

LEAD HULL SHEATHING IN ANTIQUITY¹

Thin exterior sheathing of lead is a relatively common feature of ancient shipwrecks in the Mediterranean. It normally consists of large sheets, one to two millimeters thick, laid over some sort of fibre impregnated with resin or pitch and held in place by copper tacks in a characteristic “quincunx” pattern. It has been suggested, perhaps on analogy with the development of copper bottom sheathing in the 18th century CE, that ancient hull sheathing was intended to protect the underlying wood from attack by marine borers, such as the mollusc *Teredo navalis*, and other destructive sea life.² Such protection would certainly be useful in the Mediterranean, where wooden vessels have exceptionally short working lives, even with modern anti-fouling paints and preservatives. Metal could provide a barrier to such organisms, and, indeed, was eventually chosen as the most effective means of preserving modern wooden vessels travelling to the even more destructive tropical waters of the West Indies.³ Alternatives to metal include the use of light wood sheathing, which could be stripped off and replaced before infestation reached structural timbers.

Careful examination of the way lead sheathing was used in antiquity suggests that the primary purpose was not, in fact, protection against borers. Where sheathed hulls have been sufficiently preserved, the lead (or evidence of it) usually extends well above the waterline, generally to the limits of preservation.⁴ Borer protection is not needed on most of the topsides, and modern copper sheathing stopped just above the load waterline. More importantly, several of the sheathed hulls seem to have been poor candidates for this sort of protection. The *Kyrenia* ship was already old and teredo-riddled when it was first sheathed in lead,⁵ and the *Nemi* barges were employed on a freshwater lake with no navigable connection to salt water, and thus no shipworm.

Surely protecting a worn-out, infested hull such as the *Kyrenia* ship was false economy; could sheathing be reasonably expected to extend the life of timber already seriously deteriorated? It has been suggested that the *Nemi* barges were covered in lead because they were imperial state vessels and as such should

have reflected the best techniques of Roman shipwrights, whether appropriate or not.⁶ While I am not qualified to interpret Roman attitudes towards conspicuous consumption, many construction features on the Nemi barges indicate that they were not typical of Roman commercial shipbuilding. The framing system, if system it is, is unique in the ancient Mediterranean and must have been a deliberate solution to the problems presented by the wide, flat floors of these immense vessels. Similarly, the heavy spikes used as edge fastenings in the planking and iron strapping in the deck structure are quite clearly responses to the peculiar requirements of floating pleasure palaces rather than examples of contemporary deepwater practice. Nevertheless, while the vanished upperworks of these hulls were the height of extravagance, there is nothing frivolous or superfluous about the underwater structure that supported them. Should there not be a more rational, practical explanation for lead sheathing on the Kyrenia and Nemi vessels? What need do they share that lead might satisfy?

All three must have leaked quite badly. As vessels age, the timbers work against each other, compressing and wearing adjoining surfaces. Joints and seams become loose, and more and more caulking is required between the planks. For larger vessels, the problem is exacerbated by the greater difficulty in providing adequate initial stiffness in long, heavy structures made of elastic materials (such as wood). The trials of the replica Kyrenia II have shown that when new, the Kyrenia ship was quite watertight,⁷ but the soft, worn-out hull of the Kyrenia ship as excavated was probably well past the point where plank swelling and mortise and tenon joints could keep all the seams watertight. The Nemi barges, because of their sheer size and weight - they must be two of the largest mobile wooden structures built in the ancient world - must have been nearly impossible to provide with much stiffness. Large Roman seagoing ships, such as the Madrague de Giens wine carrier, used complex curvatures and deep sections to create a box-girder effect within the hull, increasing the overall strength and stiffness of the structure, but the relatively shallow, flat shapes of the Nemi barges add little to overall rigidity, which must then depend on the properties of the materials and the fineness of the joinery. The barges have extraordinarily large mortise and tenon joints in the planking, plus the heavy iron spikes mentioned above, but working and leaking must have been a problem even when new. Fortunately, a small inland lake does not usually produce the waves and extreme differential hull stresses that the open sea does.

Mortise and tenon joints are effective at keeping the seams closed in new construction, at least in smaller vessels such as the Kyrenia ship, but they also discourage the use of driven caulking between the planks when the hull starts to

leak. While there is written evidence of driven caulking in the later Roman period (see below), careful examination of several Hellenistic and earlier Roman hulls has failed to produce any evidence of caulking in the seams.⁸ Seam caulking, in the form of resin-impregnated fiber, has been found on a late (4th century CE) Roman vessel, Port-Vendres I, but it is not apparent from the published information whether the caulking was driven in after planking or laid between planks during construction.⁹ If caulking cannot be driven into the seams, it must be applied to the surface of the planking, either outside or inside. Many excavated hulls, both sheathed and unsheathed, display evidence of extensive coating with resinous products on the interior, either as bedding under the frames or as a complete coat. Whether this was done to keep seawater outside or to prevent the interior of the hull from absorbing rain and bilge water, which foster rot, it is difficult to say. Pitch coatings on the outside must be for caulking, as they are certainly not antifouling.

Lead is extremely effective for sealing joints and seams, as it is malleable enough to be beaten into and around lumpy, irregular contours with ease. It was widely and cheaply available in the ancient world and could be had in large sheets of uniform thickness.¹⁰ It has been a common material for roofing, flashing, and marine patching from classical times to the present. The earliest evidence of the use of sheet lead on a ship's hull is from the Porticello shipwreck, which dates to the 5th century BCE. The excavation produced several narrow strips of lead sheet with tack holes; these strips have been interpreted as seam patches.¹¹

Unlike medieval cathedral roofing, lead sheet in marine usage does not usually form the watertight barrier itself. It is normally laid over some sort of resin-impregnated fiber, such as woven cloth, felt, fur, or leaves. The lead limits ingress of water to the seams between sheets, but it is the resin that actually displaces water. The lead serves to hold the tarred fiber in place and protect it.¹² Lead may also have performed an anti-fouling function, as bare pitch collects all sorts of floating trash.¹³ Hardening agents may be added to the resin to reduce tackiness, but if they make the compound brittle, they greatly reduce the effectiveness of the caulking, which should give with the swelling and shrinking of the wood.

The Kyrenia ship was first sheathed when old and already infested. While this makes little sense if the lead was to protect against borers, it is a practical way to squeeze a few more stadia out of a tired, leaking hull without extensive, uneconomical repairs such as major replanking or structural reinforcement. One might think of it as patching expanded to cover the entire hull. Worm protection well above the load waterline also makes little sense, but caulking is needed quite

high in the ship to accommodate rolling, heeling, pitching, and heavy seas, all of which put substantial portions of the upperworks under water.

The concept of sheathing as expanded patching suggests that it was first applied to old, decaying ships, but there is ample evidence that it was eventually used as part of new construction. The Marsala ship, from the mid-3rd century BCE, seems to have been quite new when it sank, but was completely sheathed.¹⁴ If, as Honor Frost suggests, the ship was built in wartime haste,¹⁵ a thorough caulking job might be a more economical use of labor and time than precise fitting of seams. Large vessels, such as the Madrague de Giens ship, might also profit from lead sheathing as part of original construction. Sheathing could well be an economical alternative to the massive structures necessary to assure sufficient rigidity and limit working. Note that the immense ship built for Hiero of Syracuse in the 3rd century BCE. was equipped with lead sheathing when new.¹⁶ This is not to say that ships were built “soft” or sloppily and that caulking covered a multitude of sins, but that sheathing was a practical solution to problems encountered in the construction of large vessels. Alternatively, one could say that a larger ship is susceptible to leakage earlier in its working life than a smaller one and thus should be sheathed earlier; thus it follows that eventually, a large enough ship should be sheathed before launching. The double planking found on some large Roman merchantmen from the 2nd and 1st centuries BCE may also be a response to the same problem¹⁷.

It may seem that a dense substance, such as lead, placed around the perimeter of the hull could serve as a form of external ballast.¹⁸ In fact, the ballasting action of lead sheathing is minimal. First, the total weight of sheathing is relatively small. Richard Steffy has calculated a total sheathing weight of under 1200 kg for the Kyrenia ship, of which about 200kg is the weight of the copper tacks used to hold the lead sheets to the hull.¹⁹ This represents less than four percent of a total loaded displacement of thirty-two metric tons.²⁰ As the sheeting used varies little in thickness for a wide range of hull sizes, and larger vessels have less surface area per unit of volume (and thus less surface area per unit of displacement), the weight of sheathing as a percentage of total displacement actually decreases with increases in ship size. One could thus reasonably expect the sheathing of a vessel the size of the Madrague de Giens ship to represent considerably less than four percent of the total weight of the ship, despite the slightly greater thickness of the lead commonly found on larger vessels. Second, the even distribution of weight around the perimeter and above the waterline negates much of any ballasting effect. To be effective as ballast, dense material must be concentrated low in the hull, well below the center of gravity. An appreciable amount of lead sheathing lies beside

or above the center of gravity, cancelling out the ballasting effect of much of the sheathing below. In the end, only a small part of a relatively small total sheathing weight has any effect on the stability of the ship.

Although lead sheathing has a long history in the ancient world, it can only be said to have been really common in the Hellenistic/Republican period. The earliest excavated example is from the Kyrenia ship, at the end of the 4th century BCE²¹ Earlier hull remains are unsheathed²² or only patched.²³ Most of the excavated ships from the 4th and 3rd centuries BCE. in the Mediterranean and Black Seas exhibit evidence of sheathing,²⁴ but from the 2nd century BCE onward, sheathing is less common and disappears from the archaeological record by the end of the 1st century CE. The latest securely dated evidence is from the Nemi barges, of the mid-1st century CE²⁵ but there are deepwater vessels that may have been sheathed and may date to the same period.²⁶ The apparent abandonment may only be a fluke of preservation and excavation - the "canon" of well-documented, dated ancient wrecks is notably biased toward the centuries BCE, with virtually no securely dated hulls from the 1st century CE - but the general trend does seem to be away from lead sheathing.²⁷ If it was successful enough to warrant widespread use in Hellenistic and Republican times (and perhaps into the early Empire), we must ask what changes in shipbuilding or ship-owning conditions led to its abandonment.

The simplest explanations are the development of more effective caulking methods, or a significant rise in the cost of lead. The latter is the easiest to discount, as lead was a cheap and plentiful material throughout the Roman period. Short-term fluctuations in the price of lead are to be expected, but other products that contained large amounts of lead, such as plumbing and anchors, do not seem to have abandoned it in the same period.²⁸ The exploitation of new mines in Spain and Britain probably led to a long-term drop in price, if anything.²⁹ The development of alternative caulking methods is attested by some of the written sources. Pliny and Vegetius both mention the use of wax in pitch-based hull coatings, and these mixtures may have been less tacky and more durable than pitch alone.³⁰ Certainly there is archaeological evidence for pitch or pitch-based coatings on both the interior and exterior of unsheathed hulls. More importantly, Pliny directly mentions the use of beaten reeds for caulking *interiecta navium commissuris* ("inserted in the joints [seams?] of ships") in the 1st century CE³¹ Strabo, however, describes the caulking driven into the seams of the heavy ships of the Venetii in such a way that implies that such construction was contrary to Mediterranean practice.³² Driven or clamped seam caulking has been a characteristic of northern European craft since the Bronze Age, so it is at least

possible that the concept was imported into the Mediterranean after the Roman conquest of the northern rivers. The Port Vendres I vessel shows that driven caulking may have been in Mediterranean use by the 4th century CE³³. Still, lead remained the preferred material for a multitude of terrestrial and marine waterproofing jobs, such as patching leaks, capping exposed and grain and sealing repairs, throughout the Roman period and into our own times.³⁴ It is difficult to imagine that an unprotected surface coating could be superior in any quality other than cost. Once edge-to-edge mortise and tenon joints were abandoned, driven caulking could be employed more easily. This is a superior general caulking method, as it strengthens the hull, is less subject to damage through abrasion and less trouble to apply.³⁵

Lacking good evidence for a significant long-term rise in the cost of lead or the widespread adoption of driven caulking before the end of the Empire, we must suppose a change in the economic environment that would render lead sheathing an expensive luxury. In this regard, Lionel Casson has suggested that economic pressures in the form of growing labor costs (due to the decline of slave labor) during the early Middle Ages stimulated the abandonment of mortise and tenon joinery in hulls and the growth of “frame-first” shipbuilding.³⁶ I believe that the roots of this trend can be observed in the early Imperial period, and offer a serviceable explanation for the demise of lead sheathing.

Ancient shipbuilding reached a peak of sophistication (or complexity) in the 1st century BCE or CE. Large vessels pushed traditional mortise and tenon joinery to its limits. Double planking, complex backbone structures (such as the sternpost of the *Madrague de Giens* ship³⁷), recurved hull sections, large and closely-spaced tenons, and lead sheathing all reflect a classical approach to structure in which stresses were shared more or less equally among shell, frame, and shape. Later vessels relied increasingly on internal timbers for strength, with a corresponding decrease in shell strength and complexity along with greater variation in hull form.³⁸ Large vessels from the later Imperial period, such as the merchantmen from *Caesarea Maritima*³⁹ and the *Bourse at Marseilles*,⁴⁰ as well as the marble carrier at *Torre Sgarrata*,⁴¹ have a single, thick layer of planking reinforced by massive, closely-spaced frames and are characterized by a greater overall simplicity of shape and construction. The exaggerated hollow garboards of earlier ships were reduced until they eventually disappeared in straight deadrise or flat floors. The *Nemi barges* are considerably simpler in hull structure than the *Madrague de Giens* ship, yet no expense was spared in their construction and they are admirably suited to their purpose.

It is possible that the growing reliance on heavier internal structures and more frequent connections between keel and frames increased the stiffness of ancient hulls. Stiffer hulls work less and are thus less prone to leak. Driven caulking, if properly applied, contributes to hull stiffness, a property of which at least some Romans were aware. Tighter hulls have less need of extensive surface caulking, so it is conceivable that lead sheathing was abandoned because it was no longer necessary. If this is the case, one could expect to find its use increasingly restricted to larger ships, which are more difficult to build with adequate rigidity. The archaeological record (although the sample is too small to be statistically significant) seems to support this, as the known and possible 1st-century CE examples (Nemi and Caesarea) are enormous ships.

An economic explanation will also serve. I believe that economic pressure for reduced capital costs is largely responsible for the growing overall simplicity of mortise and tenon construction, just as it later prompted the abandonment of such joinery all together. The ships of the Empire were cheaper to build because they took somewhat less material but substantially less labor is not free. The labor of skilled slaves, such as shipwrights and tutors, is especially valuable and not spent needlessly. The single-planked, unsheathed ship also has maintenance advantages; planks in need of repair are detected and replaced more easily.

In return for savings on the initial investment and some operating expenses, the Roman owner was apparently willing to sacrifice the extra amount of working life the Kyrenia ship's owner was trying to obtain. On the other hand, any decrease in ship life was probably more than compensated for by the initial savings if an average cost per ton of cargo is figured. In an environment where marine life is hard on ships, an extremely long working life is unlikely in any case. Still, one would expect to find lead sheathing lasting the longest in the construction of large ships, which depended more than small vessels on external caulking for watertightness.

As for the cause of such a change in the economic climate, that is a topic too immense for this paper. Perhaps the reorganization of provincial administration under Augustus streamlined and stimulated long distance commerce, thus creating a greater demand for cheap tonnage, especially in bulk cargoes. The long distance transport of bulk goods is only profitable as a regular endeavor where supplies and markets are relatively steady and transport costs are minimal. Low transport costs (freight) depend on ships that are relatively cheap to build and cheap to operate. In such a climate, lead sheathing, which was never ubiquitous, became one of several costly options.

What this change represents is a distinct step in the evolution of the western economy. Where ships of the Classical Greek and Hellenistic eras had been built expensively, even lavishly, in terms of the labor involved, Roman ships were increasingly subject to a wider range of economic influences. Craftsmanship had a more tangible price. Comparing ships separated by a millennium, the Kyrenia vessel and the 7th-century ship from Yassiada,⁴² the difference in the level of craftsmanship is startling. The Byzantine ship is a crude but efficient packing crate next to the yacht-like Hellenistic ship. In this context it is tempting to see the growing simplicity of Roman construction as a decline in quality, but it should instead be seen as a rise in economic consciousness and sophistication.

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NOTES

1. This paper began as a discussion with Cemal Pulak, who simply will not let an idea pass by unchallenged. It later formed part of a paper submitted for a seminar on classical seafaring taught by George Bass at Texas A&M University. Since then, it has benefitted from comments by Richard Steffy and Michael Fitzgerald. I thank them all for their interest and assistance, but any fault for errors lies solely with the author.
1. Linder and Rosloff, Ma'agan Michael wreck
2. Lionel Casson, *Ships and Seamanship in the Ancient World* (Princeton, 1971) 209-10; Fernand Benoit, "Fouilles sous-marines: L' épave du Grand Congloué à Marseille", Supplement 14 to *Gallia* (Paris, 1961) 154; Jurgen Hausen, *Schiffbau in der Antike: Beitrag zur Geschichte des Schiffbaus. Konstruktion und Festigkeit der Schiffe in der Antike* (Herford, 1979) 183; D.J. Blackman "Further early evidence of hull sheathing," *IJNA* 1 (1972) 117, among others.
3. See Peter Goodwin, *The Construction and Fitting of the English Man of War 1650-1850* (London, 1987) 226-27 on the copper sheathing of English warships. The Royal Navy tried lead as an anti-worm barrier between 1670 and 1770, but eventually judged the material too soft for this purpose - John Fincham, *A History of Naval Architecture* (London, 1851) 94-95.
4. J. Richard Steffy, "The Kyrenia ship: An interim report on its hull construction," *AJA* 89 (1985) 99; Guido Ucelli, *Le Navi di Nemi*, 2nd edition (Rome, 1951) 153 and Fig. 70, p. 70; André Tchernia, Patrice Pomey, and Andrea Hesnard, "L' épave romaine de la Madrague de Giens (Var) (Campagnes 1972-1975)", Supplement 24 to *Gallia* (Paris, 1978) 85. The Marsala ship is an exception, as its sheathing appears to stop at the lower edge of the lower wale - Honor Frost et al., "Lilybaeum (Marsala) - The Punic ship: Final excavation report," Supplement to *Atti della Accademia Nazionale dei Lincei* 8th series, 30 (1976) 262.
5. Steffy (*supra* n. 4) 98.
6. Benoit (*supra* n. 2) 154; Hausen (*supra* n. 2) 183. Ucelli (*supra* n. 4) 153-54 notes that the sheathing was not needed for watertightness or protection from the worm, but suggests that it represents the extreme, even excessive, care lavished on these hulls.
7. After minimal time in the water, the timbers of the replica swell sufficiently to prevent the entry of water even under extreme conditions of hull stress (Richard Steffy, pers. comm.)

8. For example, Kyrenia: Steffy (*supra* n. 4) 98; Madrague de Giens: Tchernia, Pomey and Hesnard (*supra* n. 4) 86, n. 27; Nemi: Ucelli (*supra* n. 4) 152-53. Steffy notes ([*supra* n. 4] 98) that pitch may have been laid into the garboard seams before assembly of the garboards to the keel.
9. Bernard Liou, "L' épave romaine de l'Anse Gerbal à Port-Vendres," *Comptes rendus de l'Académie des Inscriptions et Belles-Lettres* (July-October, 1974) 422.
10. J.D.C. Boulakia, "Lead in the Roman world," *AJA* 76 (1972) 142-44.
11. Cynthia J. Eiseman and Brunhilde Ridgway, *The Porticello Shipwreck* (College Station Texas, 1987) 16.
12. Honor Frost (*supra* n. 4) 263 suggested that this was the purpose of the lead sheathing on the Nemi barges.
13. Indeed, bare pitch was originally used on *Kyrenia II* but was abandoned in favor of modern marine anti-fouling paints due to the amount of disgusting harbor refuse that became attached to the sticky goo (Richard Steffy, pers. comm.)
14. Frost (*supra* n. 4) 262-63.
15. Frost (*supra* n. 4) 278.
16. Athenaeus 5.207a. The relevant passages concerning this ship were translated with commentary by Lionel Casson (*supra* n. 2) 191-99.
17. For example, the wrecks at Madrague de Giens: Tchernia, Pomey, and Hesnard (*supra* n. 4) 85; Grand Congloué: Benoit (*supra* n. 2) 152; and wreck A at Dramont: Claude Santamaria, "Note préliminaire sur la construction de la coque de l' épave romaine Dramont 'A' (Cap Dramont - Commune de Saint Raphael)," *CahArchSubaq* 2 (1973) 133.
18. This aspect of lead sheathing was not originally addressed in this paper, but was brought up by Avner Raban after the paper was delivered. As Prof. Raban's point was well taken, I hope he will forgive me if I take the liberty of responding to his question here in the text.
19. J. Richard Steffy, pers. comm.
20. The replica *Kyrenia II* was weighed, with spars but without sheathing, when launched at 8.7 tons. The amphora cargo (if full of wine) plus the millstones weighed in the vicinity of 22 tons; J.R. Steffy, pers. comm.
21. Steffy (*supra* n. 4) 98. A wreck off the Crimean coast of the Black Sea has produced several moderately-sized sheets of lead and may date to the late 4th century BCE - V.D. Blavatsky and B.C. Peters, "Korablekrusheniye kontsa IV - nachala III vv. do n.e. okolo Donuzlava", *Sovietskaya Arkheologiya* 1969 (3) 151-58, published in English as "A wreck of the late 4th or early 3rd century BC near Donuzlav," D.J. Blackman, trans., *IJNA* 2 (1973).
22. The Porticello wreck, dated to the 5th century BCE is only patched: Eiseman and Ridgway (*supra* n. 11) 16. The Ma'agan Michael wreck, described elsewhere in this volume by Elisha Linder and Jay P. Rosloff (see), dates to the late 5th century BC and has no evidence of lead sheathing or patching, but it appears to have been a very new ship at the time of its loss.
23. Of Hellenistic wrecks, only the Secca de Capistello ship lacks evidence of sheathing: Don Frey, Faith D. Hentschel, and Donald H. Keith, "Deepwater archaeology. The Capistello wreck excavation, Lipari, Aeolian Islands," *IJNA* 7 (1978) 295. In addition to the more accessible published material, Cemal Pulak reports that two Hellenistic wrecks surveyed by the Institute of Nautical Archaeology off the Turkish coast, one off the southwest coast and one in the Sea of Marmara, present convincing evidence of lead sheathing; Cemal M. Pulak, "Turkish coastal survey yields wrecksite inventory," *INA Newsletter* 12.2 (1985) 2-3. See also Cemal Pulak and Rhys Townsend, "The Hellenistic shipwreck at Serce Limani, Turkey: Preliminary Report," *AJA* 91 (1987) 35.

24. Ucelli (*supra* n. 4) 153.
25. Chief among these is probably the large, single-planked vessel off Caesarea Maritime. While no sheathing or tacks have been found on the hull remains themselves, large, crumpled sheets of lead were found in the vicinity and much of the bottom of the hull remains unexamined. Michael A. Fitzgerald, "The Ship," in John Peter Oleson (ed.), *The Harbours of Caesarea Maritima: Results of the Caesarea Ancient Harbours Excavation Project, 1980-1985 II: The Small Finds and the Ship*, BAR International Series (Oxford, forthcoming). I thank Mr. Fitzgerald for sharing this information with me.
26. This trend has been noted by Casson (*supra* n. 2) 214-17, App. I, and forms part of a series of general trends in Roman shipbuilding observed by Patrice Pomey, "L'architecture navale romaine et les fouilles sous-romaine 5. Recherches d'archéologie celtique et gallo-romaine (Paris, 1973) 41.
27. Lead-stocked anchors are extensively covered in the literature; see, for example, Piero Gianfrotta's paper in this volume.
28. Boulakia (*supra* n. 10) 139-41, 143.
29. Pliny, *NH* 16.56; Vegetius, 4.44.
30. Pliny, *NH* 16.158. Casson (*supra* n. 2) 209-10, note 39, translates *commissuris* as "seams," and I see no reason to disagree.
31. Strabo, 4.195, as noted by Casson (*supra* n. 2) 209, n. 38.
32. Liou (*supra* n. 9) 422.
33. The Kyrenia ship was patched with lead on the interior Steffy (*supra* n. 4) 97; The keel-to-post scarf of Port-Vendres I was sealed with a lead sleeve - Liou (*supra* n. 9) 417 and 421, Fig. 6.
34. Pliny was aware of these advantages; *NH* 16.158. By the 11th century CE, driven caulking was certainly in use. Crushed fiber, possibly a tarred grass, was observed (and samples removed) in the plank seams of the 11th-century vessel from Serce Limani (Frederick van Doorninck, Jr., pers. comm.), and this vessel also carried a complete set of caulking irons and reefing tools, the earliest such set known (I am currently preparing the tools from this wreck for publication).
35. Lionel Casson, pers. comm.
36. Patrice Pomey, "Le navire romaine de la Madrague de Giens," *CRAI* (1982) 137, Fig. 3.
37. Pomey (*supra* n. 36) 37-51.
38. Fitzgerald (*supra* n. 25).
39. Jean-Marie Gassend, "Decouverte d'une épave antique," *Archaeologia* 79 (February, 1975) 72 and Jean-Marie Gassend and Jean-Pierre Cuomo, "Un acquis récent des recherches d'architecture navale: La 'construction alternée' des navires antiques," in *VI Congresso Internazionale de Arquelogia Submarina, Cartagena, 1982* (Ministerio de Cutrura, 1985) 343-50.
40. Peter Throckmorton, "The Torre Sgaratta Ship," in Harry Tzalas (ed.), *Tropis I: Proceedings of the 1st International Symposium on Ship Construction in Antiquity* (Athens, 1989) 264-65.
41. Frederick H. van Doorninck, Jr., "The hull remains," in George F. Bass and Frederick H. van Doorninck, Jr. (eds.), *Yassi Ada: A Seventh-Century Byzantine Shipwreck* (College Station, Texas, 1982) 32-64.