ANCIENT SCANTLINGS:
THE PROJECTION AND CONTROL OF MEDITERRANEAN HULL SHAPES

It has been eighteen years since Lionel Casson combined most of the known literary and archaeological sources to produce *Ship and Seamanship in the Ancient World*,[1] still a basic sourcebook for our discipline, and nearly that long since Lucien Basch wrote his thought-provoking article on the state of nautical archaeology that introduced the first volume of *IJNA*.[2] We have recorded a lot of frames, planks, nails, and mortise-and-tenon joints since then, but our research has added virtually nothing concerning the methods by which ancient Mediterranean ships were designed, the ways in which shipwrights controlled hull construction, the techniques that permitted large fleets of warships to be built as quickly as literary sources claim, or a clear understanding of the economics of shipbuilding. In short, we have documented a lot of trees these past two decades, but we still have to find the forest.

Part of our problem might be attributed to the limited number of extensively preserved wrecks that have been excavated, while economic, political, or other constraints affected some of the projects. Nevertheless, we must concede the fact that our recording of hull details also has been generally insufficient and our avenues of research too narrow and unimaginative. Now archaeology has entered the computer age, bringing with it expanded possibilities for examining data and analyzing hull structures. More than ever before, we must document our finds more completely to take advantage of this new medium. At the same time, we must reevaluate the ways in which we have been considering our hull remains and take new approaches to these old problems.

As an example, this paper will consider one of these problems—the ways in which shipwrights projected and controlled hull shapes. In the past, theories have ranged from the use of standing control frames to the haphazard assembly of planks, but I am not convinced that any of them are accurate and certainly none of them are complete. Let's examine the problem by first reconsidering the Kyrenia and Serçe Limani wrecks, which are used as examples only because they are so similar. Both had approximately the same principal dimensions, sailed the same waters, were built almost exclusively of pine, had identical planking thicknesses, relatively small keels, and two belts of heavy wales.

Fig. 1 illustrates the midship section of the Serçe Limani merchantman, which was excavated off the southern coast of Turkey about ten years ago and whose remains have been reassembled in the Medieval castle at Bodrum, Turkey[3]. It shows one of ten frames, or partial frames, whose shapes were predetermined and erected immediately after the keel and posts were set up, before any planking was installed. By the first quarter fo the eleventh century in the eastern Mediterranean, and probably long before, the assembly and resulting shape of the outer shell of planking was controlled by standing frames, at least in the middle of the hull. That control was lateral in orientation.

The midship section of the Kyrenia ship, which was excavated off the northern coast of Cyprus and whose remains have also been reassembled in a Medieval castle at Kyrenia, Cyprus, is shown in Fig. 2[4]. It sank in the late fourth century BCE. By means of outward-driven tenon pegs beneath frames and other features, we have determined that none of the frames was erected before the planking strakes they spanned. In fact, none of the frames was fastened to, or even touched, the keel. There is an abundance of evidence to suggest that the nine bottom strakes were installed immediately after the keel and posts were erected, being held to each other by means of closely-spaced mortise-and-tenon joints. Next the floor timbers were installed, then the side planking and wales and, finally, the rest of the frames, futtocks, and top timbers. But was the control of the resulting hull shape also lateral in orientation? Probably not. Many of us are accustomed to studying hulls by means of body plans, section drawings, and other lateral views. Therefore, it is quite natural for us to use this modern perspective for ancient hulls as well, and perhaps to be influenced into thinking that ancient builders also pondered their construction in this manner. But if one builds a faithful model of a mortise-and-tenon joined vessel, another perspective becomes practical in the shaping of the hull, a perspective that should be considered in future research. I believe that the Kyrenia ship's hull shape (and to varying degrees, all ancient hull shapes) was formed and maintained from a longitudinal perspective. In the Serçe Limani hull, the initial shaping members were frames set transversely on the keel; thus the hull was shaped by a series of transverse guides. In the Kyrenia and similar ancient hulls, the initial shaping members were planks set parallel to the keel; thus the hull was possibly shaped by a series of longitudinal guides.

Therein, I believe, lies the greatest difference between the construction of ancient Mediterranean and later vessels—the direction on which hull shapes were accomplished. I will go one step further and suggest that the greatest difference between the mentalities of ancient and later shipwrights—the difference in their structural philosophies—was that one visualized his hulls in longitudinal bands, the other in athwartships configurations.

There were other notable differences between these two vessels, the most profound of which was the fact that the seams of the Kyrenia ship's planks were joined with pegged mortise-end-tenon joints, while the seams of the Serçe Limani planks were not.

Herein lies the key to understanding ancient Mediterranean ship design and construction methods. The mortise-and-tenon joint is the very hallmark of ancient Mediterranean construction, the feature that most profoundly separates those ships from all others. Our initial problem in comprehending this form of construction perhaps lies in our designation of ancient shipbuilding. We say these hulls were "shell-built" or made "shell-first". Those might have been acceptable terms in the past, but they are now insufficient, even misleading, and should be retired with the other ghosts of the past. We seldom refer to Viking ships as shell-built; we say they are "clinker-built", a term that simultaneously recognizes the primary role of their shells of outer planking and the method by which those overlapping planks are secured—with clenchers. Then why not extend the same degree of accuracy to the designation of their southern counterparts and call them "tenon-built?" Such a term would be far more descriptive, since it is not so much a matter of whether or not planks preceded frames as it is whether or not mortise-and-tenon joints were utilized in the hull's construction.

Secondly, we have not examined the function of these joints thoroughly enough—we have not fully appreciated their true purpose. Too often they have been treated as mere fastenings when actually they were hull components, just as frames and knees and stringers were hull components. One of their functions was to serve as fastenings, of course—where they were pegged on either side of the seam, they held the plank edges together. But if that were their only purpose, they could have been spaced much farther apart and their spacing would have varied according to the amount of tension on the seam; at the ends of the hull they would have had to be spaced closer together than along its flat sides, as they were at the end of the Classical period and the beginning of the Medieval period, when their employment had declined to that of mere fasteners or aligners.

But from the fourth century BCE to the first century CE, the period in which mortise-end-tenon joinery had reached its apex in Mediterranean shipbuilding and to which this paper is limited, there is plenty of evidence to suggest additional reasons for their existence. Only four arguments will be presented here.

1. Joints were spaced about 12 cm between centers on small vessels, and that spacing remained rather consistent throughout the hulls (Fig. 3). On large, single-planked vessels such as those at Nemi[5] and Antikythera[6], spacing was similar but here the joints were staggered to take advantage of the thicher seams, the tenons being so large that their adjacent edges were sometimes in alignment or nearly so (Fig. 4). On large, double-planked hulls such as the Madrague de Giens ship, the inner layer joints again were spaced about the same frequencies as on the other vessels but the outer layer joints were spaced somewhat farther apart (Fig. 5)[7]. However, the combined seam ratios of tenon thicknesses, widths, and frequencies to planking thickness exceeded that of single-planked hulls. The consistency of dimensions, spacing, and the ways in which these joints were adapted to their hull forms over half a millennium suggests structural functions beyond that of mere fastenings.

2. The fact that outer planking layers of double-planked hulls were edge-joined, rather than being directly fastened to the frames and interior planking, indicates a structural function other than mere edge attachment.

3. Even when rotten planks were replaced, the structural importance of mortise-and-tenon joints was recognized and maintained. On the Kyrenia ship, a rotten seam was cut away to nearly the centers of the adjacent plank and a new plank inserted.[8] With the frames and adjacent planking still in place, it would have been necessary only to nail the new plank in place and caulk it. That was done eventually, but not until elaborate repair mortises were carved into the inner and outer plank surfaces and curiously-shaped tenons inserted to maintain the normal joint dimensions and spacing (Fig. 6). It was obvious that this shipwright

considered these joints to be more than mere fastenings. Indeed, when one compares the workmanship lavished on these mortises, tenons, and plank edges with that of the fit between inner plank surfaces and frames, it appears that he considered the edge system to be more important that the frames.

4. It required a lot of effort to mark off the mortise locations on the planks, cut the mortises to the desired dimensions and angles, manufacture the hardwood tenons, drill the peg holes in either side of the seams, shape the tapered pegs and drive them, and align and fit the planking edges to the standing tenons and to each other. And yet, little Kyrenia had nearly 4,000 such joints and the big Roman freighters must have had at least five times as many. That was a staggering investment in labor, materials, and time. Even if slave, or poorly compensated, labor was utilized, the cost of those joinery systems still had a profound effect on shipbuilding economics and construction schedules. If those joints were intended to be mere edge fastenings, surely many cheaper and faster alternatives were available.

I have long maintained that mortise-and-tenon joints were, in addition to being edge fastenings, little internal stiffeners—miniature inside frames, if you will—that contributed greatly to the strength of the planking shell. That was evident when we built our sectional and sailing replicas of the Kyrenia ship. With very little shoring and no frames to stiffen the planking shell at all, the shells were quite solid when workmen walked around within them. But there was an additional advantage to these joints. Tests have shown us that they created a seam bond that was nearly as strong and, in some cases, stronger than the plank itself. From a lateral orientation, that explains the relatively weak framing systems found in most of these ancient hulls. For instance, the Kyrenia framing system was much lighter and weaker than that of the Serçe Limani hull of the same size and plank thickness. The added integrity of Kyrenia's seams, however, contributed enough additional strength to more than account for framing deficiency, whereas the Serçe Limani frames provided the sole lateral strength of the submersed part of that hull. Even the framing system of the big Madrague de Giens ship seems relatively weak, considering the size of the hull and the discontinuous nature of its frames[9]. Here, however, both the double rows of joints and the laminating effect of the two layers of planking combined to create a very strong outer shell.

It was from a longitudinal orientation, however, that these joints provided the most benefit, and we have not given this factor enough consideration. The sum of all the joints along a continuous planking seam resulted in an enormous longitudinal strength factor, as if a thick stringer were placed here and, because the joints were internal, locked the curvature of the seam in its desired sweep. That was, I believe, the most important reason for closely and evenly spaced mortise-and-tenon joints—the longitudinal strength factor. Thus small, round hulls like Kyrenia could be made sufficiently strong without the longitudinal benefits of a keelson, stringers, or even permanent ceiling. Longer, larger hulls required additional support, if only to reduce the possibility of tenon shear; the stringers on the Madrague de Giens ship are a good example[10]. Long, narrow warships perhaps required even more stringers and *hypozomata* as well. But, in all cases, the joints themselves contributed appreciably to the longitudinal strength of the hull. It is because of the above statements, as well as the fact that the ratio of frame to shell strength of all these ancient hulls was rather low, that I contend we should reconsider the ways in which the ancient shipwright might have pondered his hull structure.Look again at the midship section of the Kyrenia ship (Fig.2). The lateral shapes of the hull on either side of the keel are not symmetrical, frames are discontinuous and relatively weak, and the floor timbers, which are only 9 cm square and spaced at approximately 50 cm intervals, do not touch, nor are they fastened to, the keel. That hardly looks like a laterally planned section, but rather one that resulted from the construction process.

The planking, on the other hand, appears to be planned rather well. They are not the sort of planking shapes one would use if the frames had been there already, but for this form of construction they are perfect. The first four seams are distributed to compliment the areas of the bottom and ends so that a relatively straight plank could be installed just before the turn of the bilge. The next four strakes are very broad and establish the rounding of the bilge, as well as beginning the definition of the sheer of the sides. By the time the main wale is reached, the desired sheer is nearly accomplished. This, I suggest, is the way in which ancient shipwrights viewed their hulls— by the longitudinal shapes of their inner or outer planking surfaces. I will go one step further and suggest that given hull designs employed given proportions for the shapes of those planks— not precise dimensions or edge angles necessarily, but proportional widths at given locations so that the shape of the hull could be described with a fair amount of accuracy solely by the erection of the planks. Such a process, if formalized and recorded, could have simplified greatly the construction of large numbers of warships at widespread locations.

This, after all, is the way hulls were being shaped in the Bronze Age. Planking shapes such as those for the Royal Ship of Cheops are excellent examples of the way in which planking shapes can form hulls[11]. Better still are those of the Dashur boat at the Carnegie Museum in Pittsburgh, which was completely disassembled, recorded, and then reassembled in the new Egyptian museum section there[12]. These planks appear to have been made by cutting rough,oversize blanks and then literally carving their curvatures in all directions with adzes. This hull, which has no frames at all, was entirely formed by those planking shapes.

The Kyrenia ship is but a sophisticated extension of that form of construction, and the lines of pegged mortise-and-tenon joints are the greatest contributor to that sophistication. I believe that its builders shaped the hull one plank at a time, determining those planking shapes by means of traditional or predetermined proportions or dimensions, and securing the standing structure with rows of closely-spaced joints whose effect on the structure was that of stiff longitudinal frames or stringers. Toward the end of the Classical period, when labor became more of a factor in overall cost, these longitudinal joint systems were replaced by stringers, keelsons, and other internal framework,and joints became smaller and more widely spaced.Eventually, in the Medieval period, they were no longer pegged and contributed little, if anything, to hull strength.

I chose this topic because I feel it is time to alter some of our standing theories, as well as our methods of recording, in order that better progress can be made toward unlocking the secrets of ancient shipbuilding. The recording of hull scantlings, especially, has been a problem in the past. Of the twenty seven wrecks used for this study, few have been recorded well enough to permit a complete analysis of the hull structure. Too often planking widths have been given but not thicknesses, while the reverse would be more informative, or frame and joint spacing was not observed, or key timber dimensions omitted. To record a shipwreck properly, scantling lists and drawings should be complete enough so that one could write contract specifications from which the surviving part of the hull could be built. This includes the dimensions of all timbers and strakes, taken at frequent intervals, planking thicknesses both at the center and edges of the planks and,especially, the complete recording of joint details—widths, lengths, and thicknesses of both mortises and tenons, tenon and mortise shapes, peg location with respect to the seams and the joints, external and internal peg diameters, and the distances between joint centers. The precise recording of these joints is especially important, for they are not merely fastenings. They are components of the primary structure of the hull —the shell— just as much as the planks are components.

To conclude, the following points should be reemphasized as viable considerations in future shipwreck recording and research.

1. The ancient shipwright considered his planking shell the primary hull structure.

2. Whether by mental image, traditional proportions, or formal documentation, he comprehended his hull design before construction began and could predict and control it with a fair degree of accuracy.

3. The hull was shaped, and its form controlled, by the carefull determination of longitudinal planking shapes. On the Kyrenia ship, that might have been a fairly simple and informal process. On large warships or freighters, such as the Madrague de Giens vessel, it must have been a rather sophisticated process and propably at least as accurate and scientific as the projection of frame shapes in the seventeenth century. Such a process, if formalized and recorded, could have simplified the construction of large numbers of warships in widespead locations.

4. While cleats, braces, control frames, and other devices might have been used to help maintain the hull shapes during construction, it was the mortise-and-tenon joints that played the most important role in this respect.

5. Mortise-and-tenon joints were as vital to ancient Mediterranean hull structures as frames, keels, and planks. They joined the seams, provided longitudinal and lateral stiffening, and contributed greatly to the overall strength of the hull.

6. We must record and publish hull remains more completely if we are to fully understand ancient shipbuilding technology.

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NOTES

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9. Pomey, *Madrague de Giens*, 80-84, Pl. XXX, XXXVII.
10. Pomey, *Madrague de Giens*, Pl. XXVII, XXXVI.
11. For instrance, see fig. 42 in Paul Lipke, *The Royal Ship of Cheops*, BAR Int Series 225, Greenwich (1984).
12. Cheryl Ward Haldane, *The Dashur Boats*, Master's thesis, Texas A&M University (1984): 39-64.

ILLUSTRATIONS

Fig. 1 A half-section of the Serçe Limani hull at amidships.

Fig. 2 A simplified drawing of the Kyrenia ship's surviving timbers at amidships.

Fig. 3 Mortise-and-tenon joint details for a typical small vessel. Not to scale.

Fig. 4 Typical arrangement of joints at the planking edges of large, single-planked hulls. Not to scale.

Fig. 5 Typical arrangement of joints at the planking edges of large, double-planked hulls. Not to scale.

Fig. 6 A portion of one of the replacement strakes in the bow of the Kyrenia ship. The view at right shows a cross-section of a typical repair ("patch") tenon installation. Not to scale.

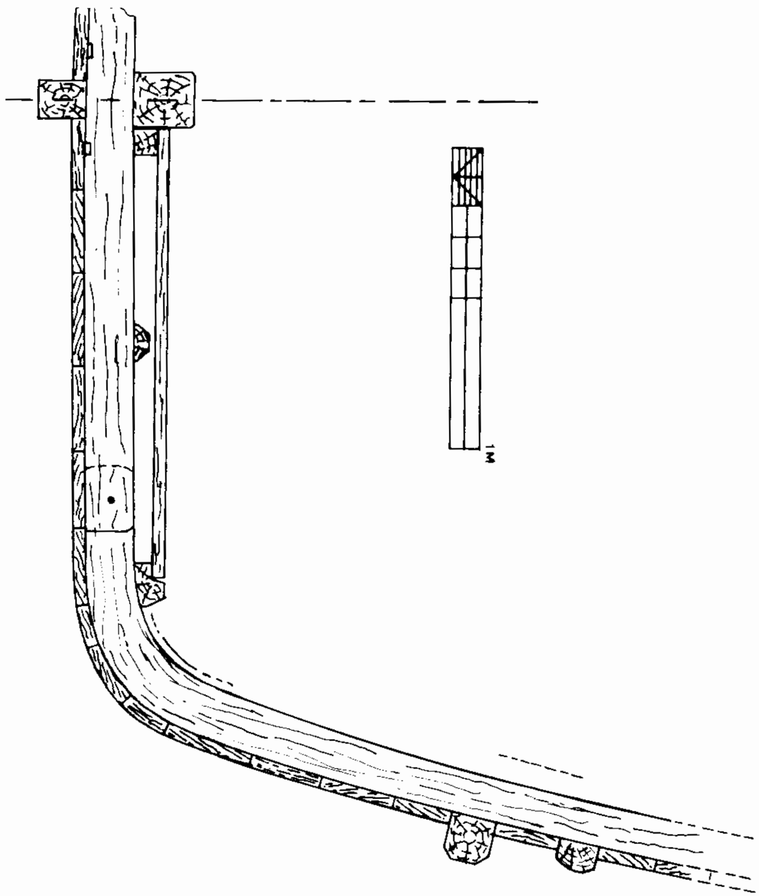

Fig. 1

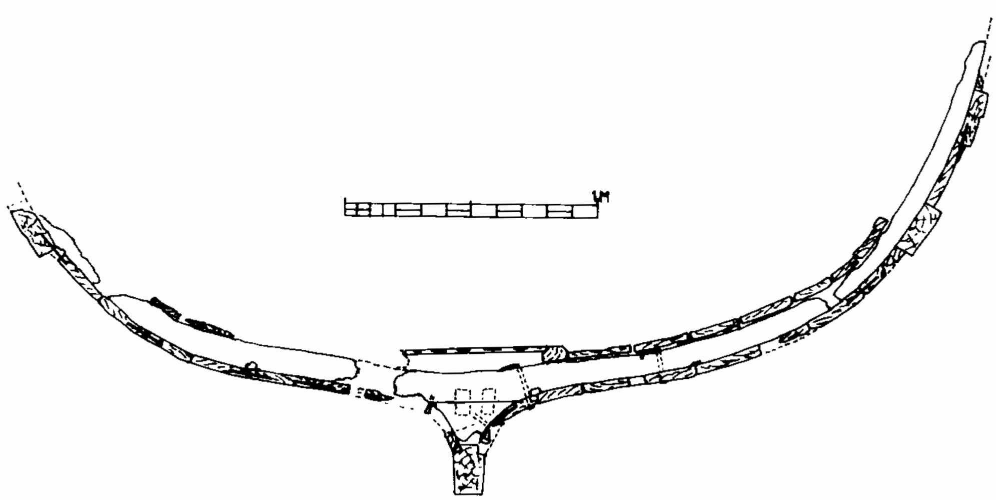

Fig. 2