The development of ancient and medieval shipbuilding techniques

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The shipbuilding processes that preceded and may have influenced the development of Iberian shipbuilding are numerous and varied. Essentially, the subject encompasses the history of shipbuilding technology as it evolved throughout the Mediterranean region and northern and western European coasts and rivers over a period of more than ten millennia. The following pages list what I consider to be the most important features and processes from those areas.

We can only guess at the origins of watercraft in these two great maritime theaters. Certainly there were reed boats and animal skins and rafts of various sorts, but eventually wood became the most widely accepted material for hull construction; it remained the material of choice for most ship and boat builders until the last century. From a practical standpoint, formal shipbuilding technology began when two or more pieces of wood were assembled to produce a displacement vessel. It, too, was a process that originated thousands of years ago and continues to evolve to this day. While there is plenty of iconography and some textual material relating to this evolution, the most important features and processes can only be interpreted by studying actual watercraft from the periods in question. The oldest example dates to fourth-dynasty Egypt. Let's begin with that.

Southern Shipbuilding

Many people are impressed by the Great Pyramid at Giza in Egypt, but I am far more impressed by what was in a pit beside the pyramid — a disassembled but nearly complete wooden boat, known as the Royal Ship of Cheops, that dated to about 2650 BC (Lipke, 1984). Although this was a funerary boat and may have had no practical seagoing or riverine function, it probably was built by some of the best shipwrights available to the pharaoh; its design and workmanship are superb. At the very least, it can be compared with iconographic sources and some conclusions formed concerning early Bronze Age ship and boat construction in the Mediterranean region.

What impresses me most about the Royal Ship of Cheops is how much thought and finesse went into its construction. Indeed, the transition between the first log or reed boats and the great clipper ships of the last century must have been halfway completed by this time in this part of the world. These early builders obviously knew a lot about the properties of wood and they probably had a strong sense of the problems of hull strength, buoyancy, stability, and handling. They also produced miracles with bronze tools.

The Cheops ship was a large vessel — 43,63 m long, 5,66 m broad amidships, with a hull weight estimated at nearly 40 tons (Fig. 1a). Its hull consisted of only three major components: planking, frames, and beams. There was no keel, keel plank, or backbone of any sort. Cedar planks, 12 to 15 cm thick, supplied most of the hull's strength. Their edges were aligned with loose tenons, and they were held together by means of a complex transverse lashing system (Fig. 2a). Planking edges were joggled in order to provided resistance to hogging and shifting. Planking ends were joined by means of butts and scarfs. Sixteen frames

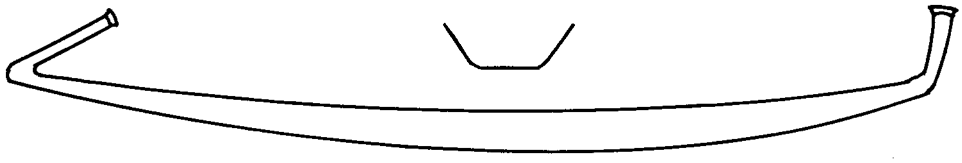

FIG. 1A – The Cheops hull.

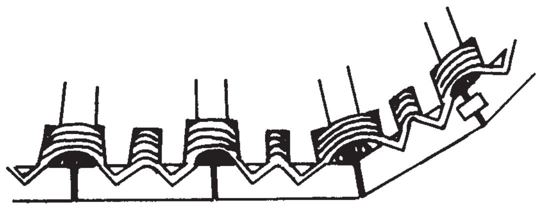

FIG. 2A – An edge view of the belts of transverse lashing on the *Cheops* hull.

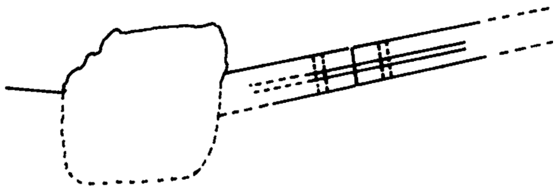

FIG. 2B – An *Uluburun* planking seam, mortise-and-tenon joint, and part of the keel.

provided lateral stability and strength. Sixty-six deck beams supplied additional lateral support, and three longitudinal beams increased the strength in that direction and must have helped appreciably in combating hogging. They, too, were lashed in place.

There was a superstructure and other hull components, but the planks, frames, and beams described above were the primary hull components. Thus, more than forty-six centuries ago, there were shipwrights capable of building vessels more than 40 m long that had fairly sophisticated solutions to the problems of structural integrity. Several hull components already appeared to have resulted from long periods of development and experimentation. Planks were strong, well formed, and were joined into strakes by means of scarfs, butts, and rabbets. Tenons were already in use to align edges, although they lacked pegs and therefore were not fasteners. Frames, while sparse and poorly formed, supplied a considerable amount of lateral integrity, as did the beams. Certainly, working vessels like the seagoing ships that delivered the cedar to construct this and a similar hull nearby must have had an equal, if not far greater, amount of hull strength. It is unlikely, however, that their structural arrangements were any more elaborate.

Ship timbers found at Lisht had been used in a ramp or roadway near the pyramid of Sesostris I. Believed to have come from a very large working vessel, these planks had mortises and tenons in their edges that were considerably larger than those at Giza, yet the construction appears to have been similar in all other respects (Haldane, 1988, p. 141-152). Reliefs of Hatshepsut's eighteenth-dynasty seagoing ships show papyriform hulls with construction features that might not have differed dramatically from the Cheops hull, although here an elaborate squaresail rig and a pair of quarter rudders are illustrated. Most importantly, these vessels used a gigantic truss system to compensate for hogging.

Thus the basic forms of Mediterranean ship construction and handling were already defined in dynastic Egypt, and perhaps in slightly different forms in other Mediterranean areas. It was a definition that would prevail in one version or another until well into the medieval period. Unfortunately, the only Bronze Age seagoing ship to provide structural information is the fourteenth-century Uluburun wreck, and even that hull is represented by only a few percent of its original structure (Pulak, 1988, p. 1-37). There is an unrabbeted keel or keel plank, sided 27,5 cm and molded 22 cm (Fig. 2b). Plank edges, 6 cm thick, are joined with huge mortise-and-tenon joints spaced at approximately 21 cm intervals. These joints penetrated the planks deeply, in some cases nearly spanning their entire widths. One joint had a mortise 17 cm deep and 7 cm wide, and its tenon was nearly 2 cm thick. Most importantly, these joints were locked with 2.2 cm diameter pegs. No frames or frame impressions were found within these limited planking surfaces, and there were no seam lashings. Thus the Uluburun wreck appears to have been planked with a relatively thick skin that was secured with strong, locked mortise-and-tenon joints. Frames, if they existed at all, must have been very widely spaced. As of this writing, there is no new information concerning additional timbering details or hull design.

No other substantial seagoing hull remains have been recorded in the Mediterranean that date before the sixth century BC. Obviously, a lot more Bronze Age and early classical ship remains are needed to complete our understanding of the development of early Mediterranean shipbuilding. The sixth century finds were nearly all sewn boats, with the Bon Porté and Marseilles vessels providing the best understanding of this form of construction. Survival of the little Bon Porté hull was limited to part of its bottom, but that bottom was rounded (Fig. 1b) and suggested a considerably fuller hull shape than those papyriform hulls discussed above (Pomey, 1981, p. 225-242). There was a small, unrabbeted keel, 2 cm-thick-planking, and widely-spaced built-up frames whose floor timbers were diagonally scarfed to futtocks. The sixth-century BC Greek hull (hull number 9) excavated a few years ago in the harbor of Marseille may have been shaped similarly, but it was larger and much better preserved, with several nearly complete frames and an extensive planking shell that utilized at least three types of scarfs (Pomey, 1995, p. 470-482). But the most interesting feature of both of these wrecks was their planking edge-joinery. There were no mortise-and-tenon joints here. Instead, treenails were inserted into aligning holes in each of the plank edges and the seams were held together with a lashing system that ran longitudinally along the lengths of the seams (Fig. 2c). Ligatures were additionally locked in place by means of small pegs driven into the ligature holes.

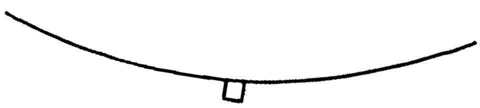

FIG. 1B – The sixth-century BC sewn vessels (central bottom shape only).

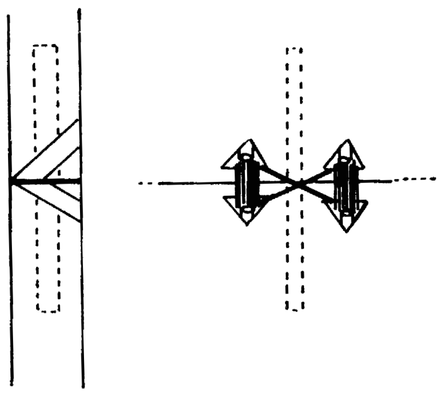

FIG. 2C – Edge and inner views of the sixth-century longitudinal seam lashing holes and one of the transverse aligning treenails (in dashed lines).

There are a number of theories concerning the role of ligatures in the evolution of Mediterranean hull construction. Some argue that ligatures were the original systems and were gradually replaced by mortise-and-tenon joints. Others contend that sewn hulls and mortise-and-tenon joined hulls coexisted throughout. Surviving hull remains merely cloud the issue. The fourteenth-century BC Uluburun hull had no ligatured seams at all. The fourth-century BC Kyrenia ship, on the other hand, also was mortise-and-tenon joined throughout. However, it had reused ceiling planks that were cut from a small hull which had ligatured seams similar to those in the sixth-century vessels (Steffy, 1985, p. 95)[1]. Obviously, the two systems must have coexisted in the eastern Mediterranean as late as the fourth century BC. Indeed, there was a coexistence of the two systems within the same hull in at least one case. The Ma'agan Michael hull in Israel had seams that were sewn longitudinally only in the ends of the hull (Linder, 1989, p. 5-7; Rosloff, 1990, p. 3-4). Elsewhere, planks were mortise-and-tenon joined. Further shipwreck discoveries, especially those dating to the Bronze Age, will be needed to clear up this mystery.

The Ma'agan Michael vessel had frames that resembled those on the Bon Porté wreck in that futtocks were scarfed to floor timbers in a single line and were widely spaced (about 75 cm centers). Elsewhere, it was constructed like the larger Kyrenia ship, which it closely resembled. The Ma'agan Michael wreck is tentatively dated to the early fourth century BC. The Kyrenia ship was built later in that same century (Steffy, 1994, p. 42-59). Made entirely of Aleppo pine, the Kyrenia ship had a rockered, rabbeted keel that was fitted with a false keel, a two-piece stem, and a kneed sternpost. Planking averaged just under 4 cm in thickness and was formed into a lightweight but strong shell with a carefully made, pegged mortise-and-tenon joint system that was spaced on 12 cm intervals (Fig. 2d). A strong framing system was composed of floor timbers and futtocks alternating with pairs of half-frames and top timbers. All frame timbers were double-clench nailed to the planks, but none were nailed to the keel. Room and space was about 25 cm. Cant frames were used to brace the ends of the hull. There was an excellently distributed set of wales, and a thick shelf clamp backed the main wale internally. Indeed, all of the major hull components that would be used for the next two millennia were present on the Kyrenia ship with one glowing exception; there was no keelson. It would be a couple of centuries more before that member was fully and properly applied. That is not to say that these ancient shipbuilders ignored the problem of longitudinal strength, however. The keel was rockered to combat hogging, and the wineglass-shaped hull was really a partial solution to the problem as well (Fig. 1c). The V-shaped entry of the lower strakes into the keel was reinforced by chocks beneath the floor timbers, producing a box girder effect that must have added considerable longitudinal strength. However, the shipwright did not improve on that strength by securing the frames to the keel. This keel merely served as the keystone of an inverted arch of planks.

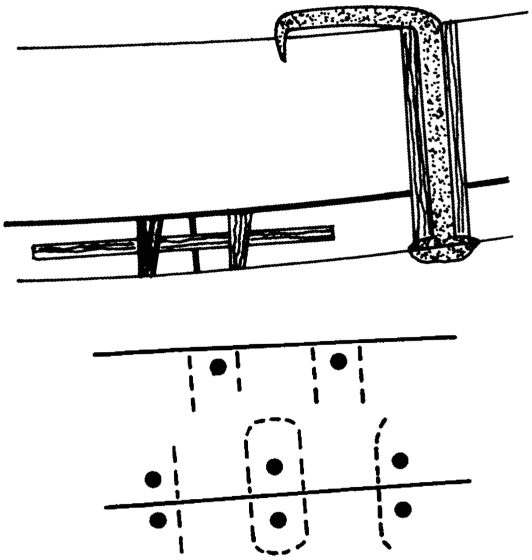

FIG. 2D – Edge and inner surface views of the mortise-and-tenon joinery systems and a typical clenched nail in The Kyrenia ship.

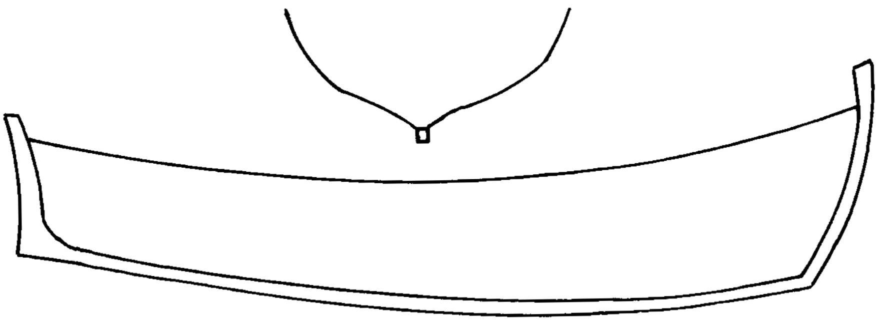

FIG. 1C – The fourth-century BC Greek hulls.

The ancient Greeks contributed appreciably to the development of shipbuilding technology, a necessity brought on by the enormous expansion of the empire. Trade routes became longer, cargoes more specialized, and the need for larger, stronger, and more serviceable vessels undoubtedly brought about more sophistication and experimentation among shipwrights. Along with the expansion of the empire came an expansion of naval forces, and stronger and larger naval galleys were a hallmark of the Greek empire. This trend was continued by the Romans, not only with warships but especially in the development of larger and stronger merchantmen.

In my opinion, the most magnificent ancient structure ever revealed to us has been the first-century BC Madrague de Giens merchant ship excavated by French archaeologists a couple of decades ago (Pomey, 1978, 1982). Some will argue that such a distinction belongs to temples or pyramids or the like. I will agree that it took a lot of labor and a certain amount of engineering to pile up all that masonry, but temples and pyramids just sat there and mostly they merely impressed people. As one of a kind items, they contributed relatively little to the advance of technology or the expansion of commerce or the improvement of society. Ships, on the other hand, were the very backbone of human development, and the one at Madrague de Giens is a reminder of the ingenuity and persistence that went into that development. This was, first of all, a big ship — 40 m long, 9 m in the beam, and capable of carrying at least 400 tons of cargo (Fig. 1d). Part of its strength was derived from lami-

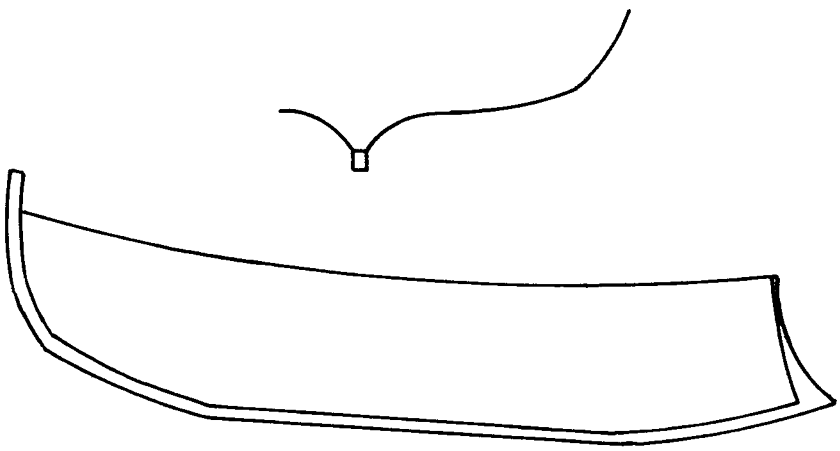

FIG. 1D – The Madrague de Giens hull.

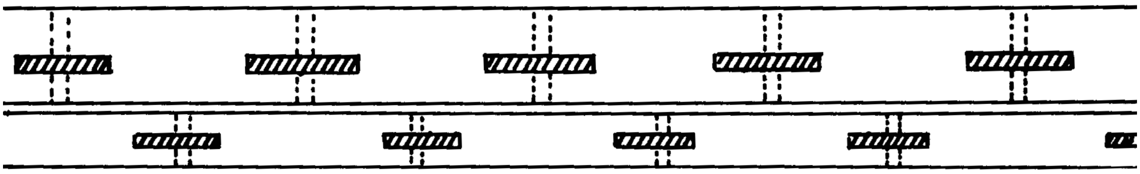

FIG. 2E – The Roman arrangement of edge-joinery in large double-planked hulls.

nation; there were two layers of planking, 6 cm and 4 cm thick, with a protective barrier between them (Fig. 2e). This gigantic shell was secured with tens of thousands of closely spaced mortise-and-tenon joints and it was nailed and treenailed to a framing system that consisted of alternating floor timbers and half-frames, each with futtocks as on the Kyrenia ship. There was a complex keel and post system, and closely spaced ceiling stringers provided plenty of bottom support.

The Madrague de Giens vessel was indeed magnificent. There was only one thing wrong with it from a modern point of view, and that was the enormous amount of labor and material required to build it. That was not so much of a problem in ancient Rome, especially the labor part, although in a few more centuries all that would change. But this was by no means the only way in which big Roman merchantmen were constructed; several of them have been excavated that had single layers of very thick planking. For instance, the first-century vessel documented at *Caesarea* in Israel had planks 9 cm to 10 thick, with gigantic mortise-and-tenon joints staggered in their edges and spaced on approximately 14 cm intervals (Fig. 2f) (Fitzgerald, forthcoming). And these were by no means the largest of Roman merchant ships. Literary documents indicate there were considerably larger ships carrying grain from Egypt to Rome as well as warships of gigantic proportions. There is plenty of evidence to suggest that all of them had mortise-and-tenon joined planking shells that were at least partially assembled before frames were inserted.

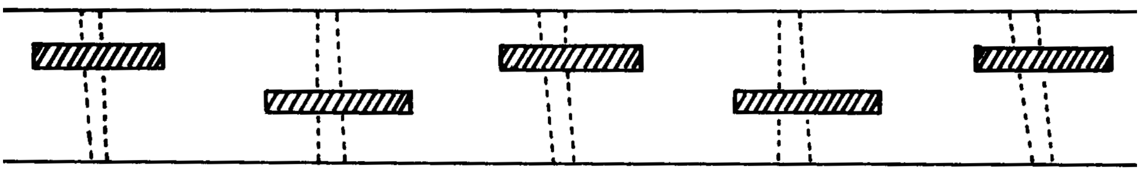

FIG. 2F – The Roman arrangement of edge-joinery in large single-planked hulls.

This form of construction appears to have continued for a few more centuries. A small and very complete merchantman excavated at l'anse des Laurons was dated by coins to the end of the second century AD. It had a shell of planking whose seams were joined by means of pegged mortise-and-tenon joints that were centered every 10 to 12 cm (Gassend, Liou and Ximénès, 1984, p. 75-105). Even its 4-cm-thick deck planking was mortise-and-tenon joined, a feature for which there is spotty evidence as early as the fourth-century BC. This was an extremely full, strong, and efficient hull, although presently it is the latest example of this form of construction. A fourth-century merchantman excavated at Yassiada, Turkey, offered clues that shipbuilding was adjusting to a different environment than that existing in the classical Roman world (Van Doorninck, 1976, p. 115-131). Planks probably still preceded frames in the construction sequence, but the edge joinery was not nearly as sophisticated or as strong as that of the *Laurons* hull mentioned above. These joints, while still pegged, were spaced much farther apart and the tenons were considerably smaller than the mortises they occupied.

The transition in Mediterranean construction maintained that direction, according to information gleaned from a pair of later vessels. The first was a small craft (about 12 m long) named Tantura A, one of a number of hulls recorded in Tantura Lagoon in Israel (Wachsmann and Kahanov, 1997, p. 3-18). It was dated to the sixth century AD. While only the keel and one side of the bottom survived, none of the exposed planking seams contained mortise-and-tenon joints. Frame survival and other planking details seemed to indicate that this hull was constructed in a manner whereby planking and frames were erected interchangeably, although the exact sequence of assembly has not yet been determined. A larger merchant vessel (about 20 m long) sank off the Turkish coast at Yassi Ada about AD 625 (Fig. 1e) (Van Doorninck, 1982, p. 32-64; Steffy, 1982, p. 65-86). The date of its construction, however, may have been close enough to that of the Tantura A vessel to warrant a comparison. This was a strong seagoing merchantman, with half-frames alternating with floor timbers, a heavy keelson, a belt of four wales, and a strong internal system of stringers and clamps. Mortises and small tenons still occupied some of the planking seams of this hull. They were not joints, really, but merely loose slips of wood that kept the planks aligned until framing was complete, much in the way such tenons were used in the Royal Ship of Cheops (Fig. 2g). The tenons were only half the size of their mortises, and none of them were pegged. Furthermore, they were mostly concentrated in locations where planking tensions were the greatest. In the ends of the hull they were spaced 35 to 50 cm apart; amidships spacing was as great as 90 cm. Even this form of seam alignment was not used in the entire hull. Above the turn of the bilge, there were no more joints. Planks and wales were erected only after a rigid framing system was in place. Straight iron nails and iron forelock bolts were the primary fasteners. A number of other examples of these two hull forms have been recorded.

It would be helpful to know what the people who are presently excavating the ninth-century Bozburun wreck in Turkey will tell us about that structure (Hocker and Scafuri, 1996). That hull might prove to be an interesting link between the Yassiada ship and the

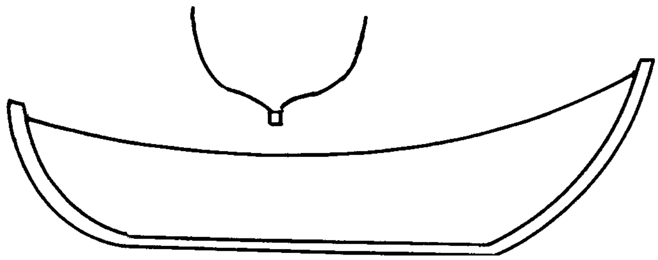

FIG. 1E – The seventh-century Yassiada.

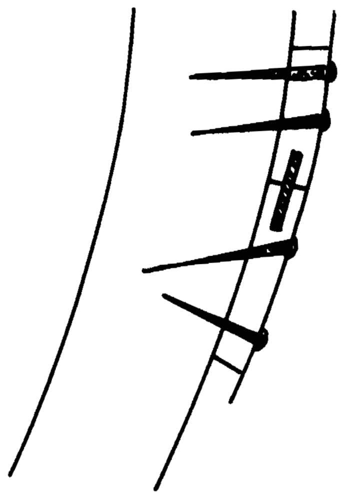

FIG. 2G – Planking seam alignment and nailing method of the Yassiada Byzantine vessel.

next one we have analyzed extensively — the Serçe Limani medieval ship (Steffy, 1994, p. 85-91). The Serçe Limani vessel, which sank off the southern coast of Turkey about 1025, was obviously a product of further improvements in this technological evolution (Fig. 1f). There was a series of pre-erected frames in the central part of the hull and at the ends of the hold (Fig. 2h). All frames crossed the keel and were nailed to it, while a large keelson was bolted to the keel with forelock bolts. Planking was nailed and treenailed to the frames. This roomy, very practical merchantman obviously was built to a well-established form of shipwrightery that used common angles, geometric proportions, and a unit of measurement that was almost identical to the so-called Byzantine foot. It seems most likely that mold lofting and batten projections of hull shapes were already understood and used by these shipwrights, albeit with less finesse than some of the Iberian methods to be presented later.

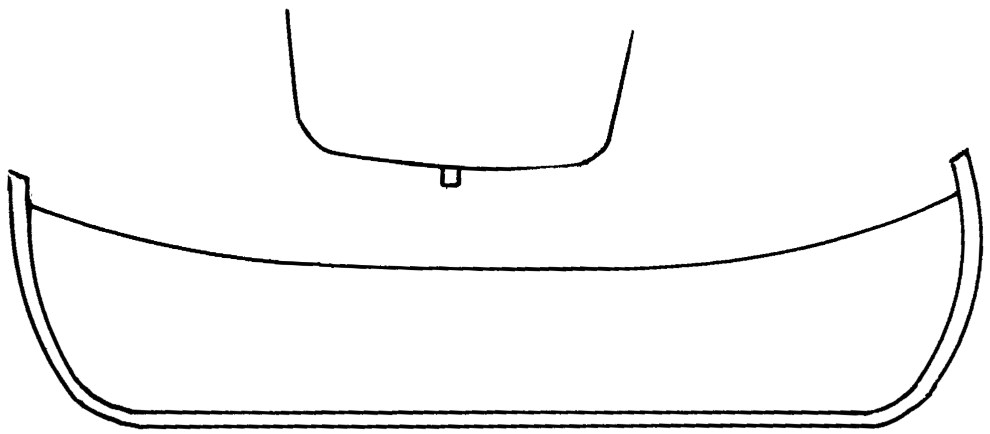

FIG. 1F – The eleventh-century Serçe Limani hull.

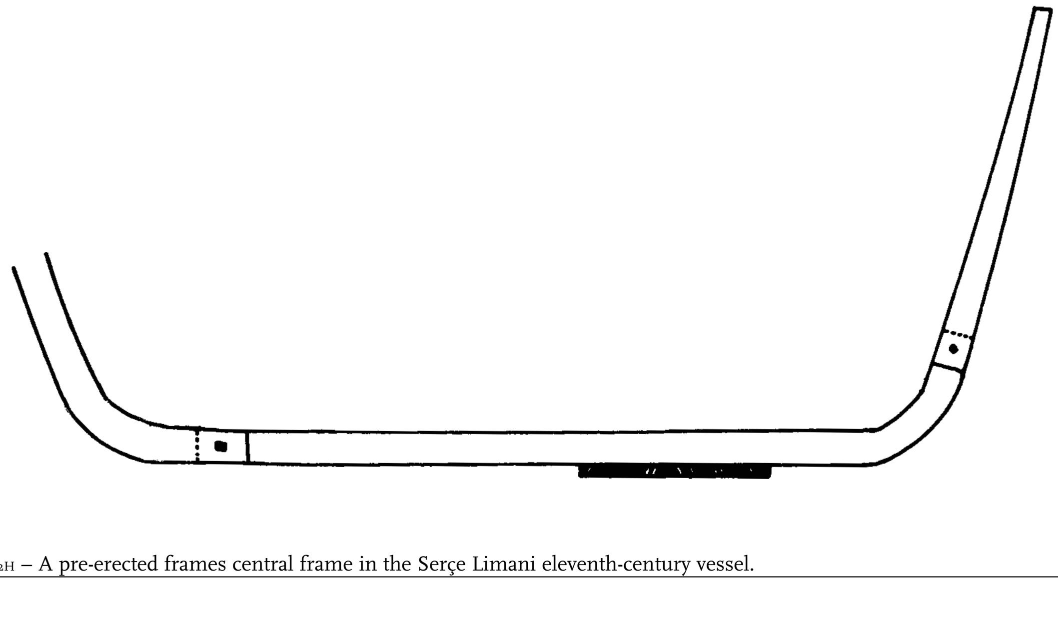

FIG. 2H – A pre-erected frames central frame in the Serçe Limani eleventh-century vessel.

A wreck known as Contarina I was excavated a century ago in Italy's Po Delta (Bonino, 1978; Relazione, ... , 1900). Its appearance and rig were similar to that of the Serçe Limani ship, except that its bilges were more gently rounded. Dated to about 1300, it displayed further improvements in the projection and arrangement of framing systems in merchant vessels. Built entirely of oak, its frames were constructed of five timbers — a floor timber, two futtocks, and two top timbers — and were placed so close together where timbers overlapped at the turn of the bilge that they resembled the framing systems of later Iberian transoceanic vessels. There were at least three control frames, one amidships and one at each end of the hull, from which the rest of the system could have been projected from standing battens. Like the Serçe Limani vessel, this also was a two-masted lateener with a very full hull. It is easy to understand, by careful examination of the construction arrangements of the Serçe Limani and Contarina hulls, how the systems described a little later in Venetian documents evolved from these earlier methods.

Northern and Western Traditions

Like southern construction, northwestern European shipbuilding evolved from a plank-first tradition, perhaps directly resulting from expanded logboat techniques[2]. Longitudinal seam lashing was already being practiced in the Bronze Age, at least in the case of the three Ferriby boats discovered in England (Wright, 1990). The best preserved of these was 13,3 m long and is presently dated to the twelfth or thirteenth centuries BC. It had three bottom strakes and is believed to have had three strakes on each side, all made from oak. The central strake was 14 cm thick and 65 cm wide, the others about half that thickness. Each seam was laced from end to end with withy pounded from yew. Planking seams were rabbeted and caulked with moss, as were the withy holes. In order to reinforce the bottom, transverse rods were run through cleats that had been shaped from the bottom planks. The bottom of the hull was rockered, and it must have presented an appearance that somewhat resembled similarly sized papyriform hulls.

And so, this earliest of well-preserved planked hulls from the northwest already showed signs of a form of development that would continue for another two millennia or so — cleats formed directly from the planking stock, lashings of withy, caulking of moss, and oaken construction. This vessel lacked the other major component of northwestern development, however — overlapping planking seams.

By the time Romans had occupied the continent as far west as the British Isles, several traditions seemed to be underway. The first, most commonly known as the Romano-Celtic tradition, is presently represented by several wrecks dating to the first few centuries of the Christian era. One such representative was the Blackfriar's vessel, a heavy oaken hull dated to the second century AD (Marsden, 1966). It had a belt of thick central planks but no keel, extremely heavy floor timbers spaced on 20 to 25 cm centers, and planking that was double-clench nailed to the frames with mushroom-headed iron nails. The planks were in no way edge-joined. The second tradition was definitely a Roman one, touting mortise-and-tenon joined edges and other features found in Roman Mediterranean craft. The third-century County Hall vessel in London is one example, although local influences could also be detected in that hull (Marsden, 1974). There were other, possibly localized hull forms in northwestern Europe, but only one of them is of importance to this study.

While the second (Roman) tradition may have involved a construction sequence similar to that of classical Mediterranean hulls, the first type was built in a sequence where frames, or some form of framework, must have preceded planks (McGrail, 1995, p. 139-145). On these so-called Romano-Celtic types, the planking played a more passive role in that it was largely a watertight skin while most of the hull strength was centered in the massive framework. Both types, however, were smooth skinned. Whatever the level of their influence might have been on medieval and later periods of hull construction, they do not seem to have had the effect of the highly documented, carefully studied lapstraked hulls. Unlike the Mediterranean progression, the northeast did not maintain its smooth-skinned designs in many areas. Overlapping planking seams ruled the roost for centuries.

Overlapping seams were recorded for hull remains in the north as early as the fourth century BC (the Hjortspring boat), where two planks on each side overlapped and were fastened to a broad central plank (Crumlin-Pedersen, 1972, p. 208-234). The Nydam oak boat, dated to AD 350-400, was a classic example of what was to follow in the forms of all types of Viking craft (Shetelig and Falk, 1937, p. 353). It had five overlapping strakes on each side of a thick, T-shaped central plank. Each overlapping seam was fastened with iron nails clenched over roves. The hull was reinforced with frames (ribs, really) lashed to cleats that were carved from the planking stock. But the best examples of this form of construction are the later Viking craft — the Gokstad (about AD 850) (Brogger; Shetelig, 1971; Damman, 1983) and the *Oseberg* ships in the Oslo and the great variety of somewhat later vessels on display at Roskilde to name but a few (Fig. 3a) (Crumlin-Pedersen and Vinner, 1986; Olsen and Crumlin-Pedersen, 1967). The Oslo hulls were also cleated and lashed (Fig. 3b), but the later Roskilde vessels had frames notched over the planking laps and rigidly fastened to the planking with treenails (Fig. 3c)[3]. They also sported heavy keels, elaborate post construction, keelsons, horizontal and vertical knees, shelf clamps, stringers, beams, and, of course, iron nails clenched over square roves at the seams. Some of these Viking vessels were enormous; one recently excavated at Roskilde was 35 m long. The Roskilde vessels also came in a variety of designs, ranging from small fishing craft to longships to roomy merchantmen.

FIG. 3A – A sketch of the sheer and body shapes of a Viking vessel.

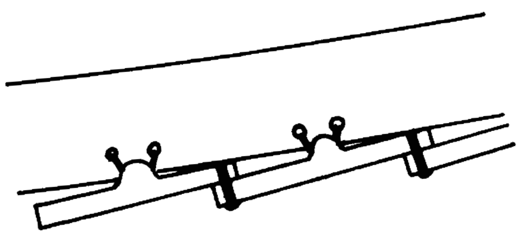

FIG. 3B – The planking laps, cleats, and frame lashing system of the Oslo vessels.

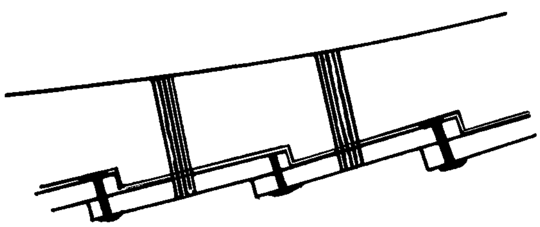

FIG. 3C – The notched frames and treenail fastenings of a Roskilde vessel.

While those later forms of Viking craft were being developed, other forms of construction were being blended with lapstrake methods to meet the demand of growing populations and expanding mercantile markets. Known as cogs, they were composed of flat bottoms, steep ends, and clinker-built sides. In the thirteenth and fourteenth centuries, these vessels are said to have developed into the large seagoing cogs associated with Hanseatic traders. Perhaps the best known of the Hanseatic traders is the Bremen cog, dated to 1380 (Kiedel and Schnall, 1985). The hull was 23,2 m long and 7 m in the beam (Fig. 3d). A keel plank and six broad bottom planks were fitted edge to edge to form the bottom. The turn of the bilge also was made up of strakes of aligned planks, but the sides above this were formed of standard lapstrake planking, the overlaps being secured with closely spaced double-clenched nails. These seams were caulked on the inside with moss, animal hair, and pitch and the compound secured with willow laths. Planks were treenailed to heavy frames. A heavy keelson and large beams were part of a strong internal structure. This vessel was steered with a stern-hung rudder.

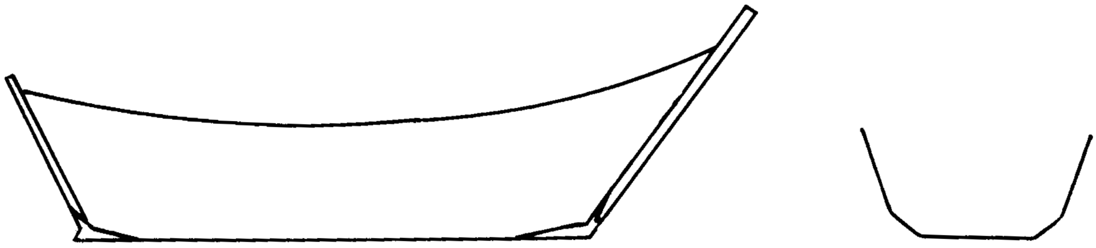

FIG. 3D – The sheer and body outlines of the Bremen cog.

Our overview must end here, even though it reveals only a tiny fraction of all the details we have learned from nautical archaeology the past few decades. Considerably more coverage was given to Mediterranean shipbuilding history, in part because there were more examples of complex technology over a longer period of time, but also because I lack personal experience in northwestern hull research and reconstructions. Nevertheless, these were the features that I feel contributed most strongly to Iberian shipbuilding. This study should have revealed that there were two distinctly different, yet often quite parallel, disciplines at work. In both areas, centuries of shell-predominant hulls with rigidly locked seams slowly gave way to frame-dominant systems with shells that were little more than watertight skins. Perhaps the most fascinating feature of this evolution was the ingenious process by which these shells were made lighter and fuller, and much more serviceable, by rigidly fastening those planking edges together — laterally in the north and transversely in the south. And finally, changing societies demanded, and existing technology permitted, an equally ingenious process of eliminating those edge fastenings. It was a process that included the adoption of geometric proportions and projections that resulted in stronger, cheaper, faster, and far more practical hulls.

I terminated my analysis with distinctly Mediterranean and northwestern European types, Contarina and Bremen merchant vessels. Although there are many other acceptable candidates, these two types of ships are fitting representatives of the culmination of the two disciplines that I believe played a significant role in the development of those marvelous deepwater vessels that ventured east to India and the Orient and west to the Americas. Each had a roomy, practical design that made the best use of local materials and labor and was the most compatible to local weather conditions and geography. And each was the result of centuries of slow but steady and innovative progress that reinvented itself as the environment and society it served changed. Contarina had a lateen rig and a pair of quarter rudders; Bremen had a square rig and a stern-mounted rudder. Both were strong, efficient vessels built to a level of technology that was amazingly complex for its time and, even today, insufficiently appreciated.

Students and colleagues must have grown tired of hearing me say that the hull is almost always the most valuable artifact on a shipwreck. It is certainly the largest and most complex of all the artifacts, and it has a history that few, if any, other artifacts can match. It was, first of all, mobile and usually it was larger than any of the other mobile structures of the world, and that put it in a class by itself. It was the vehicle that facilitated the development of international trade, of exploration, of the building of empires, the acquisition of new materials and processes, and the general improvement and expansion of the human race. These were marvelous structures, especially the big seagoing ships, and they were about to become even more impressive. It was when these two disciplines met on the Iberian peninsula that the next step of technological development occurred. Some of the best of each were combined with new and innovative improvements, and eventually the limitations of our super artifact were extended to the ends of the earth. The papers that follow will tell us all about it.

NOTES

1 Additional documentation of this feature is presently being prepared for publication.

2 For detailed information on northwestern construction, see McGrail,1998.

3 For general information on Viking ship construction and evolution, see Crumlin-Pedersen, 1987. Also see Hale, 1998.

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