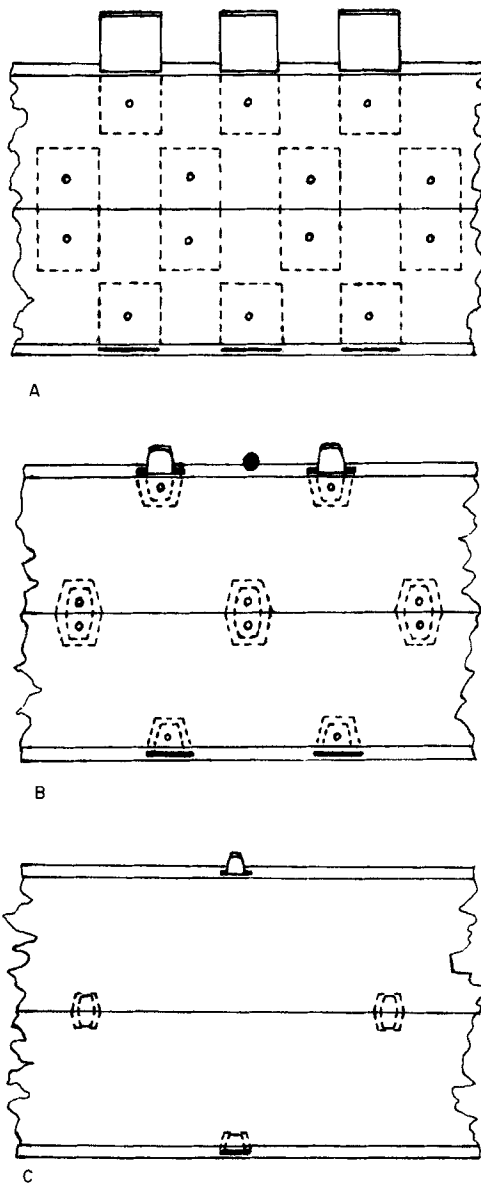


Figure 7. Schematic drawings comparing edge-joining of shell planking in A, a typical Roman hull; B, the 4th century Yassi Ada hull, and C, the 7th century Yassi Ada hull.

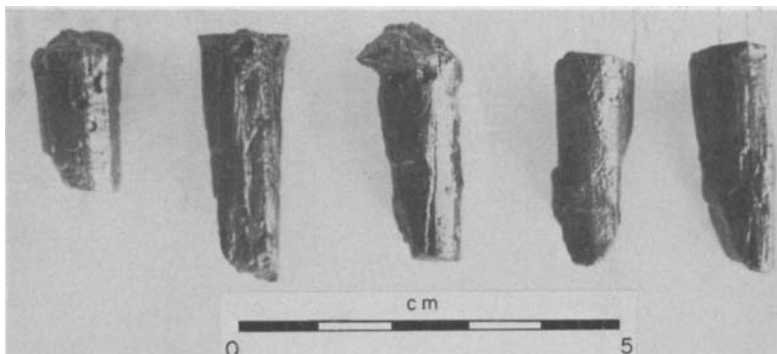


Figure 8. Wooden pegs used in fastening mortise-and-tenon joints.

show up clearly in both close-up and stereo-photographs (Fig. 2). All surviving planking forward of B-14 was uncovered, thoroughly cleaned, thumbtacked and photographed during the 1969 season. A series of maps of most of this planking was made on plastic sheets for underwater use at the outset of the 1974 season. A mark was made at every point on the maps where there appeared to be any likelihood that a peg or pair of pegs had escaped detection in 1969. After the planking had been uncovered, cleaned again and labelled for easy orientation, divers methodically re-examined the planking with maps in hand, thumbtacked any additional pegs detected, and recorded their locations on the maps. A second series of close-up photographs of the planking was then made. We managed to complete a re-examination of P-2 through P-19 from A-3 to B-14 in this way during the few weeks of the 1974 season and have every confidence that the number of pegs that have escaped notice within this area of planking are very few indeed. Forward of A-3 and aft of B-14, the planking has been thumbtacked and photographed but once. In these areas, then, a greater number of pegs have gone undetected.

These efforts have yielded some rather interesting data. The distance between mortise-and-tenon joints was not fairly uniform throughout the planking, as I had first reported (Bass & van Doorninck, 1971: 31). Around A-3 and B-13, where the planking was relatively weak due to a heavy concentration of scarfs, the joints were frequently set at intervals of from 0.07 to 0.12 m, the centre-to-centre distance being from 0.15 to 0.2 m; the most closely-spaced joints occurred around B-13. The most frequent intervals in other areas of the planking was

from 0.17 to 0.24 m, the centre-to-centre distance being from 0.25 to 0.32 m. Such intervals are much greater than those found in earlier Graeco-Roman sea-going vessels, where they rarely exceed 0.10 m. It seems to me that the considerable variance in joint spacing, the generally larger intervals involved, and the loose-fitting tenons in the hull represent an early and cautious phase in a trend toward reducing both the number of hull joints and the time and effort involved in fashioning and assembling them, thereby cutting construction costs. We find this trend well advanced in the Pantano Longarini and 7th century Yassi Ada ships (Fig. 7). By late Byzantine times, shipwrights had learned to dispense with joints entirely.

We have slight and inconclusive evidence provided by three small pieces of planking edge raised that the builders cut the mortises in the outer edge of planking strakes so that the tenons would project from the edge at the angle at which the next plank was to be set, having first trimmed the plank's outer edge so that its face would be perpendicular to the projecting tenons (Fig. 9). We had hoped to obtain confirming and comprehensive documentation of this process in 1974, but the early termination of the season made this impossible. Angles of planking edges and tenon attitudes are aspects of Graeco-Roman hull construction that have been totally neglected in the past. This is unfortunate, for these are apparently matters of critical importance in understanding how Graeco-Roman shipwrights went about the task of shaping their hulls. This will be abundantly clear in the case of the Kyrenia ship when J. Richard Steffy's study of that hull is published in the near future.

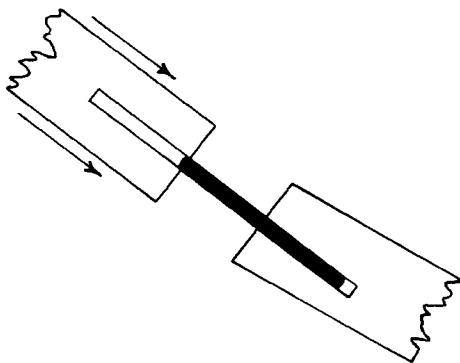


Figure 9. Schematic drawing illustrating apparent method employed to set shell strakes at desired angles.

Frames

Remnants of 48 consecutive frames survived out of an estimated original total of about 68. Frames with floors alternated with half-frames. The half-frame pairs met directly over the keel's centre line in a vertical butt joint but were not fastened together in any way (Fig. 3). The floors normally extended out as far as the 13th to 16th strake from the keel. The shortest floors for which we have evidence (A-1 and A-5) extended out only to the 10th strake; the longest (B-11), to the 17th strake. Most floors butted against futtock in a vertical butt joint, but the floors of B-4, 8 and 15 slightly overlapped their futtock instead. Curiously, only in the case of B-4 did this overlap take the form of a carefully cut scarf. Futtocks and floors were never fastened together. However, B-2 did have an initial short futtock directly fastened to the next futtock by a treenail which fastened both to P-15. The first futtock overhung the second in a diagonal butt joint.

The floors of B-29, 27 and 23 (Fig. 4) were bolted to the sternpost; the floors of B-17, 11, 4 and A-5, to the keel^[4]. None of the frames other than those with bolted floors were fastened to the spine in any way. The bolts were of iron with heads 0.037–0.045 m in diameter and shafts 0.02–0.026 m in diameter at the base of the head. They were inserted from the under face of sternpost and keel. The primary function of this series of bolts was undoubtedly to bind the spine to a keelson, which has disappeared without a trace along with the shaft ends of all the bolts. However, one shaft end

was recovered from the wreck; it had a slot for a key.

The frames varied somewhat in width. Floors bolted to the spine generally possessed the greatest widths; normally they were 0.13–0.15 m wide, although the floor of B-11 attained a maximum width of 0.191 m. Other floors generally had widths of 0.12–0.14 m. Futtocks tended to be narrower than the floors with which they were associated, occasionally (A-1, B-8 and 13) by as much as 0.04–0.05 m. Half-frames normally had widths ranging from 0.08 (B-14) to 0.13 (B-7) m; half-frame B-1 had an unusually great width of 0.15 m. Frames were 0.125 m high through most of their length but attained a height of c. 0.35 m directly over the keel.

The average centre-to-centre frame spacing between A-7 and B-23 was just under 0.27 m. The frames were set at rather uniform intervals with just a few noticeable exceptions (A4, B-16 and B-19). However, they were set a little closer together in the same two hull areas where the mortise-and-tenon joints were most closely spaced. Indeed, the centre-to-centre distance between neighbouring joints and between neighbouring frames corresponded rather closely in each particular part of the hull. The average centre-to-centre frame spacing forward of A-3 was 0.28 m, narrowed a bit to 0.25 m between A-3 and B-3, widened to 0.3 m between B-3 and B-8, narrowed considerably to just under 0.23 m between B-8 and B-14 (where the joints had their closest interval anywhere in the hull), and then widened again to 0.28 m aft of B-14.

A layer of pitch was found adhering to the inner face of the planking where each frame had been set. The original outer edges of these deposits were quite straight and occurred precisely where the side faces of frames had been located (Fig. 2). In view of this exact correspondence, it would appear that pitch was applied to the under face of each frame section just before its final installation. Admittedly, only an occasional trace of pitch was found on the under faces of the frame remnants. However, the frames had tilted over on their sides to varying degrees during the process of wreck formation, and their under faces without exception had been well scoured by the action of currents and sand.

The straight outer edges of the pitch deposits often appeared as thin, white lines in photographs taken of the planking (Fig. 2). At first, I wrongly supposed many of these edges to be score lines and unfortunately stated that score lines showing where frames were to be set were abundant on the inner face of the planking (Bass & van Doorninck, 1971: 31). Although there were indeed many random and irregular scratches on the inner face of the planking, I was able to find and carefully examine in 1974 only one long, straight, incisive scratch located where a frame edge had been set (Fig. 10). This scratch, occurring on P-7 to 9 where the after side of B-1 was located, had every appearance of being a score line and has been indicated on Fig. 1 with the label SL.

A large treenail 0.016 m in diameter was used to fasten each frame to each planking strake. Occasionally a frame was not fastened to a narrow plank, while in the case of strakes exceeding a c. 0.15 m width, two treenails were often used. In some instances where two fastenings were deemed desirable but a planking scarf occurred under the frame and one side of the

scarf appeared to be not wide enough or the planking around the scarf not sound enough to take a treenail, an iron nail was substituted^[5]. For reasons not yet evident, frames were not fastened by treenails to S-1 (and, presumably, to P-1) aft of B-14. It is not known whether or not B-12 and 13 were fastened to the garboards in any way. The floors of B-19 and 21 were in each case fastened to S-1 by an iron nail.

The treenail positions were staggered along the length of each strake in an effort to avoid long splits in the planking. The treenails often passed through the planking quite close to an edge. Extreme examples of this occurred in P-2 at B-8, P-4 at A-3, and P-14 at B-11. Treenails often damaged joints as well. An iron nail driven through P-17 into B-16 apparently repaired a badly damaged joint fastening P-16 and 17 together. The undesirable location of many of the treenails in the planking surely permits us to conclude that the holes for the treenails were drilled from inside the hull.

The treenails themselves, on the other hand, were driven in from the outside. Several treenail ends were extracted from the planking and

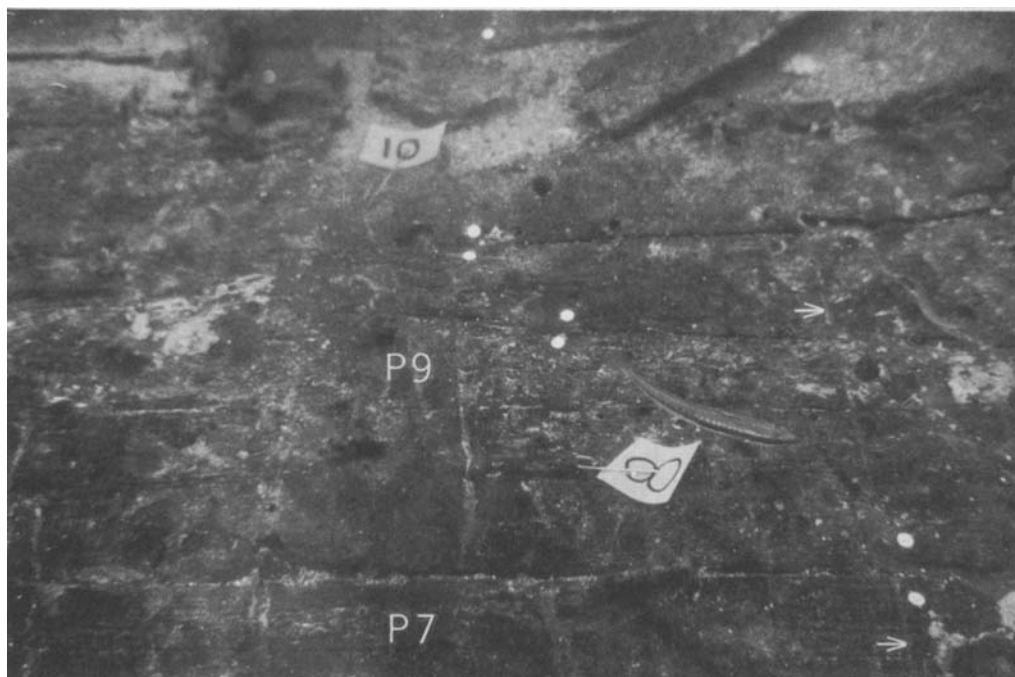


Figure 10. Close-up photograph of planking. Arrows point to score line on P-7 to 9 located where after edge of B-1 had been set. Notice random scratches on planking in left-hand part of photograph.

were found to increase in diameter in the last 0.02 m of their length from 0.016 to 0.02 m. This flaring out of the end was sufficient to hold the planking tightly in place against the frame; no trace of wedges driven down into the treenail ends was found.

Long, slender iron spikes were used in fastening the frames to wales. A hole was drilled in the frames from the inside at each point where they were to be fastened to wales. Two small frame remnants from the stern quarter of the hull on the port side, recovered in 1974, revealed that these holes were not always drilled completely through the frames. A treenail was inserted into the hole, and the spike was then driven through the treenail and into the wale. The shaft end was clenched over on the wale's outer face in instances where it passed completely through the wale.

It is interesting to note that while each consecutive frame had been fastened to the surviving sections of wale 1 raised, only every other frame had been fastened to raised remnants of wale 2, and the intervals between fastenings in the raised remnants of wale 3 ranged from every other to every fourth frame. The exact positions within the hull of the wale 2 and 3 remnants will not be known until a model is made. It may be that the locations of the nail holes in the remnants will then shed some light on the framing plan above the waterline.

After the frames were installed, additional iron nails were used to tighten up planking seams where necessary (apparent example: the nails in A-7), repair damaged joints, and close splits started by treenails (example: the two nails in P-16 at B-11). All of the nails driven through planking into frames penetrated only roughly halfway through the frames.

Apparent early erection of midship half-frame (B-7)

Since joint pegs were driven from inside the hull, frame sections overlying pegs could not possibly have been installed until after the pegs were in place. Reference to Fig. 1 will show that between A-1 and B-18 18 out of 19 frames overlay pegs at least as far out as P-17 and that 13 or more of these frames overlay pegs at least as far out as P-19. We also know that some joints in wale 2, and possibly in wale 3, were

located under frames. Certainly, then, most frames were installed only after the hull shell was either at an advanced stage in construction or virtually completed.

The pair of midship half-frames (B-7), on the other hand, may have been installed after as few as five planking strakes were in place. Pegs were found underlying this frame only as far out as P-4. Two neighbouring joints fastening P-4 and 5 were located very close to B-7, one on either side of the frame; the centre-to-centre distance between them was only 0.02 m. Beyond P-5, however, we found no joint pegs under or in really close proximity to B-7. Furthermore, the centre-to-centre distance between the closest joint on either side of B-7 in strakes P-6 to 20 was without exception abnormally great, this distance in most instances being some 0.4 to 0.6 m.

We first became aware of this anomaly about midway through the 1969 season after stereophotographs of the midships planking had been taken and studied. A complete re-examination of all the planking under and immediately adjacent to B-7 was then twice made and a few more joints were detected. The same area of planking was again thoroughly examined in 1974 four times with the aid of a map of the planking; not one additional joint was found.

Apparently, joints beyond P-5 were spaced at abnormally great intervals amidships so as to avoid placing joints under and immediately adjacent to B-7. Such an avoidance could have been due to an early erection of the midship half-frames after perhaps just five planking strakes had been assembled. This early erection of B-7 appears confirmed by the scarf in P-20. Despite the fact that this plank was 0.25 m wide, only one joint had been employed in fastening the scarf. A second joint under or near B-7 was avoided⁶¹. Instead, a pair of nails, one nail on each side of the scarf, was driven through the planking into B-7 (Figs 1 and 3). It seems far more likely that B-7 was already in place when the two sections of P-20 were scarfed together than that the builders initially fastened together the scarf with only one joint completely off centre and then strengthened the scarf at a later stage in the hull's construction.

Why would the shipwright have erected the midships half-frames at such an early stage in

the shell's construction? This is a question for which I have no ready answer. An obvious possibility is that B-7 served as a guide frame to assist the shipwright in shaping the hull, but the question remains why he would have felt the need for such assistance in the first place.

Certainly any hull planking assembled after the erection of B-7 must have already possessed its final thickness at the time of assembly, and we do have some direct evidence that the inner face of the planking was not trimmed down in any substantial way after the planking had been assembled. Adze marks visible here and there on the inner face of the planking sometimes extended to the edge of a plank but not beyond to the neighbouring plank. Notice, for example, the adze marks on P-8 below the scarf between B-5 and 6 in Fig. 2. Small score lines marking where holes for joint pegs were to be drilled were also occasionally still visible on the inner surface of the planking. They appear in close-ups of the planking, and I was able to confirm their identity in a couple of cases through underwater examination in 1974. Those score lines whose identity is reasonably certain appear in Fig. 1. They are rather widely distributed throughout the planking: at P-10 and 11 between B-5 and 6, P-14 and 15 between B-8 and 9, P-15 and 16 at A-1, and P-16 and 17 between B-12 and 13. The score line at P-10 and 11 between B-5 and 6 is faintly visible in Fig. 2. These score lines would not have survived had the inner face of the planking where they were located been trimmed down after its assembly.

An important point to be made here is that we cannot necessarily assume that the planking in a Graeco-Roman hull already possessed its final thickness when it was being fastened together. On the contrary, Steffy's study of the Kyrenia ship will show that the planking in that hull was substantially trimmed down on both faces only after the hull shell had been completed and that this process made a real contribution to achieving the final hull shape desired. One suspects, therefore, that the practice of assembling planking already possessing its final thickness was one that evolved only over some period of time. Here then is another aspect of Graeco-Roman hull construction about which we still have a great deal to learn. Yet what is involved here is a

matter of considerable import, for the ability to assemble hulls with finished planking was a precondition to the rise of skeleton-first construction.

Ceiling and dunnage

Fragmentary remnants of the ceiling survived within the hull's middle body (Fig. 3). The remnants probably belonged to 11 contiguous strakes running above P-7 to 17. All these ceiling strakes were of 0.038 m thick planking, in most cases 0.13–0.16 m wide. Iron nails were used to fasten the strakes to frames. No cuttings were found on any of the remnant's upper faces.

A rather thick deposit of bilge sludge was found covering much of the keel's upper face. It contained among other things large amounts of sawdust, wood chips and twigs, undoubtedly remnants of dunnage used in stowing cargo in the hold. Several twig fragments were also found adhering to the upper face of a ceiling remnant located above P-11 at B-5.

Circulation of bilge water

Throughout the keel's length, a single limber hole, normally about 0.06 m wide and 0.09 m high, was cut through the underside of each frame directly above the keel's centre line, permitting a free circulation of bilge water along the keel's upper face (Fig. 3). This was the lowest point within the hull, since the hull bottom was V-shaped in cross-section and the garboards' inner edge was set flush with the keel's upper face. As already noted, the spine's upper face rose above the level of the garboards' inner edge beyond either end of the keel. Here the flow of bilge water was diverted to either side of the spine, where it flowed through triangular openings formed by garboards, spine and frames. At the stern, these openings were more than adequate for the flow of water at B-23 (Fig. 4). At B-21, on the other hand, the spine was not as high above the level of the garboards' inner edge so that the triangular openings were quite small. To augment their size, triangular cuttings were made directly above them through the underside of the frame. This pair of cuttings survived, as did one of a pair in A-7, which was located in a roughly comparable position at the ship's forward end. The cuttings are visible in Fig. 4 of the preliminary report (Bass & van Doorninck, 1971).

The alternation of half-frames and frames with floors was interrupted at B-10, a partial frame which ended in a vertically-cut butt near the outer edge of P-2. In the preliminary report, I suggested that perhaps a mast step complex had in some way prevented installation of a full frame here (Bass & van Doorninck, 1971: 32). Now, however, I am more inclined to believe that partial frames were installed here to leave room over the keel for a bilge sump. What appears to be a bilge sump has survived in the Port-Vendres hull (Chevalier & Liou, 1974: 52-3). It is located directly above the keel between a pair of partial frames a bit beyond midships toward one end of the hull.

There was another partial frame at A-6. A half-frame would have occurred here had the regular alternation of floors and half-frames obtained. The reason for the substitution of a partial frame here is as yet unknown.

Lead patches

Five rectangular lead sheets have been recovered from the wreck. The exact find spots of two of

the sheets are known and are indicated on Fig. 1 by the label L: one was found lying against the keel remnant at A-5; the other (Fig. 11), underlying a small fragment of wood immediately to starboard of S-1 at A-3. The approximate find spots of two of the other sheets are known: one of these was found beneath the sternpost where the after ends of P and S-2 were attached to it; the other, somewhere around A-9 to 10 about 11 strakes out from the stem on the port side. The fifth sheet was found somewhere between A-11 and 16 within c. 1 m to port of the stem.

The sheets were generally about 0.001 m thick. Surviving corners were rounded. One of the corners of the sheet found next to S-1 appears clearly in Fig. 11. The sheets varied in size. The largest one, found underneath the sternpost, measured 0.265 × 0.17 m; the ones found forward of A-11 and around A-9 to 10, 0.175 × 0.149 m and 0.174 × 0.121 m respectively. The smallest sheet was the one found next to S-1. Its measurements are not available to me at the moment, but the sheet appears in



Figure 11. Lead patch *in situ* next to starboard garboard (S-1). Wood fragment overlies left-hand portion of patch. Notice that patch's two visible corners are rounded. Some of the tack holes running along patch's four edges are faintly visible in photograph.

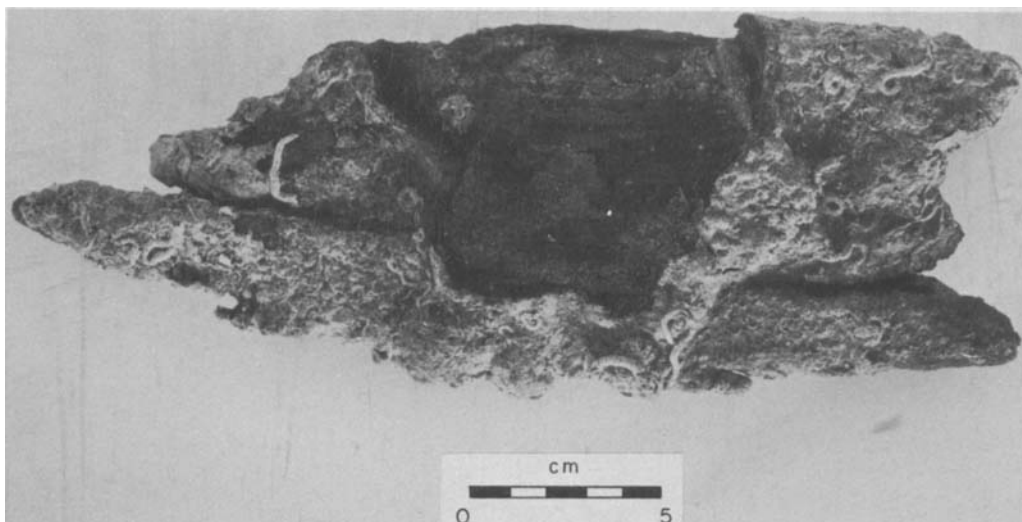


Figure 12. Remnants of two contiguous timbers that may have been part of a deck. A small fragment of a concretion that had formed around an iron axe or similar tool can be seen adhering to remnants.

Fig. 11 along with the corners of two angle iron frames of known dimensions. I estimate on this basis that the sheet measured c. 0.149 X 0.101 m.

The sheets appear to have been attached to the outside of the hull in the three instances where we have evidence. Whether or not the two forwardmost sheets were found in association with any hull remnants was not recorded. The sheets had been fastened to the hull by small iron tacks driven through the sheets along their four edges. The tack shafts were 0.02–0.03 m square at the base of the head; the heads, 0.013–0.016 m in diameter. A tack hole was found in the fragment of S-3 attached to the sternpost; its location is indicated by the label T on Fig. 1. The tack penetrated 0.014 m into the plank.

The sheets apparently served as patches. Each was found in isolation, and fragments of other lead sheets were not found anywhere on the wreck site. It is noteworthy that all of the sheets and the tack hole in S-3 were below the waterline at one or other end of the hull and in a majority of cases in close proximity to the spine. These were hull areas particularly susceptible to damage or planking starts.

Possible deck fragments

A small remnant of what appeared to be two

contiguous planks was accidentally broken off a buried iron concretion while a diver was air-lifting in the galley area at the after end of the wreck in 1974. The two fragments of apparent planking, concreted together, are illustrated in Fig. 12. The faces of the two fragments shown in the photograph are original surfaces, but neither fragment was preserved to its full thickness. The preserved thickness of the longer fragment was 0.03 m; that of the other fragment, 0.023 m. The original surface of the longer fragment was c. 0.002 m higher than that of the other fragment. The seam between the two fragments was slightly curved. One small piece of the iron concretion to which the fragments had become attached can be seen adhering to the fragments in Fig. 12. The hollow within this piece of concretion had the configuration of a corner of the cutting edge of an axe head.

The identity of these fragments is, of course, far from certain. However, the only possibility that has come to mind is that we have here a remnant of a deck on which an axe or similar iron tool had come to rest. The longer fragment may be a piece of the stern quarter portion of a king plank running along the hull's starboard side. The deck involved could have been either the main deck or the floor of the ship's galley. The latter possibility seems more likely.

Galley

There had been a transverse bulkhead within the hull at B-29; the bulkhead was located c. 1.4 m forward of the sternpost's inner face at the level of the waterline wale (Fig. 5). Forward of the bulkhead was the hold; aft of it, a galley. The evidence for the bulkhead and galley and a general description of the galley and its contents may be found in the preliminary report. Prior to the 1974 season, we had little evidence to suggest that the galley might have had a tile roof, but we now have recovered half a dozen roof-tile fragments from the galley area. At least half the fragments were from cover tiles. There is, then, a distinct possibility that the galley did have a tile roof. The issue will remain in doubt, however, until further excavation of the galley area. We also recovered from the galley area in 1974 part of a cooking pot, a pantry amphora, and a small piece of branch chopped off at either end. The latter was perhaps a piece of kindling wood for the hearth.

Wood used in the hull

Only two basic types of wood appear to have been used in the hull^[6]. Sternpost, planking, wales, frames, ceiling and pegs were of Mediterranean cypress (*Cupressus sempervirens*). The treenails and tenons were of a wood belonging to the live oak group; the keel, of a wood belonging to the white oak group.

The shipwright made the fullest possible use of his wood, which was often of rather minimal size and quality. A good deal of scrap wood was used for framing. A number of the futtocks were quite short. Note, for example, the short futtocks in A-1 and B-2, 4 and 11. Another futtock raised whose original location within the hull has not yet been determined was only 0.31 m long, and its grain did not run lengthwise but vertically! P-4, 6, 8, 11 and 14 were unusually narrow planking strakes only 0.1–0.13 m wide. They appear to have been cut from relatively small logs, and the shipwright got as much length as he could out of the logs by making the scarfs in these planks extremely long. Knots were surprisingly abundant in some of the planking. I hope to include in the final report a special planking plan that illustrates this. Recording the quality of the wood in hulls that are excavated might eventually shed some new light on the availability of timber suitable for

shipbuilding during past periods in the various regions of the Mediterranean world.

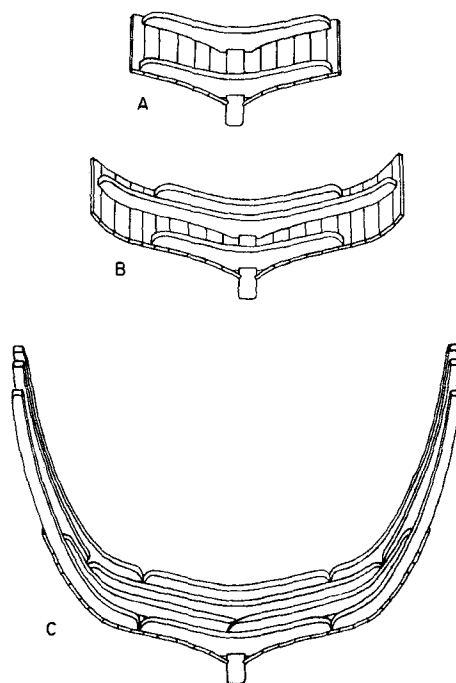


Figure 13. Schematic drawings showing hypothesized early stages in construction of 7th century Yassi Ada hull.

Historical perspective

The 4th century Yassi Ada hull is a harbinger of some of the developments in hull construction that were to occur during early Byzantine times: greater economies were made in the utilization of timber; iron bolts and iron nails driven only halfway through frames became the primary fasteners; joints became smaller, easier to fashion and assemble, much more widely spaced, and more restricted in their use. These and other developments have been documented by the 7th century Yassi Ada ship and the Pantano Longarini ship.

Early frame erection appears to have been another development of the early Byzantine period. The hull planking of both the 7th century Yassi Ada ship and the Pantano Longarini ship was edge-joined only up to the waterline. Steffy discovered when he made test models of the 7th century Yassi Ada hull that the unpegged joints in the planking (Fig. 7) were so small and widely spaced that they

would not by themselves have held together all of the planking up to the waterline. After considering all possibilities in the light of the little evidence available, he concluded that the shell had been constructed most probably in much the following way. The hull's bottom planking, temporarily held together by the joints, was first assembled. The bottom planking once completed was permanently fastened in place through installation of short floors to which the planking was nailed (Fig. 13A). The shell was then continued up through the turn in the bilge, and longer floors were installed and nailed (Fig. 13B). The shell was now continued to the waterline, after which half-frames and futtocks were installed (Fig. 13C). The early-erected frames in the 7th century Yassi Ada ship hypothesized by Steffy have now an apparent precursor in the midships frame of the 4th century Yassi Ada ship.

Acknowledgements

I am indebted to J. Richard Steffy for his critical reading of the manuscript. This study has benefited greatly from the many discussions and long correspondence I have had with him concerning the Yassi Ada ships in particular and Graeco-Roman ship construction in general.

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I also wish to take this opportunity to express my gratitude to the 1974 Yassi Ada staff. Much of the work on the wreck in 1974 was carried out with an efficiency and discipline unparalleled in my experience. The short season would have failed to produce significant results without this added measure of effort.

The staff members were George F. Bass, director. Michael L. Katzev, assistant director; Donald A. Frey, Cynthia J. Eiseman and Nancy Fries, administrative assistants; Oguz Alpözen, commissioner from the Turkish Department of Antiquities; Roger Williamson and Alan Freeman, physicians; Robin C. M. Piercy and John A. Gifford, engineers; T. Walker Lloyd, chief diver and photographer; Susan Womer Katzev and Gay Piercy, artists; Ann S. Bass, conservator. Frederick H. van Doorninck, Jr., assisted by Peter Fries, directed the ongoing work of recording the hull remains. American Institute of Nautical Archaeology summer field school students who participated in the excavation were Pierre Bikai, Brian Fugler, Faith Hentschel, Jack Irion, Karen Cannon Irion, Bradley Marshall, Fredericus Meijer, Mary Strouse, Owen Sutton, Phil Stewart, and David Switzer. Betty Jean van Doorninck and Lynne Lopez assisted in timing dives. J. Richard Steffy paid a brief visit; his advice and seminars on ship construction were much appreciated.

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Notes

- [1] My initial estimate of c. 6-6 m for the moulded beam (Bass & van Doorninck, 1971: 30) was much too narrow.
- [2] I mistakenly wrote 4-2 in the preliminary report (Bass & van Doorninck, 1971: 30).
- [3] This garboard remnant is the plank G mentioned in the preliminary report (Bass & van Doorninck, 1971: 30 and fig. 4) and there wrongly assigned to the port garboard.
- [4] The suggestion in the preliminary report (Bass & van Doorninck, 1971: 32) that the floor of A-3 might have been bolted to the keel no longer seems tenable.
- [5] This was done in P-6 at B-5, P-9 at B-1, P-10 at B-15, P-11 at A-2 and B-16, P-12 at A-4, P-13 at B-14, P-14 at B-15, P-17 at B-19, P-18 at B-16, and P-19 at B-8.
- [6] One edge of the forward third of the scarf was closely examined in 1974; no mortise was found.
- [7] Wood samples were identified by B. Francis Kuchachka of the Forest Products Laboratory, US Department of Agriculture, Madison, Wisconsin.