and Greece, has been dated to *c.*1200 BC: there are no reports of hull remains.

4.8.3.4 TRANSFER OF TECHNOLOGY

The hull remains of the Gelidonya and Uluburun wrecks raise the problem of the relationship of their plank fastenings to those used in Egypt in the third and early second millennium BC (2.7.1 and 2.8.3.4). The Egyptian mortise and tenon joints were not locked, and they were used in conjunction with other forms of fastening. The eastern Mediterranean joints of the mid-to late second millennium BC, on the other hand, were locked; whether there was also a second type of fastening (e.g. sewing) is uncertain due to the limited extent of planking so far investigated. It seems likely that there was some transfer of technology between Eygpt and the eastern Mediterranean, perhaps via the Levant: this must remain a hypothesis, however, for lack of direct evidence.

4.9
The Early Iron Age (*c.*1100–550 BC)

The Late Bronze Age civilizations of the eastern Mediterranean appears to have ended during the early twelfth century BC, possibly as a result of intrusion into the region by marauders known to the Egyptians as the 'Sea People' who had been raiding the Levant coast from the fourteenth century BC (2.9.4). Mycenaean sites in Greece were destroyed and depopulated; the Hittite culture of Anatolia collapsed; cities in Cyprus and the Levant were violently destroyed; and displaced people tried to settle elsewhere, adding to the confusion and disruption.

4.9.1 SHIPS OF THE 'SEA PEOPLE'

A fleet of Ramses III attacked a group of Sea People's ships in harbour in *c.*1176 BC, and scenes from this battle appear in relief on that Pharaoh's mortuary temple at Medinet Habu (Fig. 2.27). Four Egyptian and five Sea People's ships are depicted (Wachsmann, 1998: 166–75; figs. 8.1–8.15), their nationality being indicated by the different headdress worn by each crew. The two types of ship differ in their longitudinal profile: the Egyptian hulls have a smooth curve between bottom and rising ends; whereas, the Sea People's ships have near-vertical ends capped by a bird figurehead (Wachsmann, 1998: fig. 8.2). Otherwise Egyptian and Sea People's ships are similar, being galleys propelled by a single square sail on a mast stepped near amidships, and by oarsmen along each side. They both have a raised deck/fighting platform at each end, probably connected by a raised gangway/deck along the centreline between the two lines of oarsmen. Both have loose-footed sails with brails, and there is a fighting top/lookout at the masthead. Two Sea People's ships (N1 and N5 in Wachsmann, 1998: fig. 8.2, 8.10, 8.12) appear to have two quarter rudders: the Egyptian ships depicted appear to have only one, but two are known from ships, models, and depictions from earlier times (2.7.5). Sea People's ships N4 and N5 (Wachsmann, 1998: figs. 8.11, 8.12) have a short pointed projection at the junction of stern post with 'keel' which may indicate a special method of joining the two timbers.

Assuming that these depictions of Sea People's ships are generally typical of the Levant, ships from these two regions appear to have much in common, apart from the form of their ends which seems to perpetuate the much earlier distinction between Egyptian and Mesopotamian vessels (2.4). This superficially suggests that the Egyptian hull form may have been introduced to the Aegean (as, for example, depicted on the Thera reliefs (Figs. 4.21 and 4.22); whereas the Mesopotamian hull may have been introduced to the Levant, to be subsequently used by the Sea People. Such differences in form are merely suggestive, however, and depictions such as those of Medinet Habu do not preclude significant structural differences between the two types. It may be, for example, that Egyptian hulls were still partly fastened by sewing whilst the 'Levant' hulls were fastened by the locked mortice and tenon joints found on the second millennium BC Cape Gelidonya and Uluburun wrecks. This again is speculation: detailed investigations of the structure of further wrecks from this period are needed to turn this into a hypothesis.

The Medinet Habu relief also shows that an improved sailing rig was used in the eastern Mediterranean: it may be that this change originated in the Levant.

4.9.2 THE POST-MYCENAEAN EASTERN MEDITERRANEAN

Homer's *Iliad* and *Odyssey*, epic poems first written down during 750–700 BC, but probably based on much earlier oral traditions (4.4.6) contain references to ships and to seafaring. The Greek historians Herodotus (*c.*480–420 BC) and Thucydides (*c.*460–400 BC) discuss similar matters, from the eighth century BC onwards.

Depictions of ships also appear on Greek pottery of the Geometric (ninth and eighth century) and Archaic (seventh and sixth centuries) periods. From the same centuries there are depictions of Phoenician ships and boats on Assyrian reliefs.

4.9.2.1 HOMER'S SHIPS

The ships described in the *Iliad* and the *Odyssey* are black, and sometimes have blue bows (Rieu, 1946: 48, 124, 204). There appear to be two sizes of what might be called 'general purpose ships': smaller ones of twenty oars and larger ones of fifty-two (Rieu, 1946: 29, 124). Fifty-oared ships are mentioned in the *Iliad* (Seymour, 1907: 308; Rieu, 1950: 58). Cargo ships could be propelled by twenty oars; their distinguishing feature was their broad beam (Rieu, 1946: 150, 199).

How such ships were built is described in a passage (*Odyssey*, 5: 234–57) which has been understood in several ways. Casson (1964) has interpreted the passage in the light of information from the Cape Gelidonya and Uluburun wrecks: the planking of Odysseus' ship was fastened together with mortise and tenon joints locked by pegs. Subsequently the framing was fastened to the planking by treenails to reinforce the planking shell. This method of building is generally agreed by Morrison (1995: 142–3). On the other hand, Mark (1991) considers that the passage describes the building of a sewn-plank boat as evidenced by the sixth-century BC boats of the eastern and central Mediterranean (4.9.4). Casson (1992) argued strongly against this hypothesis and stimulated a rejoinder from Mark (1996).

Homer's description is enigmatic and incomplete: it would be impossible to reconstruct a practical method of building a boat from that text alone. A knowledge of sewn-plank or mortise and tenon techniques is needed to fill the gaps in Homer's description and produce a coherent sequence. Homer could have been describing either a sewn-plank boat or one fastened with mortise and tenon joints: in both cases, however, there are anomalies. A third possibility is that both sewn and wooden fastenings were used in Homer's boat. In the Egyptian vessels of the third and second millennium BC known to date, *both* techniques are used (2.7.1 and 2.8.3.4). Furthermore, as Morrison (1995: 143) and others have pointed out, the Greek ships at Troy may well have had sewn planking since Homer (*Iliad*, 2: 135) states that their planking had rotted and the cords had worked loose (Rieu, 1950: 43 prefers 'rigging' to 'cords'). The fact that the Cape Gelidonya and Uluburun wrecks had locked mortise and tenon planking need not undermine the suggestion that Homer's ships were sewn (at least in part): only minor samples of the Cape Gelidonya planking have been recovered and only *c.*1.8 m of the Uluburun hull has been examined: in both cases, the use of sewing as well as mortise and tenon fastenings remains a possibility.

What is probably beyond argument is that Homer describes a plank-first sequence of boatbuilding. Alder, poplar, and fir timber was used; some superstructure, perhaps an *ikria*, was added to the vessel at the stern. A washstrake of wattle-fencing was fastened to the sides to keep spray from blowing inboard.

In other sections of the *Odyssey* and the *Iliad* (Rieu, 1946: 46, 47, 124, 163, 198/9, 205, 206, 245, 336; Rieu, 1950: 34, 35; Seymour, 1907: 312–13), we learn that masts of fir were set in a mast step and supported by two forestays and a backstay; the mast rested in a notch in the mast beam, and could be lowered into a crutch at the stern. Sails were of white linen and, when not needed, they were stowed under the thwarts in the bottom of the boat. These sails were controlled by braces, brails/halyards, and sheets, and these and other ropes could be made from oxhide/plaited leather, wood, or papyrus. Oars were of pine and were worked against a thole through a leather grommet.

4.9.2.1.1 *Ship operations*

Victuals embarked for a voyage of several days included: wine in jars or in skins, water in skins, and barley meal or corn in sewn skin bags (Rieu, 1946: 42, 94).

Ships could be anchored offshore in a sheltered cove using an anchor stone. After anchoring, the stern was brought to the beach in 'Mediterranean moor' fashion (Seymour, 1907: 314). For an overnight stay mast and sail were sometimes put ashore. At times boats were

dragged up the beach and held upright with props. On occasions, a vessel could be propelled up the beach so that half the keel's length was ashore. When a storm was expected anchored ships would be beached stern first, and dragged inland for shelter. Boats that had been beached were 'run down' into the sea; beached ships could be launched by the use of levers (Rieu, 1946: 26, 78, 94, 202–3, 210–11; Rieu, 1950: 36). Navigation at the time of Odysseus has been considered in 4.4.6.

4.9.2.2 HERODOTUS

Herodotus (1. 163, 165–6) identified the Phocaeans, from the Aegean coast of Anatolia, as the foremost and earliest of Greek overseas explorers: in the Adriatic, to Italy and Corsica in the Tyrrhenian Sea, and as far west as Tartessus on the Atlantic coast of Iberia. He also mentioned, almost in passing, how the Greeks had traded and settled overseas; at *Bubastis* and *Naucratis* on the River Nile; on the coasts and rivers of the Black Sea region; and on the Libyan coast in Cyrenaica (2. 154, 2. 178, 4. 24, 4. 51, 4. 151–8).

Three types of early seagoing sailing ships are mentioned by Herodotus (1. 163, 1. 152, 1. 166, 3. 136, 4. 148, 4. 153, 4. 156, 6. 26, 6. 95, 6. 101, 7. 25, 7. 97, 7. 147):

(a) Ships used for settlement voyages: these were either thirty-oared or fifty-oared, and could also be sailed.

(b) Merchant ships: these were distinguished from other types by being 'broad-beamed'. In early times, the Phocaeans used fifty-oared ships for trading voyages; it may be that, in contrast, the later broad-beamed merchant ship had no oars, or possibly just a few for manœuvring.

(c) Fighting ships: these always appear to be galleys, i.e. capable of being propelled both by sail and by a full complement of oarsmen. Spartan ships were fifty-oared, whilst those of the Phocaeans had rams. Sea battles are described in the Sardinian Sea, off Artemisium (Rieu, 1946: 501) and off Salamis (Herodotus, 8.84–92).

Penteconters (fifty-oared ships) were evidently the mainstay of Greek shipping, being used for exploration, settlement, trading and fighting. It could be that the phrase 'fifty-oared' was a measure of size of vessel, regardless of how many, or how few, oars were embarked. On the other hand, a penteconter may have actually been propelled by fifty oarsmen as well as by sail, a general purpose ship used in many roles. Such a ship, with twenty-five oarsmen each side would have been *c.*30 m in length overall, and at least 2 m broad at the waterline for much of this length.

There is little on the operation or the performance of ships in Herodotus. He does, however, note that fighting ships were hauled ashore to dry out (7. 59); that Cape Malea was difficult to make eastbound in the *Etesian* wind; and he seems to imply that Greek ships could tack on a fine reach, i.e. making good a track some seven points off the wind (6. 139–40).

4.9.2.3 THUCYDIDES

Thucydides, writing in *c.*411 BC, mentions three groups of Greeks as being active in the maritime field in earlier times: the Athenians who colonized Ionia (Aegean coast of Asia Minor) and the offshore islands, and who, in later years, took part in several battles at sea, and sailed from Cyprus up the River Nile as far as Memphis; the Phocaeans who defeated the Carthaginians in a sea battle and founded a settlement at Massalia/ Marseilles; and the Corinthians of the Peloponnesian isthmus, who not only are thought to have built the first triremes in Grece in *c.*700 BC, but also to have taken part in the first recorded sea battle, against the Corcyraeans in the mid-seventh century BC, and attained eminence in overseas trade (Warner, 1954: 20, 21, 70; Loseby, 1992).

Most of these voyages and battles were undertaken in 'longboats' and fifty-oared vessels without decks, i.e. they were 'open boats' (Warner, 1954: 18, 21). In the mid-sixth century BC, however, Polycrates, ruler of Samos, added forty triremes to his fleet (Warner, 1954: 21; Papalas, 1999: 12), and by the early fifth century, triremes were being used in great numbers (Warner, 1954: 21).

4.9.3 SHIPS IN THE EASTERN MEDITERRANEAN

4.9.3.1 AEGEAN

Ships which appear to be 'longships', some of them possibly penteconters, are depicted on Greek Geometric pottery from the ninth and eighth centuries BC (Casson, 1971: figs. 62–8, 70–2, 74, 77; Wachsmann, 1998: figs. 7.11–7.14). Most of these depictions seem to represent



Fig. 4.24. Ship depicted on a Late Geometric vase from Dipylon (Louvre, Paris).

warships. Herodotus' penteconter merchant ships and those used on settlement voyages were probably broader in the beam than the warships, and had greater height of sides and therefore more freeboard, although, as Coates (1990*a*) has pointed out, a monoreme penteconter has inherently more space for cargo and people than a bireme or trireme.

These ships are all depicted in profile, and most have a high curving stern and a ram (4.12.3). Some of these vessels (Fig. 4.24) have one tier of oarsmen, but others (Fig. 4.25) appear to have two tiers. It has been argued that the apparent bireme in Fig. 4.25 is actually a distorted perspective plan view of a monoreme, and this may be so, since only the oars of the lower/nearer oarsmen appear to enter the water to starboard. However, other fragments of pottery dated 760–735 BC (Morrison, 1995*a*: fig. 175; Morrison, 1995*b*: 55; Casson, 1971: 70–2; Wachsmann, 1998: figs. 7.12–14) do appear to show biremes, which, if they still carried fifty oarsmen,

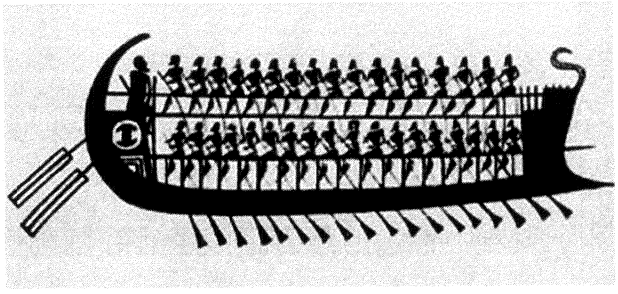


Fig. 4.25. Ship depicted on an eighth-century bowl from Thebes (after Casson, 1971: fig 74).

would have been much shorter and therefore more manœuvrable than the monoreme.

Both types have raised decks at bow and stern and some of the monoremes appear to have a deck for armed men above, and probably inboard of, the single tier of oarsmen. Most of these depictions appear to be propelled by oars alone, however, there is a mast on a shard from the Acropolis, Athens, dated late eighth century (Casson, 1971: fig. 70; Morrison, 1995*b*: fig. 175A; Wachsmann, 1998: fig. 7.14), and this suggests that these warships/pirate ships were galleys which used a sail in fair winds, but oars in action and in foul winds.

Ships depicted on Archaic pottery of the seventh and sixth centuries BC (Morrison, 1995*b*: figs. 177–9; Casson, 1971: figs. 81–5, 88–91) are generally similar (both monoremes and biremes) but almost always have a mast stepped, sometimes with a sail set. In a number of these depictions, the ram is clearly being used offensively—see, for example, the Aristonothos vase of the mid-seventh century BC (Basch, 1987*a*: fig. 482).

4.9.3.2 LEVANT COAST

Around 2000 BC, a number of city-states emerged on the Levant coast. The inhabitants became active in maritime trade from the early second millennium BC, and there was a continuity in their nautical terminology from the Late Bronze Age to the sixth century BC (Stieglitz, 1999: 415). These seafaring people subsequently came to be called 'Phoenicians' by the Greeks, although they were known to themselves from at least 1450 BC as 'Canaanites' (Aubet, 1993: 8–9). In the *Iliad* (23. 743–4) these people are referred to as 'Sidonians' after one of their principal cities (Herodotus, 1. 2; 2. 116). These were the seafarers and overseas traders in fast, black ships that the early Greeks met in the Aegean (*Odyssey*, 13. 272–86). Herodotus (7. 89, 1. 1) believed that they originally came from the Persian Gulf region to settle in the part of Syria known as Palestine. He knew them as experienced seafarers who made long trading voyages from their ports of Tyre and Sidon, with Egyptian and Assyrian goods (1. 1, 1. 2, 2. 116). Although literate (they taught the Greeks to write—Herodotus, 5. 58), they left almost no descriptions of their ships or their seafaring activities, and we have to rely on accounts by Egyptians, Greeks, and Hebrews, and on representations of their ships mainly from Assyria and Egypt.

4.9.3.2.1 *Phoenician seafaring*

From the mid-second millennium BC onwards, the Canaanite/Phoenicians made exploratory trading voyages eventually encompassing the length and breadth of the Mediterranean. They principally sought out raw materials, mainly metals—gold, silver, copper, tin—which were needed in the Levant and neighbouring countries: in return they supplied timber to the Israelites (1 Kings 5: 8–9; 10: 11); timber, slaves, and wine to the Egyptians (2.9.2); and resins and spices to the Greeks (Herodotus, 3. 107, 111). They also traded with Cyprus, Sicily, Sardinia, Malta, southern Spain, and places along the north African coast. By the mid-first millennium BC they were trading with Atlantic harbours beyond the Pillars of Hercules (Herodotus, 4. 196).

In the eighth century BC a Phoenician colony was established at Carthage and in the mid-first millennium BC, Himilco and Hanno were sent out from there to explore the Atlantic coasts. Himilco sailed along the European coast, possibly only as far as Cape St Vincent (the Sacred Cape) but maybe as far north as Coruña and beyond (Avienus: 116–29); whilst Hanno sailed along the African coast possibly as far as Senegal, Cameroon, or even Gabon (Ramin, 1976; E. Taylor, 1971: 46; Oikonomides and Miller, 1995). Other Carthaginians probably visited the Canary Islands since Punic coins have been excavated there.

In addition to Carthage, Phoenicians settled in Malta in the eighth century BC, Sardinia, and the region around Gadir (Cadiz) in southern Spain, by the ninth century (Aubet, 1993: 222). The Phoenicians appear to have had an eye for natural harbours (Aubet, 1993: 140): many of these, like Tyre and Sidon, were on islands or peninsulas: Gadir in Atlantic Spain; Motya in western Sicily dominating the Carthage strait; Mogador and Lixus in Atlantic Morocco; and notably Carthage. They built artificial basins (*cothon*) at some of these sites to increase harbour capacity and to improve loading facilities.

The seafaring abilities of the Phoenicians were clearly recognized by the Egyptians, the Persians, and the Israelites, and, grudgingly, by the Greeks. Pharaoh Necho II (twenty-sixth dynasty, *c.*600 BC) chose a Phoenician ship to investigate the possibility of circumnavigating Africa clockwise, i.e. south down the Red Sea and back into the Mediterranean through the Strait of Gibraltar (2.10). Herodotus (4. 42) says that they took about two-and-a-half years and when they returned to Eygpt, they reported that, as they sailed south and west around southern Africa, the noon sun was to the north. Although they were not believed by their contemporaries, or by Herodotus, their statement is clear proof that they had been in the southern hemisphere and probably had circumnavigated the continent. For a recent critical appraisal of the evidence, see Kahanov (1999).

The Persians also much valued the Phoenicians' experience and included them in their war fleets; indeed, Herodotus (3. 19) states that the whole naval power of Cambyses (*c.*530–522 BC), son of Cyrus, depended on the Phoenicians, and they were very prominent in Xerxes' fleet at the Battle of Salamis (480 BC).

To the rulers and scribes of Israel, the Phoenicians were men 'who knew the sea' (1 Kings 9: 26–8) and 'rulers of the sea' (Ezekiel 26: 16), who did 'business with the nations in innumerable islands' (Ezekiel 27: 1–3). The Phoenicians 'whose traders were princes, whose merchants, the great ones of the world', 'whose goods travelled over the sea, over wide oceans' (Isaiah 23: 1–8).

The Greeks, who rivalled the Phoenicians in exploration and trading from the eighth century onwards, did not eulogize so. Nevertheless, from Homer to Strabo, they testify to the Phoenician abilities at sea. Strabo (1. 1. 6) gives precedence to the Phoenicians in matters of navigation, a view which was subsequently endorsed by the Roman Pliny (*NH* 7. 57) who understood that the Phoenicians were the first in the Mediterranean to apply a knowledge of astronomy (learnt from the Chaldeans) to the problem of navigation in the open sea. For example, the Phoenicians identified the constellation Ursa Minor and realized that, since it orbited the celestial North Pole in a tighter circle than did Ursa Major, it gave them a more accurate direction of North (Fig. 4.26). It is significant that the Classical world called this most useful, but not easily recognized, constellation, 'Phoinike' (Aubet, 1993: 142).

4.9.3.2.2 *Canaanite/Phoenician ships*

Cargo ships from the Levant coast are mentioned by Egyptian pharaohs in the mid-second millennium BC

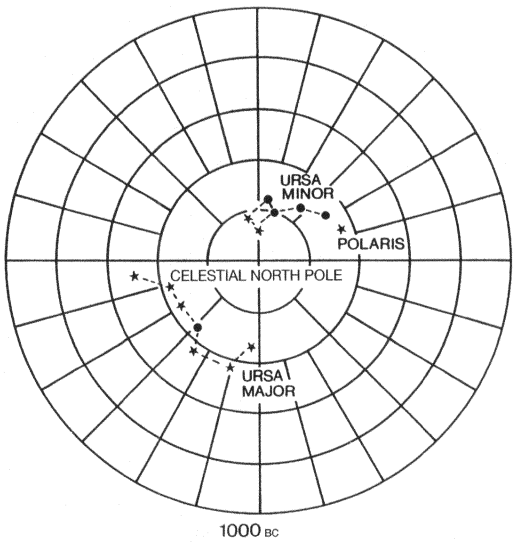


Fig. 4.26. Night sky in *c.*1000 BC (after Taylor, 1956: fig. 5A).

and there are references to overseas traders in ports along this coast in the Armana texts and in Ugarit documents (Wachsmann, 1998: 39–41). Although much is said about the cargo these ships carried, and these merchants dealt in, the only fact about the ships is that they had cedar planking.

4.9.3.2.2.1 *Iconographic evidence*

A cylinder seal (Fig. 4.15) found at Tel el Daba in the Nile delta, and dated to the eighteenth century BC, is thought to be Syrian in origin (Wachsmann, 1998: 42). The ship on the seal is schematic rather than realistic, but it appears to be near-double-ended, with a mast amidships supported by forestay and backstay. More can be learnt from ships depicted in the early fourteenth century BC tombs of Nebamun and Kenamun at Thebes, Egypt (Fig. 4.27). These ships, which are identified as Syrian by the dress of crew and merchants, are bringing wine or oil, pottery, and cattle to Egypt in return for food, textiles, and sandals (2.9.2) (Wachsmann, 1998: figs. 3.2–3.9, 14.6). One feature which differentiates them from contemporary Egyptian vessels is the vertical post at the stern, rather than the curvacious finial at the stern of Hatshepsut's ships of *c.*1500 BC (Fig. 2.25). However, vertical stern posts are depicted on seagoing vessels of the Egyptian Old Kingdom (those of Unas and Sahure—Fig. 2.14) and it may be that, in this respect, Hapshetsut's ships are unrepresentative of Egyptian merchant ships of the mid-second millennium BC. No hogging stay is depicted on the Syrian ships. This absence of evidence may not be significant: on the other hand, the Levantine ships appear to be relatively much shorter than Egyptian vessels and would therefore be less likely to need a hogging stay. It may be that, by the mid-second millennium BC, the Syro-Canaanites had developed a 'round' ship with a keel, and a stronger hull (4.9.3.2.3) which was not so susceptible to hogging, and more suitable for a seagoing cargo vessel.

As in the rest of the eastern Mediterranean, there is a dearth of information about Levantine ships until the

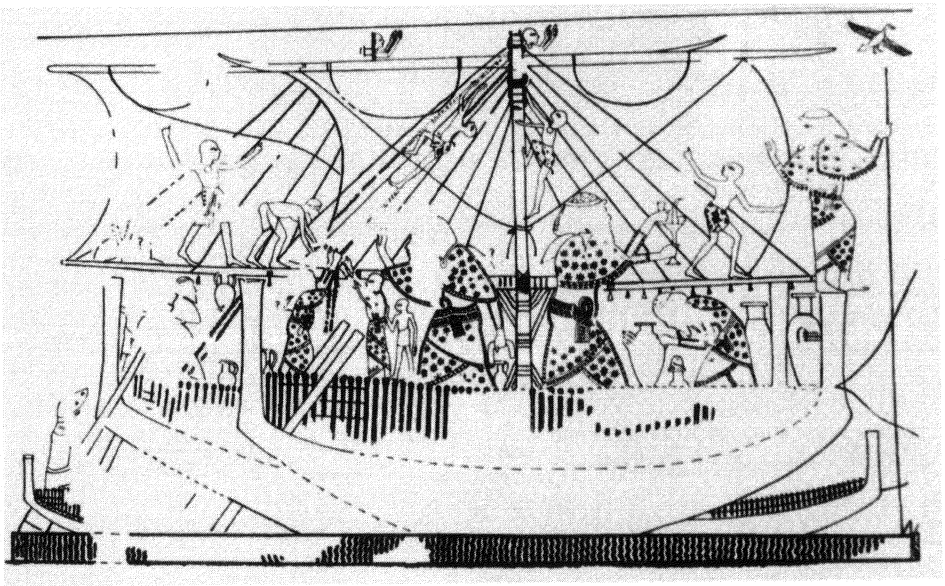


Fig. 4.27. Syrian ships depicted in the tomb of Kenamun (after Casson, 1971: fig. 57).

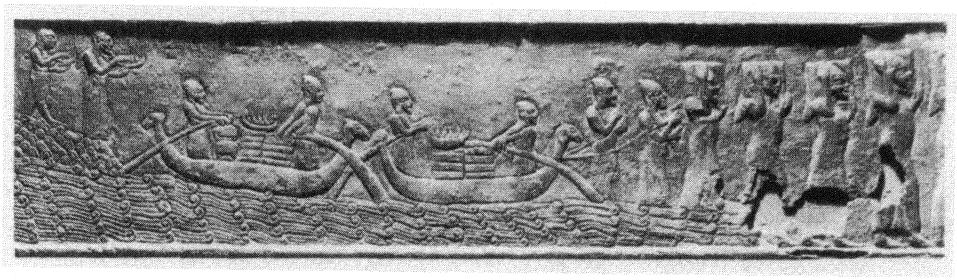
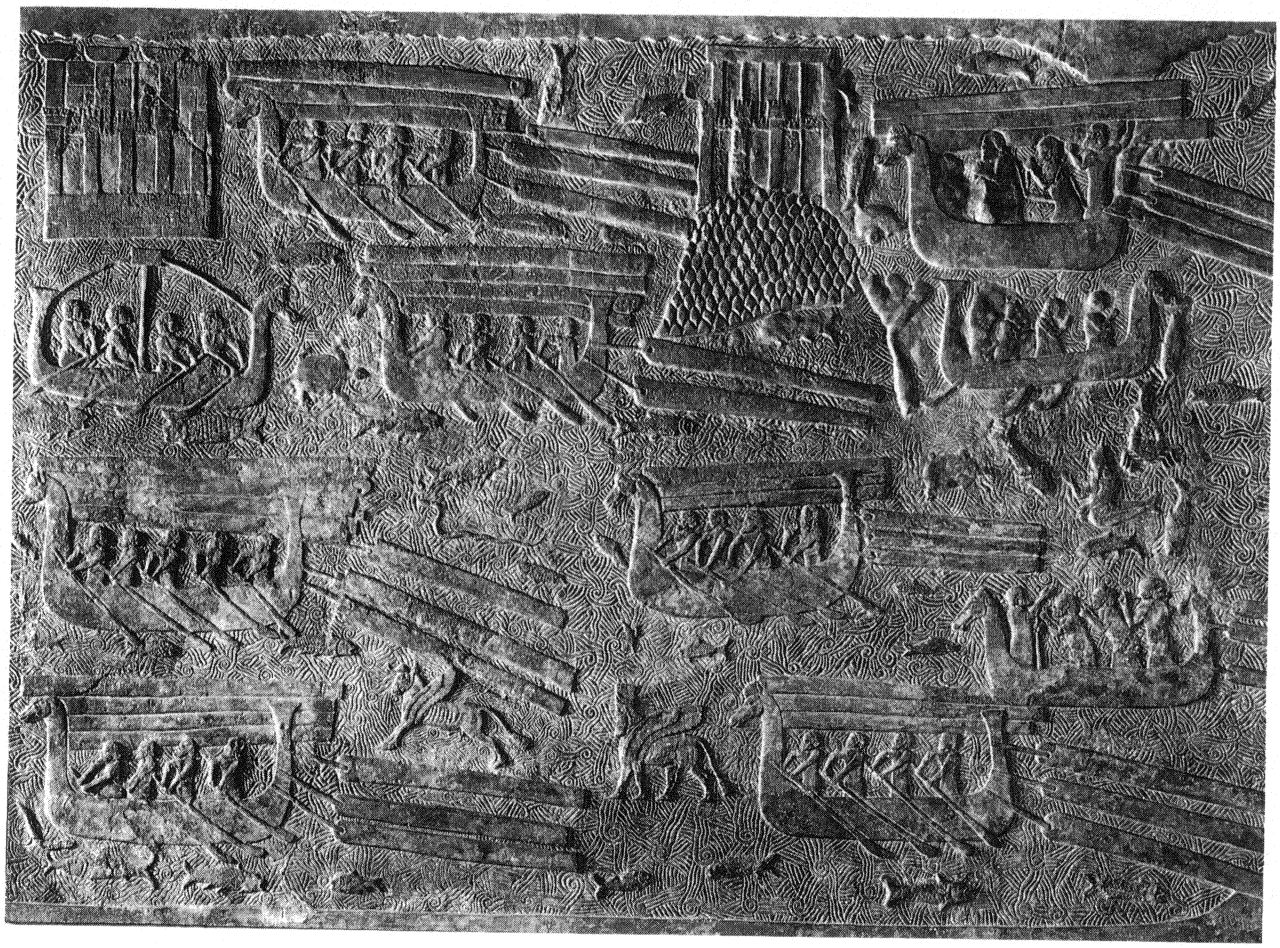


Fig. 4.28. Phoenician vessels depicted on the Tell Balawat gates (British Museum).

Fig. 4.29 (*below*). Phoenician vessels towing timbers, depicted in the palace of Sargon II at Khorsabad (Louvre, Paris).

ninth century, by which time the Assyrians had the Levant coastal city-states under their control. Bronze reliefs on the Tell Balawat gates of Shalmaneser III of *c.*850 BC, depict Phoenician vessels bringing tribute from their island kingdoms to their Assyrian overlord (Fig. 4.28). These coastal craft have near-vertical ends with horsehead figureheads (*hippoi*) at both ends. They appear to be steered by a steering oar to starboard, and propelled by oars in the stand/pull mode. A Judaean seal of *c.*725 BC (Stieglitz, 1999: fig. 3) has a ship with a square sail and a *hippos* at the bow.

A wall relief from the palace of Sargon II (722–705 BC) at Khorsabad has similar craft, but with a *hippos* at the bows only, towing two, three, or four baulks of timber astern (Fig. 4.29). Tribute rather than trade is probably depicted, since such reliefs appear to have been designed to commemorate some Assyrian triumph. The craft appear to be propelled by oars in the mode stand/push: the oar blades are similar in shape to those on other Assyrian reliefs (3.5.4 and Fig. 3.16). One craft that is not towing timber (Fig. 4.29, left of second register) has a mast stepped near amidships with stays fore



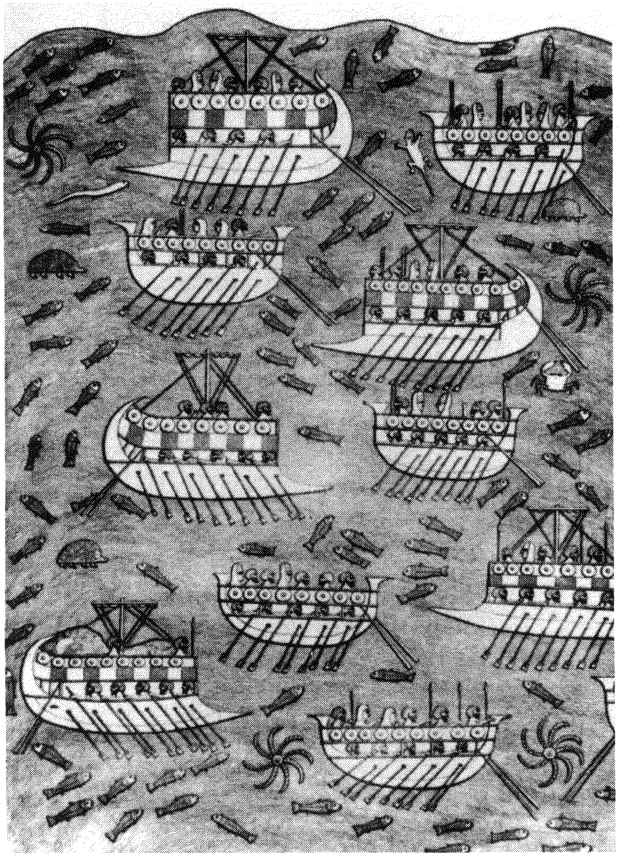


Fig. 4.30. Phoenician warships and cargo ships on a relief in the palace of Sennacherib at Khorsabad (British Museum).

and aft; there is a structure at the masthead, possibly a top or lookout platform.

In 1848, Layard excavated several depictions of Phoenician seagoing ships which had been carved (705–681 BC) in low-relief on limestone in Sennacherib's palace at Khorsabad. Only fragments of these now remain, but Layard had drawn some of them soon after exposure, and photographs were taken of some of the reliefs in 1903–4, although by this time, they had deteriorated significantly. Basch (1987*a*: 303–18) has pointed out that some of the detail in Layard's drawings are 'improvements' on the original. However, he has concluded that, in general, Layard's drawings are a reasonable record of the reliefs as found.

The scene depicted (Fig. 4.30) is the evacuation of the population of Sidon and Tyre by sea to Cyprus in advance of the invading Assyrians in *c.*701 BC (Basch, 1969: 144; Morrison, 1995*b*: 145). Warships and cargo ships are depicted: both types have two levels of oars manned, the upper tier pivoted at sheer level, the lower through oarports. At a third, higher, level, there are passengers and/or armed men behind a bulwark on which there are shields: these people are probably sitting on benches (cargo ships), or standing (warships), on a deck which appears to run from bow to stern and which may extend the breadth of the vessel (and thus be over the upper oarsmen's heads) or merely be a catwalk along the middle line. Both cargo and warships have steering devices on each quarter: these seem to be steering oars rather than rudders.

Neither type has a figurehead: nevertheless, in later centuries, Phoenician and Carthaginian ships could be identified by a characteristic *hippos* at the bows (3.4.7; Pliny, *NH* 7. 57; Aubet, 1993: 147). Strabo (2. 3. 4), quoting Poseidonius, noted that Eudoxus had found a horse-headed figurehead (*hippos*) when he was shipwrecked in Somalia on his return from his second voyage to India in the late second century BC (6.3). Eudoxus was told, on his return to Egypt, that such a figurehead could only have come from a Phoenician ship based at *Gades*/Cadiz (Johnstone, 1988: 93; Dilke, 1985: 61).

The Khorsabad cargo ships have a 'rounded' hull in longitudinal profile, and are double-ended with near-vertical posts. In contrast, the warships have a less curvaceous hull with a metal-sheathed pointed ram at the bow (Morrison, 1995*a*: frontispiece) and a stern which, at the tip, curves back on itself. Unlike the cargo ships, the warships have a mast stepped near amidships with stays fore and aft and braces from yardarm to deck: the sail appears to be furled to the yard.

These warships appear to have a series of plain and cross-hatched panels between the upper oarsmen and the upper bulwarks. An incomplete relief from Kuyundjik (Nineveh), also dated to the reign of Sennacharib, depicts a similar warship on which the stanchions that support the deck above the upper level of oarsmen can clearly be seen (Fig. 4.31). Basch (1969: 147) has interpreted the panels as protective screens for the upper oarsmen which he suggests the craftsman has misplaced. Morrison (1995*b*: 146), on the other hand, considers that the panels represent an unmanned third level of oars: that is, he believes these warships were triremes rather than biremes. A third possibility has been put forward by Sleeswyk (1999) who presents cross-sectional scale drawings of oarage systems in support of his thesis. Sleeswyk suggests that two types

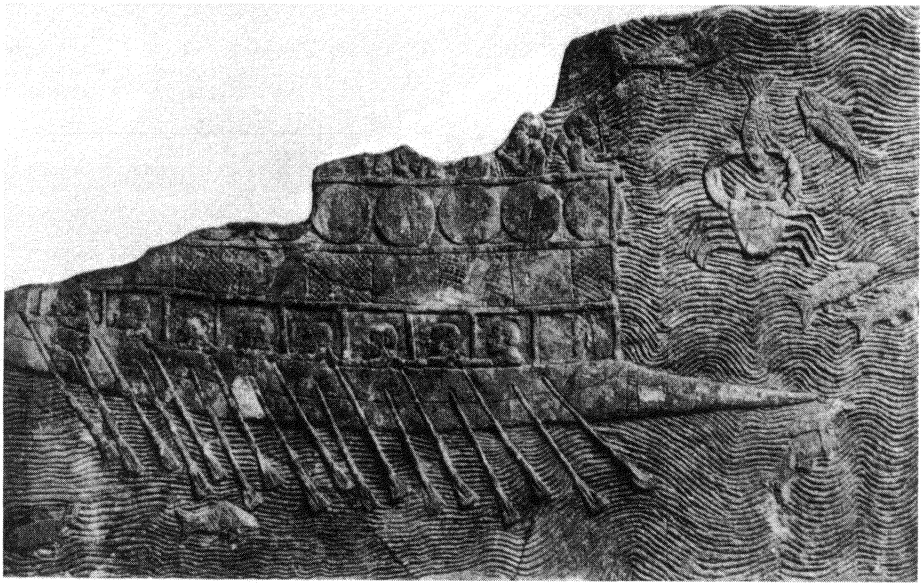


Fig. 4.31. Phoenician warship on a relief from Kuyundjik of *c.*700 BC (British Museum).

of warship are depicted: those with tumblehome (sides curving inwards); and those with outriggers. These theories depend upon the detailed interpretation of certain features (e.g. the precise position of the foremost upper oar in one of the warships) which may not have been the intention of the craftsman. Furthermore, Sleeswyk does not explain the series of plain and cross-hatched panels except to conclude that they could not be protection for the upper oarsmen in the way Basch visualized.

It must be accepted that these depictions are diagrams rather than draughtsman's scale drawings. The minimilist interpretation is that these Phoenician ships are biremes (two tiers of oars) and not triremes. The cargo ships have, at a third level, a deck with a bulwark behind which passengers (and others) can sit. The warships also have a deck at a third level, with a higher bulwark behind which armed men stand.

4.9.3.2.2.2 *Description*

Ezekiel (27: 3–10), writing in the early sixth century BC, mentioned a warship of Tyre. Parts of his description are difficult to translate, however, it is generally agreed that the mast was of cedar and the oars of oak, the sails were of linen, and she had a purple and scarlet awning (Jerusalem Bible, 1974: 1202–3; Wachsmann, 1998: 227; MacLaurin, 1978). The hull planking was fir or juniper; the deck planking was cedar or cypress. MacLaurin, however, translates the latter phrase as 'lattice bulwarks of tamarisk'. Another phrase in this passage is usually thought to refer to caulking seams: Wachsmann has pointed out, however, that an equally valid translation would refer to fastening planking together.

4.9.3.2.3 *Early mortise and tenon joints*

Locked mortise and tenon joints were used in the superstructure of the mid-third millennium BC Egyptian Cheops ship, although the comparable joints used in the hull were unlocked (2.7.1). The Dahshur boats of *c.*1850 BC also had unlocked mortise and tenon joints in the hull, and locked ones in wooden artefacts found with the boats (2.8.3.2). By the mid-first millennium BC, on the other hand, the hull of the Egyptian Matariya boat (2.8.3.4) appears to have been fastened with locked mortise and tenon joints.

The earliest recorded use of locked mortise and tenon fastenings in the Levant region is on a wooden table from a tomb in Jericho dated to the mid-second millennium BC (Wachsmann, 1998: 241, figs. 10.28 and 10.29): this is roughly contemporary with the Uluburun ship. Sleeswyk (1980) has shown from documentary evidence that the Romans knew this type of joint as *coagmenta punicana*—'Phoenician joints'.

Bass (1991; 1997: 269), and Wachsmann (1998: 206–8) following him, believe that the mid-second-millennium BC wrecks off Cape Gelidonya and off Uluburun were Levantine (i.e. Phoenician) in origin. Others have argued for Cyprus or the Aegean: whilst Cyprus is almost indistinguishable from the Levant, in terms of

archaeological evidence from this period, an origin in Greece would have very different implications for the history of shipbuilding. Identifying the 'nationality' of a shipwreck is a difficult task and a definitive answer cannot be expected (1.4.2.1), but the evidence at present available seems to suggest Levantine/Cyprus rather than the Aegean. The Uluburun wreck (4.8.3.1) of *c.*1305 BC, provides the earliest evidence for the use of locked mortise and tenon joints to fasten together hull planking, a technique which, by the mid-first millennium BC, seems to have become widespread in the Mediterranean.

It is therefore conceivable that, in the mid-second millennium BC, the Phoenicians may have pioneered the use of locked mortise and tenon joints to fasten the underwater planking of seagoing ships, thus giving the hull more structural integrity. Improved woodworking techniques could have enabled them to do this without an increase in water seepage into the hull. The frames may have continued to be lashed in position by methods that did not involve boring holes through the planking (2.7.1). Such an innovation could well have led to the Phoenician reputation for seafaring excellence (4.9.3.2.1).

4.9.4 EARLY SEWN-PLANK VESSELS (Fig. 4.3)

Sewing was the principal means by which the Cheops ship's planking was fastened together: this may also have been the case for the Dahshur boats. References in Homer (4.9.2.1) suggest that Greek ships of the eighth century had sewn planking. Statements by Virgil (Aeneid 6. 413–14) and by Pliny (*NH* 24–65) support this interpretation. The next evidence for sewing comes from the sixth century BC and later, when there are several excavated ships which are either fully or partly sewn.

4.9.4.1 GIGLIO (Parker, 1992: no. 451)

This wreck, in Campese Bay, Giglio, off the west coast of Italy, carried ingots of copper and lead, and a cargo of Etruscan, Samian, Punic, and Ionian origin which has been dated to 600–590 BC. Part of an oak keel, the two garboards and three other strakes from one side were exposed and recorded (Bound, 1985). The pine planks were positioned by treenails within the planking thickness and then sewn together through diagonally disposed holes which had a trapezoidal notch inboard: the stitches were then wedged within their holes. In a preliminary report, the excavator considers that the ship was Etruscan.

4.9.4.2 BON PORTÉ; (Parker, 1992: no. 106)

Keel fragments, some frames and a few strakes were excavated in 1973–4 from this wreck off the south coast of France, near St-Tropez (Jestin and Carrazé, 1980). The cargo, which was mostly Etruscan, Ionian, and Massilian pottery containers, has been dated to 530–525 BC. Initially this ship was thought to have had wooden plank fastenings, but re-evaluation by Basch (1976*b*) and Pomey (1981, 1997*a*) has demonstrated that this was a sewn-plank vessel, although no sewing survived. The 20 mm thick planks were first positioned by 9 mm diameter treenails across the seams and within the planking thickness, at 160–140 mm spacing. The planks were sewn together (probably over caulking) by diagonal continuous stitches which were wedged within paired holes. The seams were then treated with pitch internally. The relatively heavy frames (m. 140, s. 120 mm) were spaced at *c.*1 m, and appeared not to be fastened to the planking recorded. A large mast step was fastened to the framing by mortise and tenon joints (Pomey, 1981: fig. 5). Pomey (1981) believes this was an Etruscan vessel not more than 10–12 m in length, with a round hull, but a flattish bottom.

4.9.4.3 VENICE LAGOON

Fragments of planking excavated in 1968 from Venice, and dated to *c.*530 BC, are thought to be the remains of a sewn boat (Beltrame, forthcoming).

4.9.4.4 PLACE JULES-VERNE, MARSEILLES

Two of the boats excavated during 1992–3 from the Place Jules-Verne in Marseilles have sewn planking (Pomey, 1995, 1996, 1999): Wreck 9, a fishing boat some 5 × 1.5 m; and Wreck 7, a cargo ship *c.*14 × 4 m. Both vessels are dated to the end of the sixth century BC. Wreck 9 had locating treenails within the seams, and appeared to have been sewn throughout with the stitches countersunk outboard (Fig. 4.32). She had a rectangular keel with rabbets, and a gently curving

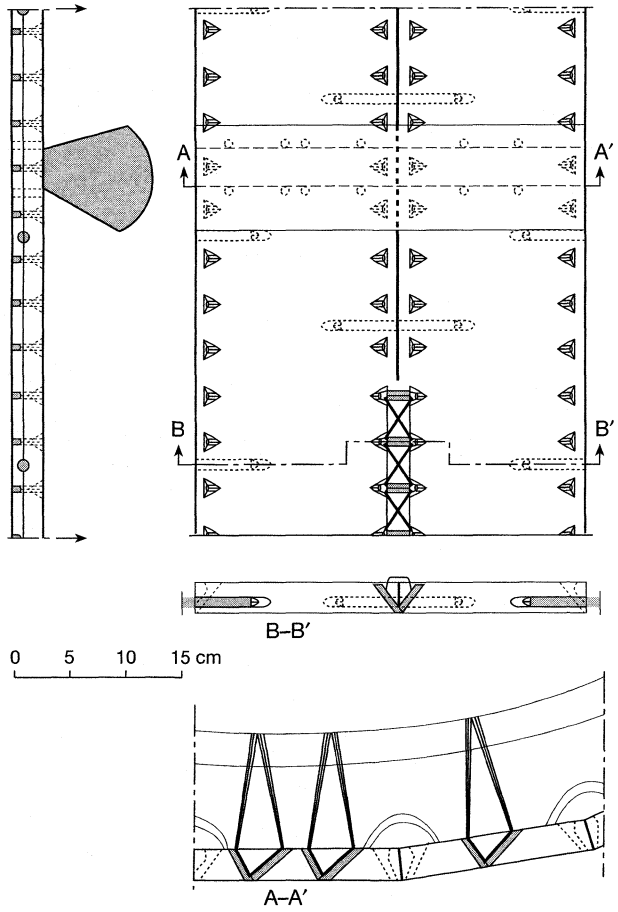


Fig. 4.32. Sewn fastenings on the Place Jules-Verne 9 wreck (after Pomey, 1997c: 92).

transverse section (Pomey, 1996: fig. 5). The frames were notched to fit over the caulking running along the seams, and were lashed to the planking.

The planking of Wreck 7 is mainly fastened by locked mortise and tenon joints, but sewn fastenings were used at the ends of the hull, and for a number of plank repairs. The tenons measure 140–50 × 30–5 × 5 mm, and are spaced at 190–120 mm apart. The framing is nailed to the planking by iron nails, the earliest known use in the Mediterranean. Pomey (1995) believes both vessels are of Greek origin, and come from a period when mortise and tenon fastenings were replacing sewn fastenings. Research is still in progress.

4.9.4.5 GELA (Parker, 1992: no. 441)

This relatively well-preserved wreck from off southern Sicily has been dated to the late sixth/early fifth centuries BC by reference to the cargo of Greek, Ionian, and Phoenician pottery (Freschi, 1991): 6–7 tonnes of ballast was also carried, laid on matting in sand. The plank fastenings in the lower hull are similar to the earlier examples described above, with a layer of 'fabric' as a caulking along the inner seams before the planks were sewn together. The inner hull was then payed with pitch (see also Pliny, *NH* 16. 21, 23). In the upper hull mortise and tenon joints were used to fasten the planking together (Kahanov, forthcoming). The framing was fastened to the planking with copper and iron nails—second only to the Marseilles wrecks. A keelson was notched to fit over the frames, and a mast step was associated with it (Freschi, 1991: fig. 202). Research is still in progress.

4.9.4.6 MA'AGAN-MICHAEL (Parker, 1992: no. 612)

This wreck of *c.*400 BC was excavated from close inshore, some twenty nautical miles south of Haifa (Kahanov, 1999). Research is still in progress. The ship had been carrying *c.*13 tonnes of stone which mainly had its origins in Corsica and Calabria in the Tyrrhenian Sea, but some also came from Cyprus: this ballast was on grass matting laid in a dunnage of pine and oak. There was also Cypriot and Ionian pottery, cordage, shipwright's tools, and a one-arm wooden anchor (Rosloff, 1991).

The 40 mm thick pine (*Pinus halepensis*) planking was fastened together generally by mortise and tenon joints spaced at *c.* 87 mm, locked by tapered oak treenails. However, the ends of the first three strakes were sewn to the posts and to both post-knees ('dead wood'), and the garboard strake was sewn in places to the keel, the details being similar to sewn fastenings of the earlier ships (Fig. 4.33). The tenth strake was a wale, being thicker than the others. Fourteen pine frames, spaced at *c.*0.75 m, were similar to those in the Bon Porté and Gela ships, each consisting of a floor and two futtocks joined by treenail-fastened hooked scarfs. These frames were probably assembled before installation and were fastened to the planking (but not to the keel or the post-knees) by copper nails clenched inboard by turning the tip through 180° (hooked) (Kohanov *et al.*, 1999).

The pine keel was joined to the posts in short scarfs which were fastened by locked mortise and tenon

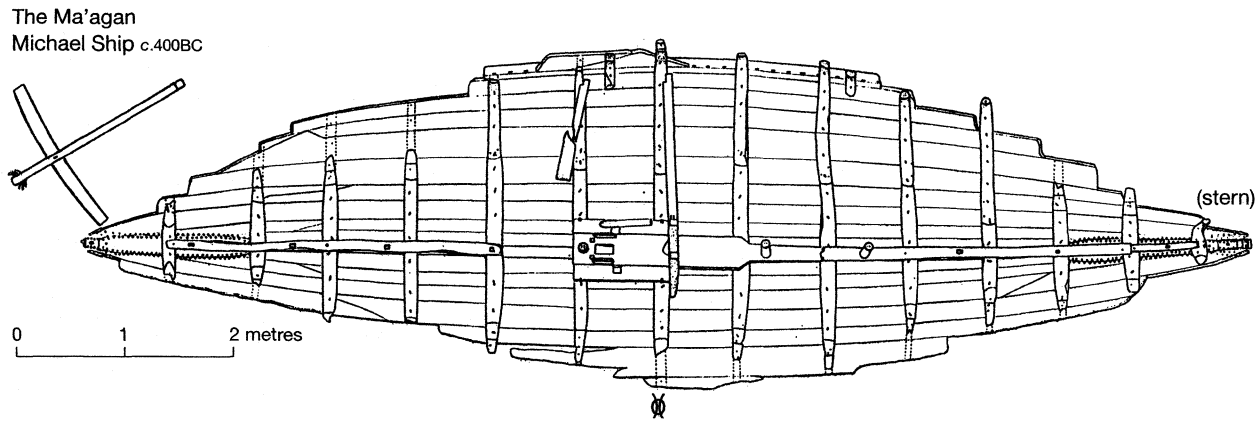


Fig. 4.33. Plan of the Ma'agan-Michael wreck (Yak Kahanov).

joints. The keel had no rabbets and the deadrise of the garboards was determined by a bevel worked along their inner edges. A false keel was fastened below the keel, whilst above it, on the centreline and over the floors, were timbers forming a discontinuous keelson. One element of these timbers was a pine mast step which was notched to fit the framing near amidships, and had partners on both sides.

The ship was originally *c.*13.5 m in length and had a wine-glass shaped transverse section, rather than the full-form of earlier sewn plank ships: such a reverse-curve hull maximizes both strength and resistance to leeway. Kahanov's hydrostatic calculations (forthcoming) indicate that, in addition to the 13 tonnes of stone, she could have carried *c.*3 tonnes of cargo. She appeared to be relatively new when excavated: there were no shipworm holes or barnacles in the planking, freshly worked chips of wood were found in the bilges, and there was no observable wear on the keel, false-keel, wale, bow, or stern, or on the anchor. Kahanov (1996) has summarized the evidence for her origins and for her final voyage:

stone	Aegean or Cyprus
food	South-west Anatolia or the Aegean
ceramics	Cyprus and Greece
wood species	Levant coast, Turkey, Cyprus, and Greece
copper for nails	probably north-west Cyprus (Kahanov *et al.*, 1999: 284)
hull structure	the nearest parallels come from the central Mediterranean

The stone may well have been recycled ballast from another ship. The wood species used in the hull, and for tools and dunnage—Allepo pine (*pinus halepensis*), eastern plane (*Platanus orientalis*), olive (*Olea* sp.), Pistacia pine (*Pistacia Palaestina*), and oak (*Quercus* sp.)—could all have been found on the Levant coast in the fourth century BC, and the ship may have been built in that region. She may have been wrecked on return from a voyage to Cyprus and western Anatolia.

4.9.4.7 ROMAN AND MEDIEVAL SEWN-PLANK BOATS

The Cavaliere wreck of *c.*100 BC (Parker, 1992: no. 282) has sewn planking as part of the superstructure and as a repair in the stern. The second-century BC wreck, La Jeanne-Garde B, has two reinforcing framing timbers sewn to the planking (Carrazé, 1977: fig. 7); whilst in the late first-century BC wreck Cap Bear C (Parker, 1992: no. 171) lashings and treenails were used alternately to fasten framing to planking. The seventh-century BC wreck from Playa de la Isla, south-eastern Spain (Negueruela *et al.*, 1995) appears to have mortise and tenon-fastened planking, whereas the framing is lashed to the planking. On the evidence of the cargo, the excavators believe this to have been a Phoenician ship. Work continues on this site so that these early observations may not be conclusive.

A number of sewn-plank boats dated from the late centuries BC to the eleventh century AD have been excavated from coastal sites in the Adriatic, in Croatia, and in the delta of the River Po. This seems to be a relict

population which survived for over 1,000 years despite fundamental technological change in adjacent regions, because they fitted well into a particular environment: lakes, lagoons, and deltas (Beltrame, forthcoming; Pomey, 1981, 1985; Brusić and Domjan, 1985).

The two Nin/Zaton boats (Parker, 1992: no. 1248–9) of the early centuries AD, and the Ljubljana/Laibach boat of the late centuries BC were all from Croatia. The latter had a flat bottom connected to flared sides by a hollowed transition strake (Fig. 4.34). The planking was caulked with limebast, and fastened together with limebast rope by continuous stitching through holes 80–100 mm apart. Numerous floors were notched to fit over the seams and treenailed to the bottom planking, whilst knees were similarly fastened to the sides and bottom. Four longitudinal stringers were treenailed and iron nailed to the bottom through the floors. The iron nails were clenched by turning their tip along the outer face of the bottom planking (McGrail, 1981: fig. 4.1.17).

The Nin boats (McGrail, 1981*b*: fig. 4.1.16) were round-hulled and had a keel to which the planking was fastened by continuous sewing over a longitudinal lath, which presumably trapped caulking (Fig. 4.35). The stitches were wedged within the sewing holes, the holes blocked with resin and the outboard part of the stitch cut away—a technique also used recently in boats of the Lamu archipelago, east Africa (Prins, 1986), so that the stitching cannot be damaged when the boat takes the ground or is dragged across the foreshore.

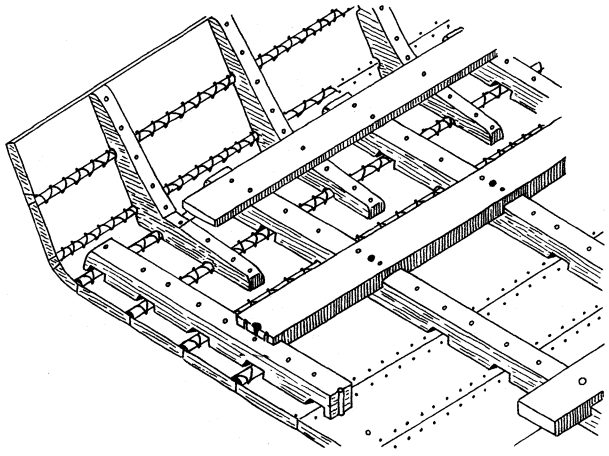


Fig. 4.34. Constructional details of the Ljubljana boat (after Müllner, 1892).

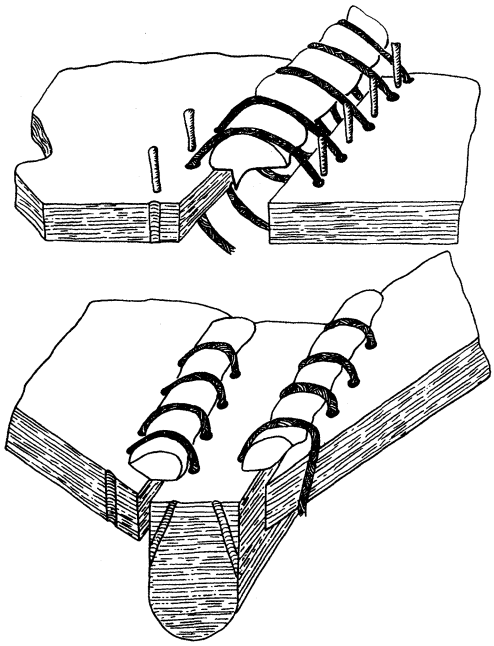


Fig. 4.35. Plank fastening details of the Nin boats (after Brusić, 1968: fig. 8).

Six other boats came from the River Po region: Comacchio/Valle Parti (Parker, 1992: no. 1206) of the first century BC; Venice Lido and Corte Cavanella 1 and 2 (ibid. 339; Beltrame (forthcoming) of the first or second centuries AD; Cervia (ibid. 293) of the second to fourth centuries AD; and Pomposa (ibid. 862) and Borgo Caprile (ibid. 109) with early medieval dates. Generally these six boats were fastened with continuous sewing, but nails were also used in the Comacchio wreck to fasten scarfs and to fasten plank-ends to the posts. Nails were also used in the Cervia boat. The frames of Comacchio were lashed to the planking, whereas those of Corte Cavanella (and possibly others) were treenailed.

None of these boats was recorded in detail, nevertheless, it is clear that on eastern and western coasts of the Adriatic, boats with their planking mainly sewn together continued to be built and used in lakes, rivers, and deltas from Roman times (and probably much earlier) into the medieval period.

4.9.4.8 SEWN-PLANK BOAT CHARACTERISTICS

Boats with sewn planking are known worldwide: from mid-third-millennium BC Egypt to twentieth-century AD India (McGrail, 1996*c*). The sewn-plank boats so far

excavated in the Mediterranean appear to have some characteristics which are universal and some which are regional:

(a) They are built plank-first: as is the case worldwide (Prins, 1986; McGrail, 1996*c*).

(b) There are no examples of Mediterranean (or Egyptian) vessels which rely solely on sewing to position and fasten the planking together. They have either treenails or mortise and tenon fastenings within the seams, as well as sewn fastenings across the seams. The majority of sewn boats in use today also do not rely solely on the stitching (Prins, 1986). Exceptions have been noted on the east coast of India and in Sri Lanka (Kentley, 1985). The known ancient sewn-plank boats from north-west Europe (5.4) do not have any fastenings other than their sewing, but they do have framing/transverse timber, wedged or lashed to the planking which enable the planks to be aligned and also reduce shearing stress on the plank fastenings.

(c) There are no Mediterranean examples of planking being fastened by individual stitches/lashings, as found, for example, on the Bronze Age Ferriby boats of the Humber estuary (5.4.2.1) and on the fourth-century AD Pontian boat of Malaysia (8.3.5.1.1). The Mediterranean (and Egyptian) vessels all have continuous sewing.

Within the Mediterranean, the technique of sewing planking together has been found on vessels wrecked off the Levant coast in the east, the south coast of France and Spain in the west, and the estuary of the River Po in the north. The vessels range in date from *c.*600 BC to medieval times. The technique is mentioned by Homer (*Iliad*, 2. 135; *Odyssey*, 5. 244–57) in the eighth century BC, and by a range of others, from fifth-century BC Aesychlus (*Suppliantes*, 134–5) to fifth-century AD St Jerome (*Epistolae*, 128. 3). Generally speaking, these references are within a Greek context. The ships and boats described and excavated are used in a range of environments from lake, river, and estuary to fully seagoing.

The early vessels had their planking positioned by treenails within the seams and then fastened together by continuous sewing, with each stitch wedged within its hole. From the late sixth century BC, possibly as an outcome of the early sixth-century orientalization of Greece by Phoenicians (O. Murray, 1993: 81; Osborne, 1996: 167–8), mortise and tenon joints began to be used over much of the hull, sewing being restricted to the regions where leaks were most likely: either the underwater hull (Gela), or the ends and repairs (Jules-Verne 7 and Ma'agan-Michael). Caulking, which is found worldwide in sewn-plank boats, has only been reported on the Gela and Jules-Verne 9 wrecks: it seems likely that it was used (but not recognized) in the other vessels, possibly in the form of resin or tar/pitch.

How the frames of the early sewn vessels were fastened to the planking is unclear from excavation reports, but by 500 BC they were fastened with copper or iron nails (Jules-Verne 7 and Gela). Precisely how these nails were used is not clear, but by 400 BC (Ma'agan-Michael) they were clenched by turning the tip through 180° back into the frame. By comparison with early Egyptian vessels, with the seventh-century BC Playa de la Isla wreck off south-east Spain (4.9.4.7), and with late prehistoric/early medieval boats of north-west Europe (5.4.6–7, 5.7.1. 2, 5.7.1.4.1), it may be that frames of the early Mediterranean sewn-plank boats (Giglio, Bon Porté, and Jules-Verne 9) were lashed to the planking, though not necessarily to every strake. Should the framing of these early vessels prove to have partly rounded cross-sections, this lashing hypothesis would be supported.

4.9.5 SHIPS AND BOATS OF THE CENTRAL MEDITERRANEAN

The Etruscan city-states appear to have grown out of the Early Iron Age Villanovan culture which flourished in central Italy between the Rivers Arno and Tiber up to *c.*800 BC. By the seventh and sixth centuries BC, almost the entire Italian peninsula was under Etruscan dominance. In the late third century BC they were conquered by the Romans, and by the first century, Graeco-Roman culture was all-pervasive.

As with the Phoenicians, more is known about Etruscan seafaring from Greek than from Etruscan sources. During the first millennium BC, probably stimulated by Phoenician and Greek seafarers and traders, Etruscans became active in both the Tyrrhenian and Adriatic Seas (Hagy, 1986). In *c.*535 BC, allied with Carthaginians, they fought a Phocaean Greek fleet armed with rams off Alalia in Corsica (Herodotus, 1.

166–7). Pliny (*NH* 8. 209) attributed the invention of the ram to the Etruscans, but this seems unlikely: it is possible, however, that Phoenicians/ Carthaginians introduced the ram to the Etruscans at an early date.

There were trading connections between Sardinia and Italy from early times, and it is convenient to discuss evidence for boats and ships from both places in this section.

4.9.5.1 SARDINIAN MODELS

More than one hundred (eighth to fifth centuries BC) bronze boat models of the Sardinian Nuragic culture are known today, mostly from that island but some from Italy and one from Corinth, Greece (Calcagno, 1997: 51; Basch, 1987*a*: 404–6). All models are hollow and most of them have a large ring amidships by which they were presumably hung and possibly used as lamps or incense burners: thus it seems likely that a flat bottom on a model is authentic and not a craftsman's device to stabilize a standing model. On this assumption, there are two distinct groups: those with rounded hulls (Fig. 4.36); and those with flat bottoms (Fig. 4.37). In general, the models show very little sheer, which brings into question whether they can depict seagoing craft. Protruding from one end (the bow?) of every model is a representation of a horned deer or a bull's head. On many models a variety of animals stand on the top of the sides (Fig. 4.37).

Although these models strongly suggest that boats had a key role in Sardinian life, they tell us little about structure or propulsion. Johnstone (1988: 142) considers that they represent logboats rather than hide or bark boats, whilst Bonino (1995) believes that zig-zag features along the sheerline, and circular features at one end, identify them as sewn-plank boats. Casson (1971: 68) believes that some of them represent seagoing craft. All these hypotheses are very speculative: more might be learnt about structure and function if detailed, measured drawings could be compiled.

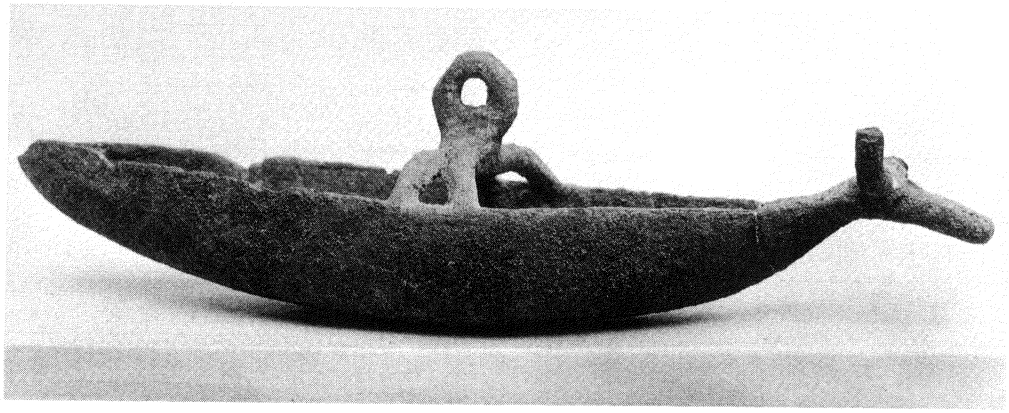


Fig 4.36. A Bronze Age round-hulled boat model from Sardinia (British Museum).



Fig. 4.37. A Bronze Age flat-bottomed boat model from Vetulonia, Sardinia (Sopritendenza alle Antichita, Firenze).

4.9.5.2 VILLANOVAN AND ETRUSCAN REPRESENTATIONS

The Villanovans placed model boats in their graves, and this tradition was continued by the Etruscans from the eighth century BC. The Villanovan models, mostly of clay and dated from *c.*1000 BC onwards, are generally flat-bottomed and with little sheer. They have a figurehead at one end which appears to be that of a bird: one model (Basch, 1987*a*: fig. 842) has these at both ends. Another model (Basch, 1987*a*: fig. 843) has seven holes through each side, just below the sheerline: these may represent oar ports; on the other hand, they could be points from which the model was suspended.

In addition to the burial of boat models, some of which are similar in form to Sardinian models but with a bird rather than an animal figurehead, the Etruscans depicted boats and ships on pottery (Basch, 1987*a*: figs. 865–77). The earliest depiction is that incised on a vase from the early seventh century BC (Basch, 1987*a*: fig. 865): this appears to represent a galley curved longitudinally at both ends where the bottom meets the rising posts. A mast is stepped amidships and four oars are depicted. The vessel is steered by a steering oar, or possibly a rudder, on each quarter, and has a raised deck at bow and stern. Towards the stern there are lines to a fish which suggest that a fishing boat is depicted, however, there is an underwater projection from the bow which has the appearance of a ram, an interpretation which has been much debated. Similar forward projections appear on other depictions of Etruscan vessels, most of them being above the deduced waterline with a tendency to point downwards (Basch, 1987*a*: figs. 482, 868–71). It may be that this enigmatic feature represents a bow which has been shaped for directional stability or for potential speed, rather than a ram.

Sail is frequently depicted on these Etruscan ships and some have a feature at the masthead which is probably for a lookout. A ship depicted in the early fifth-century BC Tomba della Nave at Cerveteri (Basch, 1987*a*: fig. 880) has two masts, one amidships, one forward. This is one of the earliest depictions of a two-masted vessel, close in date (late sixth century) to the two-masted vessel on the rim of a Corinthian krater published by Casson (1980)—see also Basch (1987*a*: figs. 499–500). The Tomba della Nave ship is probably typical of the Etruscan cargo ships which traded in the Tyrrhenian Sea during the mid-first millennium BC. This, and the other evidence, indicates that the Etruscans played their part in overseas trade in the first millennium BC central Mediterranean.

4.9.6 NAUTICAL DEVELOPMENTS THROUGH THE EARLY IRON AGE

There are no significant wrecks dated to this period except those of sewn-plank boats of the sixth century BC (4.9.4). The mortise and tenon-fastened wreck off Playa de la Isla in Spanish waters has been provisionally dated to the seventh century BC (4.9.4.7). Thus reliance has to be placed entirely on representational evidence, and information from the few documentary sources.

4.9.6.1 CENTRAL MEDITERRANEAN

The evidence here is much less substantial than in the eastern Mediterranean, but it is possible to conclude that indigenous vessels in the Tyrrhenian Sea used sail from at least the early seventh century BC. Rams were in use on warships by the sixth century, and by the fifth century, a distinctive cargo sailing ship with two masts was in use.

4.9.6.2 THE EASTERN MEDITERRANEAN

By the eighth century BC in the eastern Mediterranean a distinction was being made in written sources between warships and cargo ships. The earliest depictions of undoubted cargo ships are from *c.*700 BC in the Levant (Fig. 4.30), and from the late sixth century BC in the Aegean (Casson, 1996: fig. 1; 1971: figs. 81, 82, 97). Warships with thirty and with fifty oars (i.e. fifteen or twenty-five each side) are mentioned by Homer, and there are depictions from the ninth century BC onwards with approximately these numbers of oars. The earliest are monoremes, but biremes are depicted in the Aegean from the mid-eighth century BC (Fig. 4.26) and a little later in the Levant (Fig. 4.31)—these Phoenician biremes have a third level deck on which soldiers and/or passengers can be carried. The change from one level (monoreme) to two levels (bireme) of oarsmen resulted in a shorter vessel (*ceteris paribus*). As Coates (1990*a*) has pointed out, this has several advantages: agility is improved all round with increased rate of turn, acceleration, and speed. Furthermore, a

bireme penteconter probably cost less than one that was a monoreme, and, since its longitudinal bending problems were reduced, the bireme was much less likely to suffer major damage in a seaway, and with less leakage, would have had a longer, useful life. These qualities would have been of most use to warships, but they would also be useful in a cargo ship seeking to evade pirates—probably the reason why the merchant galleys of *c.*700 BC were biremes.

The ram is first depicted in the late ninth/early eighth-century BC Aegean (Fig. 4.24), and in the early seventh century in the Levant (Fig. 4.31). The earliest rams are pointed (4.12.3), but during the sixth century BC, blunt-ended ones appear (Casson and Linder, 1991: fig. 5.4). The bireme warship galley, armed with a ram, was widely used in the eastern Mediterranean in the sixth and fifth centuries BC: it led to the trireme.

4.10 The Trireme of the Seventh–Fourth Centuries BC

Some ten years after the Persian, Darius, was defeated by the Greeks at Marathon, his son, Xerxes, led another invasion by land and by sea. In Xerxes' fleet there were said to be 1,207 triremes drawn from Egypt, the Levant, Cyprus, Asia Minor, and some of the Aegean islands (Herodotus, 7. 89–95). In 480 BC, at Salamis, this fleet was defeated by a Greek fleet in which there were 380 triremes (Herodotus, 8. 82). Herodotus (3. 44; 2. 159) also refers to the use of triremes in the sixth century BC: Polycrates, ruler of Samos, had 40 triremes in *c.*540 BC; and Nechos II of Egypt (*c.*600 BC) had triremes built, some on the Mediterranean coast, others on the Arabian Gulf, though Wallinga (1993: 45–6) has questioned this. In the sixth and fifth centuries the trireme evidently was the main warship in the eastern Mediterranean, but its origins must lie in the seventh century BC or earlier.

The earliest known reference to a trireme is by Hipponax in the mid-sixth century BC (Papalas, 1997: 25). However, Herodotus (1. 166) described a battle in *c.*600 BC (Morrison, 1995*c*: 152) in the Tyrrhenian Sea between Phocaean Greeks and a Tyrrhenian and Carthaginian fleet in which Thucydides (Warner, 1954: 21) believed there were triremes. Thucydides (1. 13) also noted the belief that the first Greek triremes were built in Corinth and that a Corinthian shipwright, Ameinocles, built four ships (presumably triremes, but Meijer (1986: 35) doubts this) for Samos, around 700 BC. Basch (1969: 139) has argued that the trireme was evolved in Sidon *c.*700 BC, and Morrison (1995*d*: 54–7) generally supports this view. Wallinga (1993: 1–32), on the other hand, has argued that the trireme did not emerge until the late sixth century BC. Papalas (1997) recently evaluated these views, and others, and concluded that the trireme appeared in *c.*700 BC, but was not used offensively until *c.*525–500 BC when the Greeks evolved the *diekplous* and other ramming tactics.

These opinions on the origins of the trireme are based on the interpretation of documentary sources: no wreck resembling a trireme (or even a bireme) has so far been excavated. It has been argued that, since triremes were so lightly built and needed no ballast, they did not sink when damaged in battle but remained crippled on the surface until they could be towed away (Morrison and Coates, 1986: 128; Casson, 1991: 82); thus it is suggested that remains are unlikely to be excavated. However, triremes wrecked in a storm or by other marine hazards may well have become waterlogged and eventually sank to the sea bed where, in some circumstances, they may remain to be excavated. Moreover, triremes were sometimes run ashore and abandoned (Herodotus; 6. 16); and after the battle of Salamis, captured Phoenician triremes were dedicated and displayed at the Isthmus, at Sunium, and at Salamis itself (Herodotus, 8. 12). Fragments of triremes may yet remain buried on land.

4.10.1 EVIDENCE FOR THE TRIREME

Since there is as yet no direct evidence for the trireme, documentary, iconographic, and some indirect archaeological evidence has to be used to establish its characteristic features, a task that has intrigued scholars since the Renaissance (J. Shaw, 1993*b*). From *c.*1975 there has been a relatively concerted attack on the matter, resulting in the building of the full-size reconstruction *Olympias* in 1985–7 by Dimitrios Tzakakos at Piraeus, under an Hellenic Navy contract and to a design (Fig.

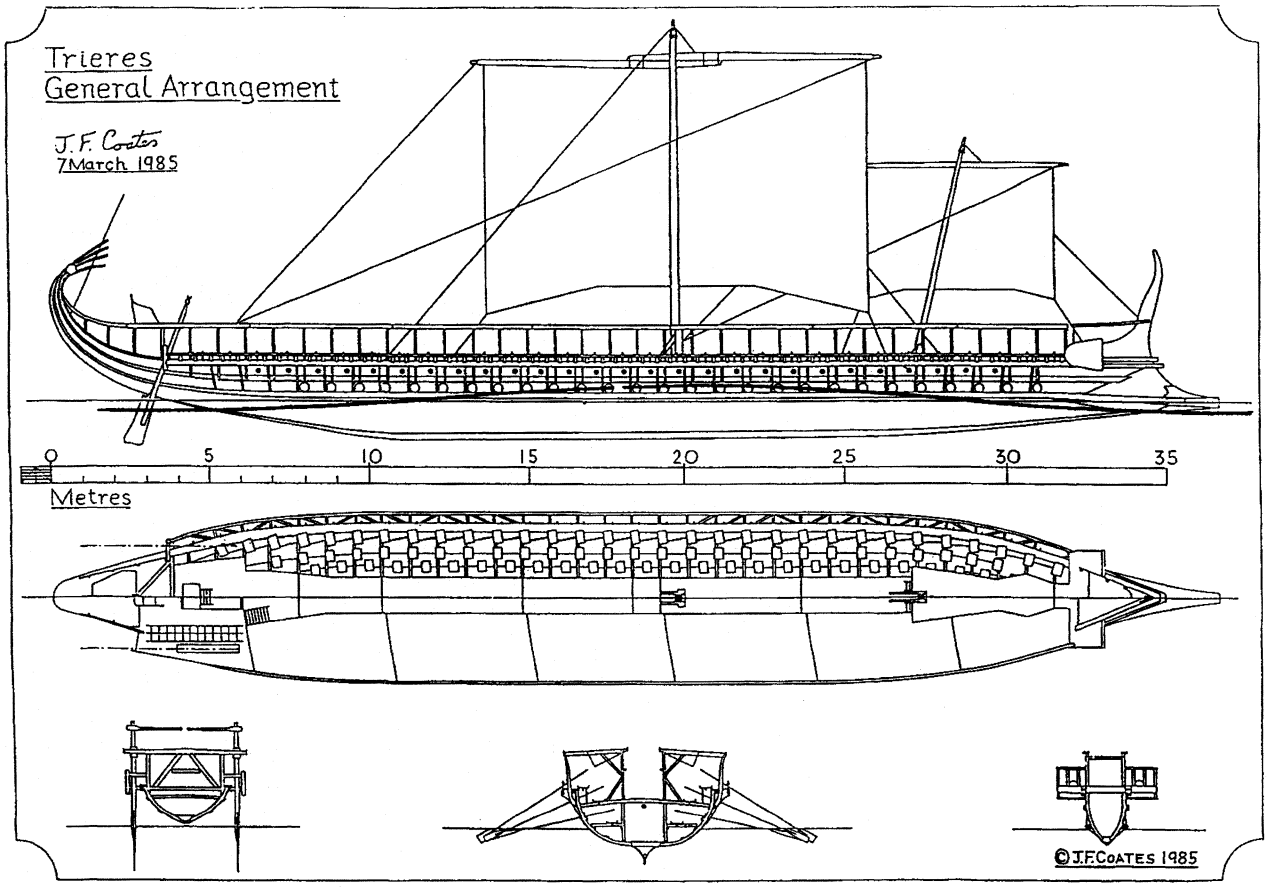


Fig. 4.38. Plans for the reconstructed trireme *Olympias* (drawing: John Coates).

4.38) and specification by the British Trireme Trust (Coates and McGrail, 1984; Morrison and Coates, 1986, 1989; Coates, Platis and Shaw, 1990; Shaw, 1993*a*; Morrison, Coates, and Rankov, 2000).

A fundamental point in the interpretation of the documentary evidence has been the meaning behind the Greek term *trieres* (trireme): the Trust has translated this as 'three-fitted' or 'three-rowing' (Morrison, 1995*d*: 63) and has taken this to mean that there were three files of oarsmen on each side of the ship. A remark by Vitruvius (1. 2. 4) that a warship's *interscalium* (distance between oarsmen) was two cubits suggests that this was the standard spacing in a trireme in his day. Other sources show that there was one man to each oar; that some oars were slightly longer than others; that outriggers were used; that a hogging stay or hawser was needed; and that ships had large and small masts, yards, and sails. Representations of vessels thought to be triremes suggest how oarsmen may have been arranged within their groups of three (Morrison and Coates, 1986: figs. 36, 41). Fifth-century ship sheds thought to have been used by triremes at Zea, Piraeus, suggest maximum lengths and breadths for triremes of that era.

Evidence for the sailing rig has also had to be drawn from literary and iconographic evidence (Roberts, 1990; 1993). Triremes are seldom, if ever, shown under sail since their intrinsic characteristic was their ability to use the ram under oars, therefore depictions of other ships' rig have been used. Roberts has incorporated brails, halyards, parrels, braces, tacks and sheets, and stays, but no shrouds, in his rig design: the area of the low-aspect ratio main sail (95 m^2) was calculated so that, in a steady Force 4 (a moderate breeze), the hull would not heel more than 9° so that the lower lee oarports would remain above water. The evidence considered by O. Roberts (1990: 288; 1993: 34–5) suggests that, generally, when under sail, the mainmast and sail were

used alone; the smaller mast was embarked instead of the mainmast before a battle and used, presumably in the main mast step near amidships, for a speedy retreat downwind if necessary. Nevertheless, both masts were included in the reconstruction as 'a reasonable archaeological experiment' and to ensure the directional stability of *Olympias* when running before the wind.

Since no trireme has been excavated it was necessary to draw upon structural evidence from later wrecks such as the Kyrenia ship of the fourth century BC (4.12.1) and the Marsala ship of the third BC (4.12.2). The main features here were that eastern and central Mediterranean hulls of this era were built planking-first; their planking was fastened by locked mortise and tenon joints; and framing was fastened to planking by iron nails through treenails. The 'wine-glass' midships section of these ships, the framing pattern of the Masala wreck, and the remains of hull structure inside the third-century BC Athlit ram (4.12.3) were used when designing the reconstruction (Fig. 4.38) (Coates, 1984, 1989*a*, 1989*b*, 1990*b*, 1993, 1995*b*).

4.10.2 AN ASSESSMENT OF THE TRIREME RECONSTRUCTION, *OLYMPIAS*

There are a number of theoretical and practical difficulties in undertaking any reconstruction project (Coates *et al.*, 1995) but the Trireme project had difficulties specific to it. Most projects of this nature are concerned with establishing a rigorous method of transforming the recorded, but incomplete, remains of an ancient vessel into a hypothetical reconstruction drawing or model, from which a full-size version is built. Since there are no excavated triremes the problem for the Trireme project has been to design a hypothetical reconstruction which would match documented aspects of performance whilst meeting constraints imposed by iconographic, historical, and archaeological evidence. With hindsight it is possible to criticize aspects of the Trust's research and trials—as indeed, the Trust has itself done (Shaw, 1993*a*). The Trireme Trust's general approach has also been criticized, not least by Westerdahl (1992). However, *pace* Westerdahl, there is no intrinsic reason why a scientifically based reconstruction should not be made of a ship type for which there are no physical remains, so the Trust's reconstruction cannot be dismissed for reasons of principle alone. The Trust's interpretation of some of the evidence has also been criticized, notably by Tilley (1976, 1992, 1995) and by Basch (1987*b*, but see Coates (1995*a*)). Nevertheless, a balanced assessment must be that both theoretical and practical aspects of the Trireme project have greatly increased understanding of early shipbuilding and seafaring in the eastern Mediterranean. *Olympias* is a 'floating hypothesis' (McGrail, 1992*b*) which is probably as near as anyone could get, at the first attempt, to the Athenian trireme of the fifth century BC, with the evidence at present available.

4.10.2.1 SPEEDS ACHIEVED

Much emphasis during the sea trials of *Olympias* was laid on achieving a sprint speed of 9.5–10 knots since it was considered that this was the equivalent of a cruising speed of 7.5–8 knots which is the average speed needed to undertake the passage from *Byzantium* (Constantinople) to *Heraclea* (on the Black Sea coast of Asia Minor) in 'a long day under oars' (Xenophon, *Anabasis*, 6. 4. 2)—a 'long day' in summer in these latitudes being taken as sixteen to seventeen hours (twilight to twilight). The Trust's position seemed to be that achieving this sprint speed was a necessary, but not a sufficient, condition for validating the claim that *Olympias* was an authentic reconstruction of a fifth-century BC trireme. Xenophon's knowledge of nautical matters has been questioned by some scholars (notably Wallinga, 1993) but even if we allow that Xenophon was familiar with seafaring, his statement is hardly precise. For example, a case can be argued that the phrase 'from *Byzantium* to *Heraclea*' meant 'from the position when departure is taken from (lose sight of) *Byzantium*, to the position when a landfall is made at first sight of *Heraclea*'. In this way the 'distance' would be of the order of 110–100 nautical miles, giving the average speed required as 6.5–6 knots.

Over five seasons of trials *Olympias* achieved:

- a sprint speed of over 8.4 knots for a minute or so, with 8.9 knots momentarily.
- with a flying start, *c.*7 knots has been held for a nautical mile or so.
- over a period of one hour, 5.8 knots has been averaged.

It is therefore not unreasonable to say that *Olympias*

has probably been close to achieving the sort of speeds under oars that would be required to make the passage in a trireme from *Byzantium* to *Heraclea* in a long day.

4.10.2.2 OTHER ACHIEVEMENTS

The trials have certainly demonstrated that a three-level oar system is practicable, and that, with training, an inexperienced crew can achieve a relatively high standard. Although there are dissenters, it is also generally agreed that this oar system is compatible with the literary and representational evidence; as is the overall shape and layout of *Olympias*. The reconstruction also conforms to the excavated evidence for hull shape and structure, albeit from a period two centuries later, and from cargo ships rather than warships. Furthermore, the steering arrangements and the sail propulsion outfit generally are not incompatible with the, admittedly inadequate, evidence.

It had been thought by the Trust that, since the trireme was at the extreme of performance, the interacting constraints imposed by the ancient evidence and by naval architectural requirements were so tight that her hull form and structure, her displacement, and her oar system were defined closely with little, if any, scope for variations. It is now clear, however, that some parameters were not as fixed as was once thought: the *interscalium*, a fundamental unit in *Olympias* design, is now thought to have been 0.98 m rather than 0.88 m, and the overall length, rather than 36.8 m, may well have been 40 m, which is also compatible with the evidence from the Zea ship sheds (Shaw, 1993*a*: 108–11). This change in the perception of what was a fundamental unit does not mean that the original trireme experiment was flawed. *Olympias* had to be designed, built, and tested so that there was a focus for discussions: the hard reality of building a ship rather than flights of fancy on paper. Questions of how the ancient evidence should be interpreted have had to be tackled in the light of physics and engineering. Everyone involved, including the strongest critic, has benefited.

Much has also been learnt, from theoretical and practical studies in connection with *Olympias*, that otherwise could not have been. Coates (1990*a*) has shown, for example, that the change during the seventh–sixth centuries BC from bireme penteconter to trireme as the main warship had both advantages and disadvantages. There would have been a substantial gain in speed: for example, when cruising under oars, from *c.*5.5 to 7.5 knots. Against this gain had to be balanced a reduction in acceleration, and building costs increased threefold. Furthermore, the trireme hull was still of a length which induced increased longitudinal bending problems and leakage, and reduced length of life. This bending problem meant that a hogging hawser had to be fitted, and that it had to be arched if it was to relieve hogging stresses in the upper hull by raising the ends and imposing sagging forces (Coates, 1990*a*: 113–15).

Calculations and trials showed that ballast was not needed in a fully loaded trireme. *Olympias's* quarter rudders proved to have such a high resistance that it seems likely that, in ancient times, whenever possible, one was triced up clear of the water. Against a head wind gusting to 25 knots, *Olympias* under oars averaged 3 knots for over an hour: the crew were then exhausted. Under sail in light winds, *Olympias* evidently made *c.*1¼ knots headway when six or seven points off the wind (leeway discounted); on a broad reach she could make over 2½ knots (Fig. 4.39): Roberts (1993) believes that stays (which were fitted to the mast by *Olympias's* builder) could be dispensed with providing the mast tabernacle was firmly fastened to beams and floors.

The fact that *Olympias's* hull became hogged after three season of trials (Shaw, 1993*a*: fig. 12.1) focused attention on the important role that tenons play in the

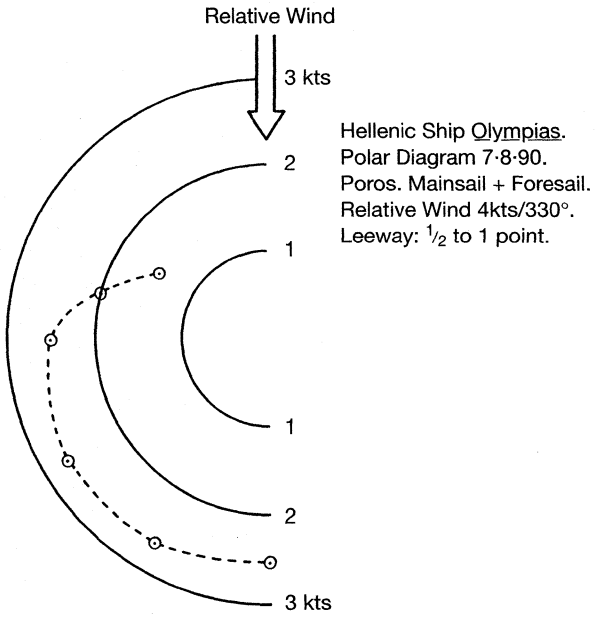


Fig. 4.39. *Olympias's* performance under sail.

structural strength of an ancient Mediterranean hull (Coates, forthcoming). The hogging occurred just above the waterline where shear stress, and the tendency for planks to slide upon each other, are greatest. Analysis has shown that, to minimize hogging, tenons must make an interference fit with their mortises in the longitudinal (fore-and-aft) direction; furthermore the tenons must be aligned so that their growth rings run across the breadth of the mortise, i.e. the tenons' radial dimension (along which shrinkage is least) must lie in the fore-and-aft direction. This alignment is similar to that found in treenails used to plug thickness gauge holes bored through the bottom of large logboats in north-west Europe and elsewhere (5.3.1).

4.10.2.3 FURTHER TRIALS

It seems clear that there are still useful trials to be done with *Olympias*. The oar system can be refined, and the methods used to measure speeds, to estimate closeness to the wind, and to plot the ship's track over the seabed need to be optimized. Once these are done, further trials, including lengthy passages, can be carried out under oars and especially under sail. The optimum design and use of the rudders needs to be investigated further, as do manœuvring and simulated ramming runs. A satisfactory means of exercising command and control without electronic assistance must be devised. Further theoretical studies are needed on the hogging hawser, and also on ramming tactics, before practical trials. Having proved herself, *Olympias* can now become a test bed for a wide range of activities which should significantly increase understanding of seafaring and warfare in the early Mediterranean.

4.11
Shipbuilding before the Third Century BC

Parker (1992: 10–11) lists 117 wreck sites dated to *c.*300 BC or earlier: of these, only eleven have any hull structural details noted. This proportion of *c.*10 per cent may reflect the apparently poor survival rate of hulls in the Mediterranean, but probably is more indicative of inadequate excavation, recording, or publication. Furthermore, the fact that hull structure is mentioned in an excavation report is no guarantee that even a partial structural analysis can be made, since descriptions, measurements, and drawings are seldom of the standard required—see also Steffy (1995*a*: 423–4). Three other early wreck sites with structural remains have been reported since Parker's work went to press: Place Jules-Verne, Marseilles sixth-century Wrecks 7 and 9; and the seventh-century wreck from Playa de la Isla in south-east Spain.

4.11.1 PLANK FASTENINGS AND FRAME FASTENINGS

These fourteen wrecks may be divided into three groups (Table 4.3) according to the nature of their primary plank fastenings.

Although certainty is impossible, since no complete hull has been excavated, it seems likely that the later hulls in Group 1, from the fifth century BC onwards, were entirely fastened by locked mortise and tenon joints. On the other hand, so little of the remains of the earlier wrecks has been investigated or reported, that it is possible that their planking was also sewn together.

Of the three wrecks in Group 2, Giglio and Bon Porté may have had some mortise and tenon fastenings in addition to their sewing, but sufficient of the hull of Place Jules-Verne 9 seems to have been recorded to make it highly probable that this was entirely sewn.

Group 3 wrecks have both types of fastenings: in Place Jules-Verne 7 and Ma'agan-Michael, the sewing is at bow and stern; in Gella the lower hull is sewn.

For the earlier wrecks and some of the later ones, the method of fastening framing to planking is inadequately documented. However, in the seventh–fifth centuries BC western Mediterranean, there are two examples of frames being lashed. From *c.*500 BC frames in eastern and central Mediterranean wrecks were fastened by copper or iron nails. In the Porticello, Place Jules-Verne 7, and Ma'agan Michael wrecks these nails were clenched by hooking the point back into the frame. In the Kyrenia wreck the nails were driven through treenails, and then hook- clenched.

Table 4.3 Plank and frame fastenings in vessels of the fourth century BC and earlier

Date (BC)	Vessel (Parker nos.)	Frame-to-plank fastening
1. *Planking fastened by locked mortise and tenon joints*		
*c.*1305	Uluburun (1193)	Unknown
*c.*1200	Cape Gelidonya (208)	Unknown
Seventh century	Playa de la Isla	Lashed
440–420	Porticello (879)	Hooked copper nails
*c.*400	Plane B (820)	Unknown
*c.*350	El Sec (1058)	Unknown
*c.*300	Halkoz Adasi (496)	Unknown
*c.*300	Kyrenia (563)	Hooked copper nails through treenails
2. *Planking fastened by wedged sewing*		
580	Giglio (451)	Unknown
530–525	Bon Porté (106)	Unknown
*c.*500	PJ-V9	Lashed
3. *Planking fastened mainly by locked mortise and tenon joints but with some wedged sewing*		
*c.*500	PJ-V7	Hooked iron nails
*c.*500	Gela (441)	Hooked copper nails and iron nails
*c.*400	Ma'agan-Michael (612)	Hooked copper nails

Notes: Only minor elements of the Uluburun and Cape Gelidonya hull structures have been investigated. Gela and PJ-V9 had dowels across the seams within the plank edges; Ma'agan-Michael had none.

Source: Parker (1992), and in the present volume. *Sites*: see Fig 4.3.

4.II.2 DEVELOPMENTS FROM *c.*1300 TO *c.*300 BC

The fourteen wrecks in Table 4.3 were excavated from the eastern, central, and western Mediterranean: they range in time (irregularly) from the fourteenth to the fourth centuries BC. Clearly there are too few of them and they are too widespread in time and space to allow firm conclusions to be drawn about hull structural changes. Furthermore, several of these wrecks, excavated decades ago, were not documented to the standards now used. Moreover, identifying any regional patterning in this data is difficult since a ship is not necessarily wrecked in home waters, and the origin, 'culture', or 'nationality' of a wreck is not easy to determine (1.4.2.1; 4.8; 4.9.3.2.3). Nevertheless the Uluburun and Cape Gelidonya (Group 1 in Table 4.3) wrecks have been identified as 'Canaanite' or 'Cypriot' by Bass (1991), and the early sewn-plank boats of the central Mediterranean (Groups 2 and 3) as 'Greek' or 'Etruscan' (4.9.4). Whilst the arguments advanced in both cases are not conclusive, the available evidence suggests that there could well be two traditions of shipbuilding: a 'Levant' tradition with its characteristic locked mortise and tenon plank fastenings (4.8.3.1–2; 4.9.3.2.3); and a 'Greek?' tradition of wedged sewn planking (4.9.4.8).

In the light of this discussion, and of matters considered in 4.8.3.4, 4.9.2.1 and 4.9.4.8, a hypothesis concerning the sequence of developments in Mediterranean shipbuilding between the third millennium BC and 300 BC may be outlined for evaluation by others. A primary assumption is that the Group 3 ships in Table 4.3 were following in the tradition of Uluburun and Cape Gelidonya (4.8.3.1, 4.8.3.2).

1. *In the third millennium* BC and earlier, Mediterranean hulls had sewn planking (without or with interplank dowels) and frames were lashed to that planking. This technological phase would be comparable with what appears to have happened (not necessarily contemporaneously) in other regions, for example, south-east Asia (8.3.5.1 : 8.3.7), north-west Europe (5.4), and in Egypt (2.6 and 2.7).

2. *Second millennium* BC. In the Levant, the locked mortise and tenon joint (known earlier in Egypt—but not in underwater hulls) began to be used as the main plank fastening. Sewing was retained in difficult/vulnerable parts of the hull. This implies that, in addition to having locked mortise and tenon fastenings, the Uluburun and Cape Gelidonya ships had sewn-plank fastenings, perhaps towards bow and stern and in other key areas. Frames continued to be lashed.

3. *In the first millennium* BC. The locked mortise and tenon joint was adopted widely, but not universally, in the eastern and central Mediterranean, but sewing continued to be used in those parts of a hull considered to be 'a problem'—for example, in the bottom strakes (Gela), or at the ends (PJ-V7, Ma'agan-Michael). At about the same time, frames began to be fastened by metal nails clenched by turning the point through 180° (PJ-V7; Gella, Ma'agan-Michael). In the far west similar mixed fastenings may have been used, but with lashed frames retained (Playa de la Isla). In the western (PJ-V9) and central Mediterranean, some fully sewn boats continued to be built, culminating in the Adriatic sewn-plank boat tradition of Roman and early medieval times (4.9.4).

4. *In the late first millennium* BC *to* c.300 BC Widely in the Mediterranean, hulls were built with locked mortise and tenon plank fastenings, and with metal-fastened framing (Porticello, Plane B, El Sec, Kyrenia, and Halkoz Adasi).

4.11.3 THE CHANGE FROM SEWN TO MORTISE AND TENON FASTENINGS

4.11.3.1 THE ADVANTAGES OF SEWN PLANKING

The advantages and disadvantages of using sewn-plank fastenings and lashed frames have never been investigated systematically, although Coates (1985; forthcoming) has shown how this might be tackled, both theoretically and experimentally. Unlike prehistoric north-west Europe and twentieth-century India (McGrail and Kentley, 1985), there are no known examples of pure sewn planks from ancient Egypt and the early Mediterranean. Egyptian and Mediterranean planking was positioned and fastened together by additional wooden fastenings—mortise and tenon (unlocked or locked), dowels/treenails/'coaks', or possibly double-dovetail cramps (2.7.1; 2.8.3; 4.9.4). Apart from locked mortise and tenon joints, these wooden fastenings and the sewn fastenings did not involve boring holes right through the planking, thereby minimizing leakage.

Most of the sewn-plank vessels so far known from the Mediterranean had dowels across the seams—from plank edge to plank edge—as well as stitches. Three of these vessels, PJ-V7, Gela, and Ma'agan-Michael, had mortise and tenon joints in addition to dowels and sewing (Table 4.3). Mortise and tenon joints were not found in the excavated parts of three other sewn-plank (with dowels) ships—Giglio, Bon Porté, and PJ-V9: it is possible that they were used in the first two, but unlikely in the third.

The use of dowels with sewn fastenings has two main advantages over sewing alone:

- adjacent planks can be positioned more easily relative to one another, not only before initial sewing, but also when re-sewing after periodic renewal of stitching.
- the dowels, *ceteris paribus*, have a greater resistance to shear forces in the planking than stitching, especially if the rays of the dowels are aligned with the plank seams (Coates, forthcoming). In the case of the Bon Porté wreck, Coates has calculated that the shear carrying capacity of her dowels would have been almost twice that of her sewing.

Shearing forces, which cause the side planks in a hull to slide longitudinally in relation to each other, lead to stressed plank fastenings and loss of hull integrity. These longitudinal forces are caused by the vertical hogging of the hull: that is, the ends of the boat are pulled down. Hogging occurs whenever a vessel is afloat due to the imbalance of weight and buoyancy along the length of a hull (other than a rectangular box shape): weight is greater than buoyancy towards the ends, and less than buoyancy amidships. These sustained hogging (hence shear) forces are supplemented by further shear forces, varying in magnitude and direction, which are generated as the immersed volume of the hull (hence buoyancy) constantly changes when the vessel is at sea in waves.

On certain assumptions, Coates (forthcoming) has calculated that, since shear forces are directly proportional to displacement, a warship (a long, narrow, and

low vessel), held together by stitches alone could not have a displacement greater than 10 tonnes: thus a triaconter (thirty-oared warship) as reconstructed by Coates (1990*b*) would not have needed dowels. On the other hand, cargo ships, generally with shorter, broader, and deeper hulls, are less severely stressed than warships, and therefore the displacement limit for sewn fastenings alone, would have been greater.

The advantages of using dowels across the seams of sewn-plank seagoing vessels are therefore clear. However, unless they are locked (as in south-east Asia—8.3.5.2.3) dowels cannot be used alone as plank fastenings: another type of fastening such as sewing has to be used to bind the hull planking together.

4.11.3.2 THE ADVANTAGES OF LOCKED MORTISE AND TENON FASTENINGS

There are also clear advantages in the change from sewing with dowels to locked mortise and tenon fastenings. Like seam dowels, unlocked mortise and tenon fastenings need a second form of fastening (double-dovetail tenons, lashings, or sewing) to bind the hull planks. Locked mortise and tenon joints, on the other hand, like clenched nails (5.7.1, 5.8.2), are positive fastenings on both sides of a seam, and can be used as the sole plank fastening in a hull. Furthermore, when fitted tightly in the longitudinal direction within mortises, they have significantly more resistance to shear forces, which occur during launching and during beach landings, and, more importantly, when afloat due to the stress reversals imposed on the planking as the hull alternately hogs and sags in response to the motion of the sea (Coates, 1996). Moreover, the tenons act as discontinuous internal frames, reinforcing the hull transversely.

The change to locked mortise and tenon fastenings would have necessitated improved woodworking skills so that joints and seams without caulking leaked minimally. The change to metal-fastened framing would also have needed increased woodworking abilities. The two innovations taken together would have increased the cohesiveness of the planking shell, both in strength and in watertightness.

It seems likely that these changes would have been stimulated by warship requirements, particularly on the introduction of the ram in the ninth/eighth centuries BC (4.12.3). Locked mortise and tenon plank fastenings and nailed frames would result in a better fighting machine than one with sewn planking and lashed framing.

Mark (1991) has suggested that fewer tools, and less knowledge and skill are needed to build a sewn-plank boat than one with mortise and tenon fastenings. Sewn-boat builders certainly need special skills to ensure that stitches are not exposed outboard in the underwater planking otherwise they would be broken during launching, landing, or unintentional grounding: in Egypt and the Mediterranean, the stitches are retained within the thickness of the planking by boring angled holes from the inner face to the edge (for other techniques see 3.6; 5.4; 6.7.3). These holes have to be precisely aligned with holes in adjacent planks if internal wear is to be minimized. The manufacture and positioning of dowels is equally skilful. On the other hand, sewn boats probably need more maintenance—ethnographic evidence suggests that they were frequently dismantled and re-sewn, sometimes annually—as in Orissa, India.

Evidence discussed above suggests that, at first, locked mortise and tenon joints were used in conjunction with sewn fastenings. Since this sewing was a design feature and not merely a repair, and seems to have been in the underwater hull and/or at the ends, the skill that had to be acquired before sewn fastenings could be entirely dispensed with, was probably the ability to cut mortises at an angle, within the thickness of a bevelled plank: this was especially needed where the hull shape changed rapidly, both longitudinally and transversely. Until this technique was perfected, mortise and tenon joints were used only in the less-curvacious parts of the hull where mortises were more nearly aligned with plank faces.

4.12
The Hellenistic Age (Fourth–First Centuries BC)

The 'Golden Age' of Greece, in which the arts and sciences flourished, as well as shipbuilding and seafaring, was over by *c.*380 BC. From the middle of the fourth

century BC, the peripheral northern Greek state of Macedon, led by Philip II and his son, Alexander the Great, began to dominate, mostly by land battles, first the Aegean states, and then the Persian Empire (Asia Minor, the Levant, Mesopotamia, and Egypt); north-east India was also invaded. After Alexander's death in 323 BC this Macedonian Empire separated into a number of large states each ruled by a Greek.

In the central Mediterranean, Rome had from the early fifth century BC expanded from its Etrurian heartland to dominate most of Italy by the middle of the third century BC. Subsequently Rome came into conflict with the Carthaginians in a series of three Punic Wars. In the first of these (264–241 BC) there were several battles at sea in a dispute over the possession of Sicily. The second war was mainly fought on land (220–200 BC) when Hannibal invaded Italy. In the third war (149–146 BC), Rome invaded and destroyed Carthage. By this time, Roman territory outside Italy included Sardinia, Corsica, Sicily, and parts of North Africa; Greece, western Anatolia, Spain, France, and the Netherlands followed. Julius Caesar invaded Britain twice, in 55 and 54 BC, extending Roman influence to its northern limits. The civil war which followed Caesar's death was resolved in the sea battle at Actium in 31 BC.

Greek culture and technology dominated the eastern Mediterranean during the fourth and third centuries BC, and continued to have a strong influence there. By this time (the Hellenistic Age), the nautical technology of the eastern and the central Mediterranean (apart from the Adriatic) may well have been very similar: ships and boats built plank-first; planking mostly fastened together by locked mortise and tenon fastenings; framing mostly fastened to the planking by metal nails. Archaeological evidence, scarce though it is, generally supports this hypothesis.

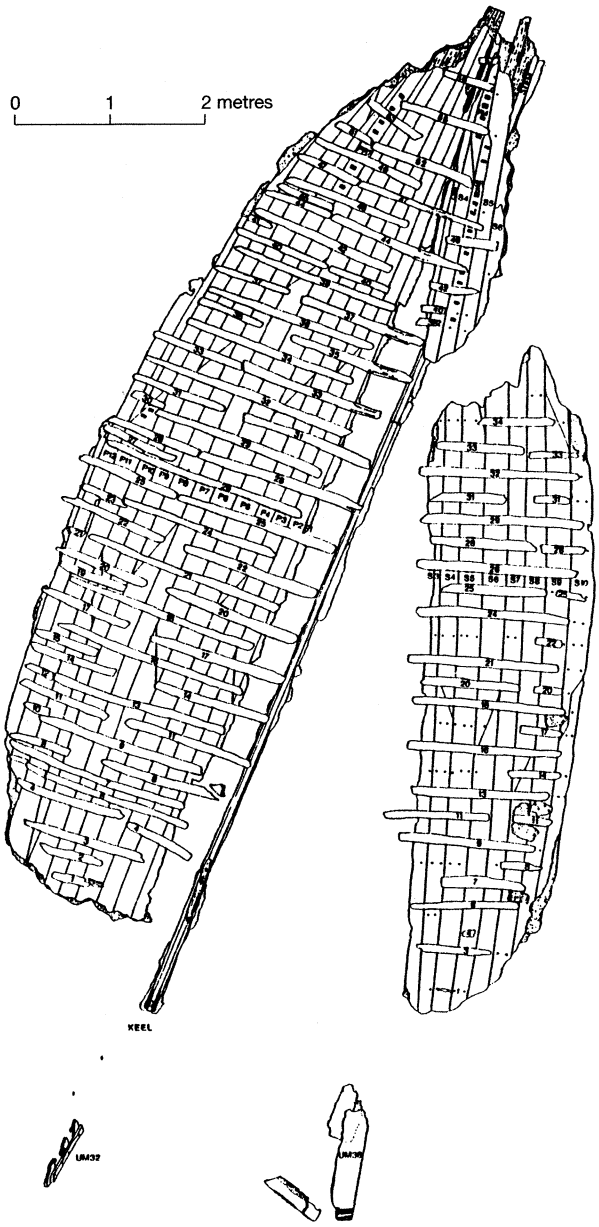


Fig. 4.40. Plan of the Kyrenia wreck (after Steffy, 1994: fig. 3.23).

4.12.1 THE KYRENIA SHIP (Parker, 1992: no. 563)

This wreck site, off the north coast of Cyprus, was excavated in 1968–9 (Fig. 4.40). The remains were lifted and conserved, and are now on display in the medieval castle in Kyrenia. The hull, which is dated *c.*300 BC by associated coins, has a 'wine glass' transverse section (Fig. 4.41), and is similar in form to that of the Ma'agan-Michael wreck (4.9.4.6). The locked mortise and tenon plank fastenings are also similar and they appear to have been used throughout the ship (unlike Ma'agan-Michael). Hooked copper nails with a round cross-section and driven through treenails were used to fasten the framing to the planking. All these structural features were to persist for 500 years or so.

The ship (Steffy, 1985*a*, 1989, 1994: 42–59, 1995*b*) was mainly built of Aleppo pine (*Pinus halepensis*), whilst Turkey oak (*Quercus cerrus*) was used for the plank

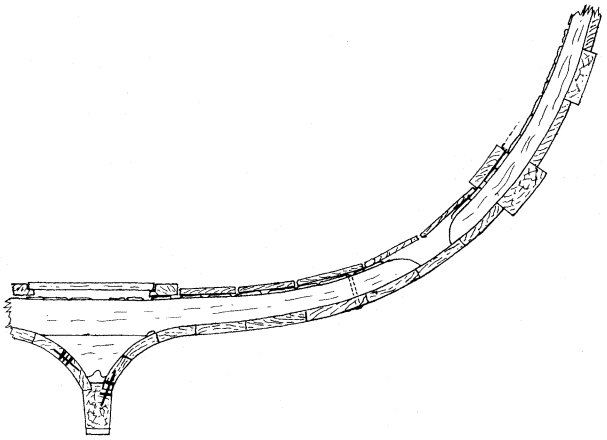


Fig. 4.41. Transverse section of the Kyrenia ship (after Steffy, 1994: fig. 3.31).

fastenings and the false keel. The keel (m/s = 200/120 mm) has a horizontal length near the middle of the ship, otherwise it is rockered. The L-shaped, two-piece stern is fastened to the keel in a horizontal hooked scarf with locked mortise and tenon joints. The curved stern post has a fixed tenon which is set into a mortise in the aft end of the keel and locked by a horizontal peg (Steffy, 1994: fig. 3.24): a large knee is fastened to the inboard faces of the post and keel.

The strakes were made up of two or three 40 mm thick planks fastened together in a horizontal scarf by locked tenons: these joints were mostly aligned with similar joints in the plank seams indicating that each plank had been fitted separately; some strakes were completed before they were fastened to the hull—in these cases the scarf mortises were cut at right angles to the scarf seams. The plank scarfs were shifted throughout the hull so that those in adjacent seams were not close together.

Plank seam mortises were *c.*6 mm thick and thus occupied *c.*12½ per cent of plank thickness: they were angled where necessary to match the changing shape of the hull and they were offset longitudinally from joints in adjacent strakes. Mortises averaged 43 mm broad (siding) and 80 mm deep: the average spacing was 117 mm. The tenons were 150–200 mm in length (i.e. approximately twice the depth of a mortise) and had rounded corners. After each strake had been fashioned and satisfactorily fitted to the tenons protruding from the lower strake, the tenons were locked within their mortises by multi-sided tapered pegs which were driven generally from inboard into 60 mm holes, above and below the seam, through planking and tenon. Steffy (1994: 48) has estimated that there were more than 4,000 mortise and tenon joints in the original Kyrenia ship.

After at least eight, probably nine, strakes had been fastened together (Steffy, 1995*b*: 26), the lower framing was added to the hull. Floor timbers spanning six to nine strakes each side alternated with paired half-frames, which did not reach as far as the keel. Side frames were added in line with, and in some cases butted to, the floors and the half-frames, but they were not fastened to them (unlike those in the Ma'agan-Michael ship). There were occasional top timbers (Steffy, 1994: fig. 3.34). None of the floors touched or were fastened to the keel, but they were fastened by unlocked mortise and tenon joints to a chock inserted in the cavity between floor and keel. The majority of framing timbers were compass timbers chosen so that their grain followed the transverse curvature of the hull. Both floors and half-frames were frequently crooked along their length and wandered somewhat across the planking. The forty-one frame stations (floors and half-frames) were about 0.25 m apart. Limber holes were cut over the seam between the second and third strakes, and over the seam between the fifth and sixth strakes, also in each chock.

Frames were generally square in section with 85–90 mm sides. They were fastened to the planking by copper nails driven from outboard through treenails and generally clenched inboard by turning the point

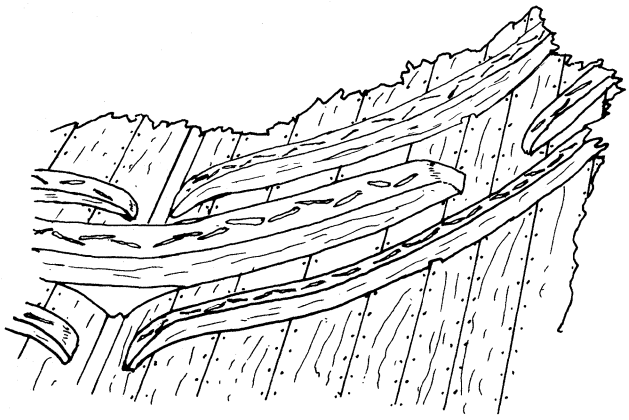


Fig. 4.42. Methods of clenching the nails fastening the framing to the Kyrenia planking (Institute of Archaeology, Oxford).

through 180° back into the frame (Fig. 4.42). Along the garboard and second strakes, where the distance through plank, floor, and chock was 0.30 m or more, copper spikes were used. The treenails were tapered and driven from inboard. The advantages of driving fastening nails through treenails are that leakage through fastenings is reduced, the stresses produced by the nail are distributed around the hole and thus the risk of splitting is reduced, and framing timbers, which are natural crooks and therefore of value, may be re-used more readily, since removing the nails need not damage the actual fastening holes.

The framing in the plank-first Kyrenia ship may be compared with that of the frame-first, Romano-Celtic Barland's Farm boat (5.6.1). Both use a mix of floors and half-frames with associated, but unconnected side timbers and the occasional top timber. The Barland's Farm boat does not have the regularly alternating framing pattern of Kyrenia, however, and her half-frames overlap (but are not fastened together) across the bottom of the boat.

Frame fastenings of these two boats are also similar: they differ in that iron instead of copper nails are used in the Romano-Celtic boat. A more fundamental difference is that in Kyrenia the frames were fastened to the planking, whereas in Barland's Farm, the planking was fastened to the framing.

The tenth strake (the first side strake) was the Kyrenia ship's main wale: that is, a specially chosen plank twice as thick as the ordinary planking. The twelfth strake, probably at the loaded waterline, was also a wale being 60 mm thick, i.e. 1½ times that of the planking. Steffy has estimated that there were two more strakes above this wale. Inboard of the main wale a stringer or beam shelf 50 mm thick was nailed to the inner faces of the framing.

The ship had loose bottom boards for access to the limber holes, and outboard of these was a ceiling of planks nailed to the framing. Kyrenia had no full-length keelson but a mast step timber was notched to fit over frames F33, 35, and 37. The mast step itself was 160 × 90 mm. Alongside the mast step are steps for stanchions which in conjunction with two of the three crossbeams (at beam-shelf level) are deduced to have supported longitudinal mast partners either side of, and *c.*60 m above, the mast step (Steffy, 1989: fig. 7). Other frames F47 and F44 were also rabbeted and may have been an alternative position for the mast-step timber; however, these frames are even nearer the bow than F33, 35, and 37.

A timber, heavily eroded by teredo, was found astern of the wreck and is thought to have been part of a rudder or steering-oar blade.

The Kyrenia ship is the earliest known to date to have been fastened solely by mortise and tenon joints. By this date, in the eastern Mediterranean at least, the locked mortise and tenon joint was well understood. This elegant fastening was fashioned to such fine limits that, unlike sewn-plank boats, no caulking was needed; its major disadvantage must have been the time needed to make the joints, and to fit and fasten each plank. Other advances seen in the Kyrenia ship of *c.*300 BC, when compared with the Ma'agan-Michael ship of *c.*400 BC are that the Kyrenia keel had rabbets for the garboards to fit into, thus improving the integrity of the lower hull, the framing pattern of alternating floors and half-frames had been evolved (this was to become the standard pattern for the next few centuries), and the keel was rockered. As well as being operationally advantageous in steering and in beach operations, this last feature also increased the hull's resistance to the stress reversals experienced in a seaway and thus minimized the working of plank seams (Coates, forthcoming). Furthermore, the Kyrenia underwater hull had been sheathed with lead during service, mainly as a barrier against teredo crustacea and as anti-fouling; lead sheathing would also have increased watertightness (Kahanov, 1994; Hocker, 1995).

4.12.1.1 THE KYRENIA RECONSTRUCTION

As with most ancient wrecks, the bow, stern, and upper sides of the hull were incomplete, when excavated. Using three-dimensional models, Steffy has reconstructed the Kyrenia hull as a lines plan (1985*a*: fig. 20; Katzev, 1989*a*: fig. 1). The bow and stern regions are conjectural to varying degrees. In his interim report, Steffy records that the sheer line was based on 'the pattern of isolated nails and scattered remote fragments which were recorded during excavation. But this evidence was slim . . . ' (Steffy, 1985*a*: 99).

From these reconstructed lines (and possibly from the three-dimensional models), construction drawings for a complete ship appear to have been produced and from these drawings a ship known as Kyrenia 2 was

built in Greece in 1982–5 (Katzev, 1986, 1987, 1989*a* and *b*, 1990).

This vessel measures 14 × 4.2 m and has an estimated cargo capacity of *c.*25 tonnes. She is double-ended with a sweeping sheer, a stern higher than the bow, and soft bilges. Katzev (1989*a*: 165) has noted that the bow configuration is conjectural, and the curvature of the stern post somewhat hypothetical. The twin quarter rudders are based on the fragmentary remains of a blade. The sailing rig is more conjectural, presumably being based on representational evidence, as is the case in almost all reconstruction experiments.

The fact that the mast step was found so far forward, with no balancing second step further aft, has been a problem for the reconstructors. In the on-site drawings the mast step appears to be approximately one-third the overall surviving length from the foremost part of the ship to survive: in published photographs of the reconstruction, the mast appears to be in this one-third position relative to the waterline of the ship as built. A square sail on a mast so far forward would not necessarily be in balance with the hull, resulting in steering problems, and it is noteworthy that rudders and tillers were broken during sea trials of Kyrenia 2. Differential brailing could be used, however, to change the effective shape of the sail and thus reduce this tendency. If the bow were to be reconstructed with a protruding forefoot, the mast step would be nearer amidships, possibly sufficiently far forward of amidships to give the lead (of centre of effort of the sail over the centre of lateral resistance of the hull) that a square sail needs to optimize directional stability and minimize steering problems (O. Roberts, 1995).

An alternative approach would be to consider a fore-and-aft sail such as a lateen or a sprit. On a mast stepped well forward, as in Kyrenia 2, such a sail should in theory be more in balance than a square sail. The iconographic evidence for fore-and-aft sails in the Mediterranean does not appear until some 200–50 years after the date of the Kyrenia wreck (4.14.1) but this should not deter experimenters from trials with different forms of sail.

Steffy's publications of the Kyrenia ship's structure, her sequence and method of building and repair, and her significance to archaeological studies is very well argued and presented, and unchallengeable. The design, building and trials of Kyrenia 2 have not yet been comprehensively published: the future publication of the final report on the Kyrenia project may dispel doubts about the value of Kyrenia 2.

4.12.2 THE MARSALA WRECKS (Parker, 1992: nos. 661 and 662)

Marsala wreck 1 ('Punic' wreck) was excavated off Punta Scario, western Sicily during 1971–4 (Frost, 1976). The remains, consisting of the lower parts of one end of the vessel (which the excavator believes is from the stern) with a fragment of the post, and parts of sixteen strakes to port and four strakes to starboard, were lifted, conserved, and displayed in a temporary museum at Marsala where they seem to have deteriorated. The bow of a second wreck was discovered near Marsala 1, after the main excavation had finished: this was photographed underwater, but not recorded in such detail as Marsala 1. These wrecks are dated from pottery types, and by inscriptions on the ship's timbers, to the mid-third century BC. The 200 painted inscriptions, identified as Punic letters or words, suggest that these vessels were built by Carthaginian craftsmen; the timber species and other evidence suggest that Marsala 1 was built in Sicily or Italy.

Marsala 1 is similar in many respects to the Kyrenia ship: the hull transverse sections and the keel cross-section are similar, as is the framing pattern; the frames are not fastened to the keel; the plank fastenings and the frame to plank fastenings are similar in form, size, and spacing; and both hulls were sheathed in lead (Steffy, 1994: 59). A main structural difference is that the after end of Marsala 1 keel turns upwards to form, as it were, the lowest part of the post, to which an outer post is fastened by mortise and tenon joints. A second difference is that in Marsala 1, whereas up to the eleventh strake the planking (30–40 mm thick) is flush-laid, above this level the planks, which seem to have been hewn externally to shape, are thicker at their lower edge than at their upper edge giving a superficial resemblance to clinker planking when seen from outboard (Frost, 1996: fig. 194). This feature is probably best interpreted as a way of planking around the turn of the bilge without having to bevel the plank edges and without leaving the planking over-thin outboard of the tenons. The excavator, on the other hand, has interpreted these 'simulated clinkers' as 'spray deflectors' (which may well be a secondary effect), and

sought their origin in some hypothetical influence from northern Europe (Frost, 1996; 1999)—see also Farrar (1987, 1988).

Phoenician letters painted on the port face and the inner face of the keel appear to be at frame stations. Lines were also incised across the planking marking the forward and after faces of each frame (Frost, 1990: 183). Frost (1997: 261) deduces from this that the 'design of the vessel had been preconceived'. The general design of this vessel almost certainly had been conceived in the mind of the shipwright before work began. A more fundamental question is whether this shipwright had a *detailed* design, either in his mind or in some other form. Since this ship, like all others considered so far in this chapter, was built plank first, the hull shape was determined, in conjunction with the posts and keel, by the angle and breadth of each succeeding strake: this shape was achieved before the framing was fashioned, fitted, and fastened. The shipwright would then have marked on the planking the required position of each frame. The incised lines on the planking appear, as Frost suggests, to have been drawn after fitting and before final trimming of each frame. Thus neither symbols nor lines played a part in determining the hull shape.

Circular imprints (interpreted as having been made by the dirty bottom of a paint pot) span the seams of certain pairs of planks in the hull above the turn of the bilge. This has suggested to Frost (1990) and Farrar (1990) that these particular planks were fastened as one unit to the hull, i.e. 'prefabricated'. These pairs of planks (not strakes) must have been close alongside one another (inner face uppermost) when the paint pot (if such it was) was placed on them: this could have happened after the planks had been sawn from the log, but before their final shaping, and well before they were fastened together. By itself, the 'paint pot' evidence does not prove 'prefabrication'.

Frost (1975*a* and *b*) has suggested that a wooden projection from what is thought to be the bow of Marsala 2 was a ram, an opinion generally supported by Sleeswyk (1996*a*). As Basch (1983*a*: 132) has noted, such projections are not necessarily rams: it seems more likely that this Marsala upcurving timber (Frost, 1975*b*: 24) is a protruding forefoot incorporated in the hull to increase the structural integrity of that part of the vessel, to increase speed potential, or to improve directional stability.

Several attempts have been made to formulate a reconstruction of the original shape and structure of Marsala 1, incorporating the bow of Marsala 2 (Adam, 1977; Frost, 1977, 1981; Farrar, 1989, 1990). This project seems overambitious when the extent of the remains is considered (Coates *et al.*, 1995). In line with an overriding idea that Marsala 1 was an oared warship (although no evidence survived for oared propulsion), the reconstructions have been given galley L/B proportions of *c.*1 : 7 by inserting approximately 14 m of parallel body between a Marsala 1 stern and a (more conjectural) Marsala 2 bow. As Owain Roberts has noted (personal communication), if most of this inserted section is removed, the L/B ratio (*c.*4 : 1) becomes more like that of the Kyrenia ship (3 : 1) which was a merchant ship. The large quantity of ballast excavated from Marsala 1, the variety of pottery excavated, the lead sheathing and the several structural similarities with the Kyrenia ship suggest that she was also a cargo ship rather than a warship.

4.12.3 RAMS

The earliest representations of rams are dated to the ninth/eighth centuries BC (Fig. 4.24): these are pointed rams, probably at or below the waterline and intended to hole the planking. During the sixth century BC, blunt-ended ones appear: these were intended to spring the planking (Casson and Linder, 1991: fig. 5.4). The first depictions of waterline 'trident' rams are dated *c.*400 BC: these have three broad horizontal fins, disposed vertically and separated by a vertical post at the head (Basch, 1987*a*: figs. 582, 633). This type appears to have continued in use into the first century AD (Casson and Linder, 1991: figs. 5.5 and 5.6).

Only two undoubted rams have been excavated: a small ram of unknown provenance, now in the German Maritime Museum at Bremerhaven (Casson and Linder, 1991: fig. 6.5), and a much longer one found in 1980 on the foreshore at Athlit (between Haifa and Caesarea, Israel), and now in the National Maritime Museum at Haifa (Casson and Steffy, 1991: figs. 2.12 and 4.1). The Athlit bronze ram of the 'trident' type, dated by the style of its decorations to the first half of the second century BC, weighs about 465 kg and measures 2.26 × 0.76 × 0.96 m. It formerly enveloped the foremost 2 m of the bow of a large warship. Steffy (1991) extracted

fragments of sixteen bow timbers from inside the ram and reconstructed the forepost of the parent ship from this evidence. These timbers included fragments of the keel, the stem post, the bottom, and some side planking, the waterline wales, a central ramming timber, and a chock, a nosing piece and a false stem. Steffy concluded after detailed examination of these timbers that the hull planking of the parent ship had been assembled and fastened together without the stem post being in place. The post had then been fastened to the ramming timber by a locked mortise and tenon joint, and the two timbers added as one unit to the hull. Subsequently the ram was cast in bronze to match the complex bow structure. How far aft the ramming timber extended is unknown, but Steffy conjectures that it may have led into a keelson, otherwise unknown at this time.

Early rams, which were pointed, would penetrate a hull more readily than blunt or finned rams; consequently their retardation would be less and would make less demands on the strength and hull integrity of the attacking ship. Coates (personal communication) cannot see why a sewn boat should not use such a ram. There are differences of opinion about the strength of the impact and the degree of retardation when a blunt or finned ram is used. Such rams are generally thought to be an advance on pointed rams in that they minimize the problem of withdrawal (probably experienced when using a pointed ram) since they merely thump the planking and start the seams. A preliminary theoretical study by John Haywood (Shaw, 1993*a*: 99–100) of the use of a three-finned ram suggests that if one fin of the ram were to penetrate the waterline wale of a target ship, there would be no great and sudden impact, rather a relatively slow retardation. Sleeswyk (paper at Henley) and Steffy (1991), on the other hand, consider that the impact would be much greater and thus the ramming ship would need to have the stiffness and strength which could only be given by closely spaced mortise and tenon joints.

Further research in this area, and into ramming tactics (Shaw, 1993*a*; Casson, 1991), is needed if a better understanding of the building and use of early eastern Mediterranean warships is to be obtained. The use of rams to break the oars of a target ship poses few theoretical problems although it may well have been difficult in practice. The use of rams to cause a hull to leak heavily, in one way or the other, is still controversial.

4.13
The Roman Age (Mid-Second Century BC–Fourth Century AD)

In the early years of this period Rome defeated both Greece and Carthage, and in time absorbed their overseas settlements: from the first century AD Rome was the undisputed seafaring power and overseas trading country in the Mediterranean. More than 60 per cent of the Mediterranean wreck sites documented by Parker (1992: figs. 3 and 4) are from these five and a-half centuries. There is also much literary and iconographic evidence for ships and seafaring (Casson, 1971: 141–7; Basch, 1987*a*: 418–98; Morrison, 1995*a*: 78–90; Morrison and Coates, 1996: 112–254). Furthermore several important specialist studies have been focused on this period: for example, that by Dubois (1976) on Roman keels, and that by Rival (1991) on Roman woodworking techniques and their choice of timber for seagoing ships. Here we shall concentrate on the structural evidence from selected excavated hulls. Since there was evidently a general continuity in building techniques from the Hellenistic to the Roman world, we shall focus on variations and changes within a generally homogenous Mediterranean technology.

The technological advance during this period was stimulated, in the main, by the growth of Rome's population and by Rome's increasing domination of the Mediterranean. From the fourth century BC, grain had to be imported to Rome in increasing quantities. Opportunities in overseas trade in other goods increased significantly from the second century BC, both to the west, France and Spain, and to the east, the Levant and Egypt, and via Egypt to India (6.3). The virtual eradication of piracy during the first century BC, and the relative peace that ensued when the Civil War ended in 31 BC set the scene for a marked increase in overseas trading voyages: this appears to be reflected in the increase in the number of known wrecks from the beginning of the second century BC (Parker, 1992: fig. 3).

4.13.1 SMALL BOATS

Two open boats, which Steffy (1994: 65–71) was able to document provisionally during excavation and before

they were removed from site for conservation, show that the techniques used to build the Kyrenia ship generally continued in use into this period. The boat from the bed of Lake Kinneret (Sea of Galilee) Israel, dated to the period 100 BC–AD 67, is estimated to have been *c.*9 × 2.5 × 1.2 m (Wachsmann, 1990). The second boat (Parker, 1992: no. 501) was excavated from Herculaneum, near Naples, where she had been overturned and carbonized by outflow from the AD 79 eruption of Mount Vesuvius (Steffy, 1985*b*). She was similar in size to the Kinneret boat but was lighter, more graceful and generally better built. Both boats were built plank-first with locked mortise and tenon joints spaced at *c.*120–130 mm. The Kinneret framing, of alternate floors and half-frames spaced at *c.*0.25 m, was fastened to the planking by spikes and by treenails with occasional nails clenched outboard by hooking (Steffy, 1994: fig. 3.53). The Herculaneum framing was generally similar but with two sets of double frames near amidships, probably in the region of the mast step (Steffy, 1994: fig. 3.56).

4.13.2 LARGE MERCHANT SHIPS

The increasing demand for cargo space is reflected in the emergence, from the second century BC onwards, of merchant ships of relatively great tonnage—up to *c.*600 tonnes cargo capacity, which may be compared with the 25 tonnes of the mid-fourth-century BC Kyrenia ship. It has been estimated that the first-century BC wreck from La Madrague de Giens (Fig. 4.43) (Parker, 1992: no. 616) was 40 × 9 m with a hold some 4.5 m deep which was loaded with nearly 400 tonnes of amphorae, stacked in three tiers, with boxes of ceramics stowed above them (Tchernia, Pomey, and Hesnand, 1978; Pomey, 1982). The first-century BC wreck from Albenga (Parker, 1992: no. 28) in Italy is thought to have been slightly bigger with a capacity of 500–600 tonnes (Delgado, 1997: 24). Other large ships from this century include: Antikythera 1 (Parker, 1992: no. 44), from Greek waters; Mahdia (Parker, 1992: no. 621) off Tunisia; the wreck from Caesarea Maritima, Israel (Oleson, 1994: 163–223) of the first century AD. Second-century BC Italian wrecks from Punta Scaletta (Parker, 1992: no. 960) and Spargi (Parker, 1992: no. 1108) are also estimated to have been over 30 m overall length (Fitz-Gerald, 1994: table 6.3). Some of these wrecks were first excavated thirty (and one even 100) years ago, and we cannot now be certain of details of their hull structure. Nevertheless something can be said in general terms about how these large ships differed from the earlier, smaller ones.

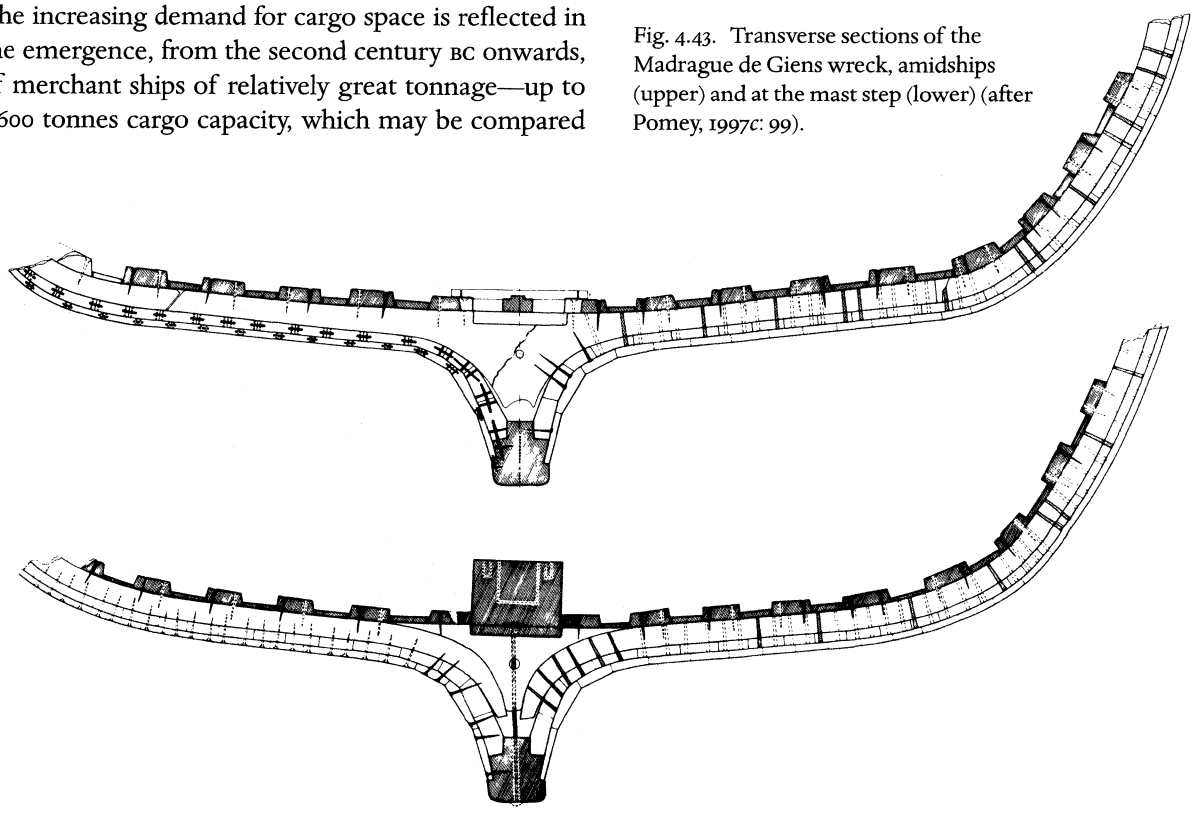


Fig. 4.43. Transverse sections of the Madrague de Giens wreck, amidships (upper) and at the mast step (lower) (after Pomey, 1997*c*: 99).

4.13.2.1 THE PLANKING

Planking was enhanced by making it thicker, and by increasing the proportion of plank length that was tenoned. The Kyrenia ship of *c.*300 BC and the Ma'agan-Michael ship of 400 BC had 40 mm planking. Two of the large cargo ships had planking *c.*90 mm thick: Caesarea and Antikythera 1 (FitzGerald, 1994: 179, table 6.3), with the mortises staggered (Steffy, 1994: fig. 3.58). Others had inner and outer planking separated by a layer of wool or some other fabric saturated in wax or pitch: Punta Scaletta, possibly 70 and 65 mm thick; Albenga, possibly 40 and 40 mm; Mahdia, possibly 50 and 36 mm; Madrague de Giens, 60 and 40 mm; Dramont 1, *c.*35 and 27 mm thick; and Île du Lévant (*Titan*) a total of 56 mm. In these double-planked vessels the mortises were only slightly staggered, if at all (FitzGerald, 1994: 179–81; Delgado, 1997: 24, 131, 252–5). As FitzGerald (1994: 178) has pointed out, these thick planks, ranging from 56–135 mm are approximately within the range recommended by Juvenal (*Sat.* 12. 58–9) for merchant ship's planking: four to seven finger breadths, i.e. 70–130 mm. Data from some practical, successful wooden fishing boats of the 1950s show that their plank thickness is a linear function of length (Palmer, personal communication). Fishing boats of a similar length to Kyrenia (14 m) had planking *c.*48 mm thick; those similar in length to Madrague de Giens and Caesarea (40 m) had planking *c.*99 mm thick. Thus, by twentieth-century standards, these three ancient ships had near-ideal plank thicknesses (Table 4.4).

Unlike multi-planked medieval Chinese hulls (10.5.1) in which the outer planking was merely fastened to the inner planking, *both* inner and outer planking in the Mediterranean hulls were edge fastened by mortise and tenon joints, with the garboard strake of each layer fitting into its own keel rabbet. As Steffy (1994: 62–5) and FitzGerald (1994: 185) have pointed out, double planking has several theoretical advantages over a single layer of comparable thickness. There would be less wastage when fashioning planks to shape and there would have been less movement and distortion of the tenons when compared with the staggered (near double) row of joints in the single planking. Where the planking had to be bent to achieve the required hull shape, especially at bow and stern, two thin planks would have been easier to fit than one thick plank. Furthermore the lamination effect of two layers would in itself probably result in a stronger hull, and the paying of tarred wool in between inner and outer planking would have added to the hull's watertight integrity. Steffy also considers that the outer planking (often thinner, and frequently of soft wood) would, to a degree, have been sacrificial, protecting the main, inner planking from physical and teredo damage.

Planking strength was further increased by having more fastenings per unit length. The data in Table 4.4 shows that in the main (inner) planking of the double-planked Madrague de Giens, the percentage of strake length occupied by tenons was 49 per cent greater than that of Kyrenia, whilst the outer planking was the same as Kyrenia. The two ships with single planking had percentages some 57 per cent (Antikythera), and 81 per cent (Caesarea) greater than Kyrenia.

4.13.2.2 THE FRAMING

The pattern of framing in the large merchant ships was generally the same as that of the smaller vessels, i.e.

Table 4.4 Mortise breadths per unit length of planking

1 Vessel	2 Date	3 Average mortise breadth (mm)	4 Average mortise spacing (mm)	5 Breadth/spacing (%)	6 Average plank thickness (mm)
Kyrenia	300 BC	43	117	37	40
Madrague de Giens	75–60 BC				
Inner		80–5	150	55	60
Outer		55–7	150	37	40
Antikythera 1	1st century BC	80	138	58	90
Caesarea	1st century AD	90	135	67	90

Sources: Steffy, 1994: 43–6, 65, 71; FitzGerald, 1994: 178–80.

floors with futtocks alternating with half-frames. One exception to this rule was the Dramont I wreck (Parker, 1992: no. 371), of the first century BC, which had eight consecutive floors under her mast-step timber (Delgado, 1997: 131). In the Caesarea and Antikythera and other wrecks of the first century BC, these frames were fastened to the planking by hooked nails through treenails, as in the earlier and smaller ships (FitzGerald, 1994: 192–7, table 6.5). In the ships with double planking frames were similarly fastened to the inner planking but merely nailed to the outer planking. Dramont I was again an exception, her frames being fastened by nails through treenails to both planking layers.

The frames of these large merchant ships were clearly of greater dimensions than that of the Kyrenia ship but, in the few examples with reliable quantified evidence (Table 4.5), this increase in frame size was less than commensurate with increase in ship size (measured by length overall). The section modulus (row 8 in Table 4.5) of the frames actually reduces with increased length of vessel (row 2). The main reason for this deficit is that the moulded dimension of the frames was not increased sufficiently to produce the required stiffness. Furthermore, the increased sided dimension of the frames in the larger ships was offset by their increased spacing (especially in the Caesarean ship) so that there was no consistent increase in the percentage of planking in direct contact with a frame (row 9), with increased size of ship.

It has been suggested that these large ships were the first to have composite framing and to have their frames fastened to the keel. In fact, the floors of an earlier and smaller ship, that for Ma'agan-Michael (4.9.4.6) were each scarfed to two futtocks before her composite frames were fastened to the planking. Similar techniques were used in the gigantic Lake Nemi ships of the early first century AD (Parker, 1992: no. 732–5; Steffy, 1994: 71–2) but they were probably royal barges and not in the mainstream of cargo-ship building. FitzGerald (1994: 189) has noted the two instances where composite frames may have been used in large merchant ships, but these are doubtful evidence. FitzGerald (1994: 198, 222) has also noted evidence for the fastening of frames to the keel. The late second-century BC Spargi wreck, and the first-century BC wrecks from Madrague de Giens and L'isola di Mal di Ventre, all estimated to be over 30 m in length, had at least some frames fastened to the keel. This technique does not appear in small merchant ships until the mid-first century AD (St Gervase 3—Parker, 1992: no. 1002).

4.13.2.3 LONGITUDINAL TIMBERS

Longitudinal timbers such as wales, stringers, keelsons, and ceiling planking all strengthen a hull. Earlier, small merchant ships such as Kyrenia had wales and some ceiling planking nailed to the floors but no full-length keelson, only a short mast-step timber; and the only stringer-like timber was a beam shelf spiked to the framing inboard of the main wale (Steffy, 1994: 52).

An innovation in the Madrague de Giens ship was that alternate planks in the ceiling were substantially thicker (60–100 mm compared with 25–40 mm) than the others, and also broader (200–300 mm rather than 150–250 mm). These were effectively stringers. This ship also had a substantial mast-step timber which, if

Table 4.5 Comparison of the framing in three ships

	Kyrenia	Madrague de Giens	Caesarea
Date	300 BC	75–60 BC	First cent. AD
L × B (m)	14 × 4.2	40 × 9	40 × 10
Average frame (m)			
Moulded	0.085	0.135	0.188
Sided	0.090	0.135	0.180
Spacing	0.117	0.150	0.250
$(M.S).10^{-3}$	7.65	18.23	33.84
Log $(e)\ \frac{M^3S}{12}$ = section modulus	12.29	10.49	9.20
% of planking in contact with a frame	77	90	72

Sources: FitzGerald, 1994: 187–8; C. Palmer (personal communication).

not a full-length keelson, did nevertheless add to the spinal strength of the hull.

4.13.2.4 STRUCTURAL INNOVATIONS (SECOND CENTURY BC TO SECOND CENTURY AD)

The number of large and small merchant ships used in the foregoing analysis is very small, and the data from them is incomplete and, in some cases, challengeable. Any conclusions drawn must therefore be provisional and need to be tested on future well-documented merchant ships from this period. Two of the features of large merchant ships—increased plank thickness (per se), and stouter frames (per se)—which, it has been suggested, clearly differentiate them from smaller ships, are in fact merely a reflection of the greater hull size, and not a great leap forward in technology.

The innovations incorporated in these large ships (in as much as we have the evidence) are:

(a) the use of double-planking, probably resulting in a disproportionately greater hull strength and integrity;
(b) greater than proportionate increase in breadth of tenons, leading to a greater percentage of the planking having 'internal, discontinuous frames', and thus strengthening the planking shell;
(c) keels of greater dimensions with complex scarfs adding to structural strength;
(d) the fastening of some frames to the keel consolidating the keel/frame assembly—structural strength;
(e) the fitting of prototype stringers and keelsons (elongated mast-steptimbers)—structural strength;
(f) hulls became fuller and flatter in transverse section—greater capacity.

In many ways the structure of these large merchant ships was a natural development from the smaller ones: they continued to be edge-fastened with closely spaced, locked mortise and tenon joints and tight-fitting tenons, and were built plank-first; their framing pattern and the frame to plank fastenings were essentially the same; and the transverse hull shape, as far as can be seen, changed but little. The first two innovations listed above seem to have been discontinued after the second century AD, when huge merchant ships were evidently no longer built. Frame/keel fastenings, stringers, and keelsons, on the other hand, became part of the standard technology.

4.13.3 TECHNOLOGICAL CHANGE IN THE THIRD AND FOURTH CENTURIES AD

After the second century AD, wrecks of large merchant ships are rare: wrecks are seldom more than 20 m overall length. Importantly, there are signs of a shift in emphasis from the strength of edge-fastened planking towards better framing, keelson, ceiling, and decking. Steffy (1994: 77–8, 83–5), has suggested that these technological changes were the result of social and economic changes. There was a decline in slavery, resulting in labour becoming more expensive; and shipowners had become independent businessmen who preferred smaller, less costly ships. Shipbuilders, in turn, sought to use their resources more efficiently. Since the 'classic' style of building was very labour intensive, especially in the fashioning, fitting, and fastening of the thousands of mortise and tenon joints in even a moderate-sized hull, efficiency meant adopting techniques that significantly decreased the man-hours needed for each ship; it also demanded the economical use of timber resources. Other, more fundamental, reasons have been suggested: changes in types of cargo, improvements in tools and techniques, deforestation, the introduction of fore-and-aft sails (Steffy, 1995*b*: 27). However, economies gained by reducing manpower, especially of skilled shipwrights, and by more efficient use of available timber seem to have directly affected the shipbuilder's approach to his work (Jezegov, 1985: 142–3).

4.13.3.1 YASSI ADA 2

The fourth-century AD wreck Yassi Ada 2 (Parker, 1992: no. 1240) provides an example of this changing technology. This wreck in Turkish waters was excavated in 1967, 1969, and 1974. The original dimensions of this small cargo ship are estimated to have been 20 × 8 m. Her hull was 'conventional' in many respects: she was built plank-first, her 42 mm thick planking was fastened by mortise and tenon joints, and her frames were alternately floors and half- frames. However, her joints

were smaller than in comparable ships from earlier centuries, and were more widely spaced, being 150–200 mm, where the planking was relatively weak because of a concentration of scarfs, but elsewhere up to 320 mm (Steffy, 1994: 79–80). Her tenons were given a double trapezium shape to match the tapering mortises: they did not fit the mortises in breadth or in depth, leaving gaps of 6–7 mm at each end, and 17–18 mm at each side (Steffy, 1994: fig. 4.1). Van Doorninck (1976: 126–7) has suggested that the paired midship half-frames were fastened to the lower hull after five strakes had been erected, and used as a master frame for the upper hull. His argument includes an assumption that 'the ability to assemble hulls with finished planking was a precondition' to the rise of frame-first techniques: this is not so—planks are finally fashioned to shape *after* being fastened to framing in Tamil Nadu frame-first boats and ships (Blue, Kentley, and McGrail, 1998).

Wrecks of the late fourth century/early fifth century AD with similar characteristics to Yassi Ada 2 include: Fiumicino 1 (Parker, 1992: no. 408) from Portus Claudius near Rome (Boetto, forthcoming), where average spacing of joints is 347 mm, and some of these are not locked; and Dramont 5 and 6 (Parker, 1992: nos. 375 and 376).

4.14
Propulsion, Steering, and Seafaring

4.14.1 PROPULSION BY SAIL AND STEERING

The single square sail is depicted from 2000 BC until Roman times. From the late sixth century BC onwards, ships are occasionally depicted with a second sail, a square sail on a foremast (Casson, 1971: fig. 97), and descriptions from the mid-third century BC refer to a third sail set on a mizzen (Casson, 1971: 240). In the first century AD, the foremast is depicted with a forward rake, and is sometimes stepped at the bow as an *artemon*. From *c.* AD 200 main topsails are depicted.

Fore-and-aft sails are illustrated during Roman times, invariably on boats rather than ships: the sprit-sail from the second century BC (Casson, 1971: figs. 175–9); the lateen from the second century AD (Casson, 1971: fig. 181). R. Bowen (1956*c*), however, disputed the identification of this sail as a lateen, and considered it to be a lugsail. In the Bay of Bengal today lug-shaped sails grade into lateen-shaped sails, and both are taken forward of the mast when changing tack (Blue *et al.*, 1997, 1998): the difference between Bowen's and Casson's interpretation may be of little consequence. Steffy's work on the fourth-century AD Yassi Ada 2 has suggested that she was rigged with a fore-and-aft sail such as a lateen rather than a square sail; his research on seventh-century Yassi Ada 1 indicates that she had two lateens (4.15.2.2). The fact that the single mast step of the Kyrenia ship was set so far forward suggests that a similar fore-and-aft sail may have been in use in 300 BC (4.12.1.1).

Theophrastus of the fourth century BC stated that Egyptian sails were of papyrus; however, Black (1996) has pointed out how very brittle such sails would be. Linen, made from flax, was used to make the sails of Egyptian boat models of the mid-second millennium BC, and this seems a more likely material for actual craft. Ezekiel's statement in the late-sixth century BC that Phoenician sails were linen gives some support to this contention (Black and Samuel, 1991). Part of a second-century BC linen shroud from the temple at Edfu, Egypt has been identified as a fragment of sail cloth with a wooden brail ring attached (Black, 1996: figs. 5 and 6). This is the earliest sail cloth to have survived anywhere; the next earliest appears to be part of a medieval sail from China (10.4.2.3). Casson (1971: 234) has deduced from a study of several representations that the edges of Mediterranean sails were reinforced with bolt rope and the corners with leather patches.

Ships in this period were generally steered by a side rudder on each quarter (Casson, 1971: figs. 108, 109, 119, 128, 147–51). The sea trials of the trireme reconstruction *Olympias* showed that such rudders induced a disproportionate amount of drag, it may be that, whenever possible, only one of the pair was used, especially on warships when under oars.

4.14.2 NAVIGATION AND SEAFARING

By the mid-first century AD there is literary evidence that it was customary for seamen to measure the

zenith altitude of particular stars by reference to the length of the mast (Lucan, *Bel. Civ.*, 8. 177–81). In this manner they had a measure of 'relative latitude': that is, they knew whether they were north or south of a haven for which they already knew the star zenith altitude (E. Taylor, 1971: 47–8; McGrail, 1983*b*: 308, 318). Apart from this, navigation and pilotage methods appear to have been very similar to those practised in earlier times by the Greeks (4.4.6) and the Phoenicians (4.9.3.2.1).

In the fourth century BC, written sailing directions (*periploi*) for coastal voyages began to be compiled from an accumulation of oral accounts. The earliest of these surviving is now known as 'pseudo-Scylax', written between 361 and 357 BC: this describes passages along the Mediterranean coast (Dilke, 1985). In *c.*320 BC, Pytheas of Massilia/Marseille undertook a voyage of scientific exploration, possibly more than one (Dilke, 1985: 136), along the Atlantic coast of Europe possibly as far north as the Faeroes and the Baltic (Roseman, 1994; Hawkes, 1977, 1984). His account has not survived but parts of it can be reconstructed from later writers.

By the mid-first millennium BC, the Phoenicians had sailed the Atlantic coast of north-west Africa (4.9.3.2.1), and they and the Greeks subsequently traded along the Atlantic coast of south-west Iberia (4.9.2.2). A *periplus* from the sixth century BC seems to have survived, incorporated by Avienus into his fourth-century AD poem, *Ora Maritima* (Hawkes, 1977: 19; Murphy, 1977; McGrail, 1990*b*: 36). This describes what was evidently an established trade route southwards along the Atlantic coast of Europe (Fig. 5.1), then eastwards through the Pillars of Hercules to Massilia/Marseille. The route is described in three stages: Ireland/Britain to western Brittany; from there to *Tartessus* (near modern Cadiz); thence to Massilia, with a subsidiary route to Carthage. The text seems to imply that the northern section of this route was undertaken by the 'hardy and industrious peoples of the islands and coasts around Ushant' (Murphy, 1977: lines 94–116), whilst the southern sections seem to have been used by Mediterranean merchants. The direct crossing from Ireland to Brittany (possibly via Britain) was certainly within the capabilities of Celtic seamen in the first century BC (McGrail, 1983*b*), and there is every reason to think it could have been done much earlier. Whether the voyage from the Ushant region to north-west Iberia was direct across the Bay of Biscay or coastal (very much longer) is difficult to say. In general terms, the Bay is a lee shore and straying to the east of the direct route across could lead to embayment. However, if a prudent course could be held from Ushant in the direction of Cape Finistere in north-west Iberia, the mountains of northern Iberia should be sighted with ample sea room to adjust course (wind permitting), even though the predominant wind from the south-west may have set the ship into the Bay. An alternative route could have been via a haven in the Gironde estuary (McGrail, 1983*b*: 319–21). The leg along the Atlantic coast of Iberia may have involved keeping well out to sea to avoid the lee shore. The problems of entering the Mediterranean have been considered above (4.2). In general terms, this southbound route would have been more arduous and would have taken longer than when northbound. The fact that a lighthouse was built at Coruña in north-west Iberia during the Roman period (Hague, 1973) must mean that these difficult voyages were relatively frequent by that date. Nevertheless, much traffic between the Mediterranean and north-west Europe seems to have gone via French and German rivers (McGrail, 1983*b*; 5.5.4; 5.6.6). Roman trade routes to India are considered in Section 6.3.

4.15
Early Frame-First Vessels (Fig. 4.3)

4.15.1 UP TO THE SIXTH CENTURY AD

All the planked boats and ships described so far in this chapter were built plank-first, i.e. the shape of the hull was determined by the planking, and much of the structural strength of the vessel came from that shell of planking (1.4.1.1). Basch (1972: 47), quoting Herodotus (1. 194), has suggested that the Greeks of the fifth century BC were also 'conversant' with the use of 'active' frames, i.e. frames that determined the hull shape, and thus must have built boats frame-first. This may be true, but only in relation to the building of hide boats, in which the framing does indeed determine the shape. Morrison (1976: 165) has taken Basch's argument a step further by quoting a description by Herodotus (2. 96)

of how a Nile plank boat was built. However, Herodotus was clearly describing a boat which had no frames at all: the Dahshur boats of nineteenth-century BC Egypt were similarly frameless (2.8.3.2), as were Sudanese Nile *nuggar* boats of the early twentieth century (Hornell, 1946*a*: plate 35*b*).

Basch (1972: 43–5) has also approached the question of early frame-first building from another direction. He points out that in the fifth and fourth centuries BC, large Greek fleets had to be built in a hurry; that, quoting Polybius (1. 20, 13; 38. 5; 59. 8) and Pliny (*NH* 16. 192), the Romans in 260 BC and 242 BC copied Carthaginian hulls and built a fleet of ships; and that in 254 BC they built 220 ships in three months. He then argues that in all these instances moulds must have been used; that is, active frames would have determined the hull shape and therefore this was the frame-first sequence of building. Furthermore, Frost has hinted that formal design methods lay behind the building of the mid-third-century BC Marsala 1 (4.12.2), and Bellabarba (1996: 264, figs. 4.5 and 6) has argued that this ship was built using moulds (equivalent in this sense to active frames) which reproduced the shape of the master frame, the rising and narrowing of the hull being determined by some predetermined procedure.

To twenty-first century people, such arguments have their attractions; however, there are archaeological arguments against them. Mediterranean wrecks dated before *c.* AD 600 were clearly edge-fastened by sewing or by mortise and tenon joints which were locked by pegs driven from inboard. As far as can be determined, they were all built plank-first: the shape of the hull was determined by the planking; frames were passive rather than active.

There have also been attempts to show that certain early wrecks were built frame-first. The Madrague de Giens of the first century BC was at first thought to have been built partly in this sequence (Tchernia, Pomey, and Hesnard, 1978). Subsequent research showed that the fourth and fifth strakes were replacements: this ship was built plank-first throughout (Pomey, 1988: 406; Parker, 1992: no. 250; Pomey, 1994; Pomey, 1998: 61–2, 66–8).

Gassend (1989) has used the fact that some of the pegs which lock the joints were driven from outboard, and some floors are fastened to the keel, to suggest that the late second-/early third-centuries AD ship Marseille-Bourse (Parker, 1992: no. 668), the second-century Laurons 2 (ibid. 578), and the Pont Vendres 2 wreck of *c.* AD 400 (ibid. 874) were all built frame-first. Pomey (1988: 399, 406–9) has argued strongly against this hypothesis, pointing out that these vessels are all clearly edge-fastened by mortise and tenon joints, that the 'inverted' locking pegs are consistent with a repair, that fastening frames to the keel is not proof of the pre-erection of active framing, and that the evidence from these three ships is entirely consistent with a plank-first sequence of building. Pomey has conceded, however, that some pre-erected framing may have been used to control the shape of the upper hull.

4.15.2 SEVENTH CENTURY AD ONWARDS

4.15.2.1 ST GERVAIS 2, TANTURA 1, AND PANTANO LONGARINI

Three seventh-century ships, from France, Israel, and Sicily were all built (at least partly) frame-first. The earliest of these is St Gervais 2 (Parker, 1992: no. 1001) of AD 600–25 (Jezegou, 1985) (Fig. 4.44). Planking at the bow and stern had widely-spaced (usually more than 1 m) mortise and tenon joints which were not locked: these joints were thus used to position the strakes and not to fasten them together. The rest of the 25–30 mm thick planking had no such joints: these strakes were not fastened together (not even the garboards to the keel), but were treenailed and nailed to pre-erected framing, and caulked. All floors, and some of the half-frames, were fastened to the keel with iron bolts: a total of seventeen out of twenty-seven surviving frames (63 per cent). The half-frames were fastened together by hooked nails where they overlapped near the centre-

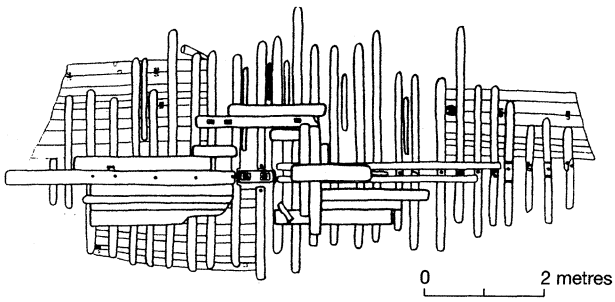


Fig. 4.44. Plan of the St Gervais 2 wreck (after Pomey, 1997*c*: 100).

line. Two wales each side were fastened by treenails to planking and framing. It is clear that in this ship, some 15–18 m in length, the framing played a more important role than the planking, at least in the underwater part of the hull. Whether plank-first or frame-first methods were used in the upper hull cannot be known since this did not survive.

The early seventh-century vessel recently under excavation in an Israeli coastal lagoon, Tantura I, appears to have comparable features (Wachsmann, 1994; Kahanov, personal communication). None of the 25 mm thick strakes investigated were edge-fastened; they were nailed to the frames which were spaced *c.*0.33 m apart. Kahanov has estimated that she was originally 12 × 4 m.

A seventh-century wreck found in a drainage ditch at Pantano Longarini in Sicily (Throckmorton, 1973; Parker, 1992: no. 787) had unlocked mortise and tenon fastenings in her underwater hull widely spaced at *c.*1 m.

4.15.2.2 YASSI ADA I

Yassi Ada wreck I (Parker, 1992: no. 123a), dated to *c.* AD 625 was sparsely preserved but intensive study of the remains by Steffy (1982; 1994: 80–3) has revealed the essential details of her construction. In essence: this ship of *c.*20 × 5 m and capable of carrying *c.*60 tonnes of cargo, was built plank-first in the lower hull where there were complex shapes, and frame-first in the upper hull with generally flat sides and a naturally curving sheerline. The garboards were mainly nailed into the keel rabbet (nails often being driven at varying angles), with a few unlocked mortise and tenon fastenings at least 2.25 m apart. The remaining underwater hull had similar mortise and tenon joints (Steffy, 1994: fig. 4.4) spaced 350–500 mm in the stern region, but elsewhere *c.*900 mm: like those in the garboards, these joints were principally for aligning the strakes until they could be fastened to the framing by iron spikes. After five or six pairs of strakes had been positioned in this manner, the first floors were installed and fastened in the hull. A further six or five strakes were then added out to the turn of the bilge, when the larger floors were added. More strakes were added, still edge-fastened out to the light load waterline, the sixteenth strake. The remaining half-frames and most of the futtocks were then added. The upper hull was then planked up in the frame-first manner, the planks being nailed, and the wales fastened by forelock bolts, to the framing. The deck, fastened to cross-beams supported by knees, was continuous except for the hatch area and the galley near the stern, thus increasing the structural integrity of the hull.

4.15.2.3 SERÇE LIMANI

The movement away from an edge-fastened, plank-first hull towards a frame-first hull evidently culminated, between the seventh and the eleventh centuries, in a frame-first ship with none of the planking fastened together. This innovation did not necessarily take place in the Byzantine Empire, although the best documented example is from those waters. Serçe Limani I (Parker, 1992: no. 1070), dated to *c.* AD 1025, is the earliest known Mediterranean ship of this type. Again, detailed post-excavation work by Steffy (1994: 85–91) has revealed her probable building sequence, and something about the methods of design used (Fig. 4.45). This ship is estimated to have been 15.36 × 5.12 m, not much bigger than Kyrenia (14 × 4.2 m) yet, because she had a hold of box-like proportions (Steffy, 1994: fig. 2.8), she had a much greater cargo capacity—*c.*35 tonnes compared with *c.*25.

Steffy's building sequence may be summarized:

1. Posts scarfed to keel.
2. Two composite master frames, some 0.32 m apart, nailed to the keel near the midships station. The heads of these frames would have been at, or near, the intended sheerline.
3. A pair of floors, shaped to give slightly more rising and narrowing of the hull than that of the floors of the master frames, were then nailed to the keel, one *c.*1.28 m forward of the forward master frame, and one *c.*1.28 m aft of the after master frame.
4. A second pair of floors was then fastened to the keel, half way between each master frame and the floors placed in 3.
5. Two further pairs of floors were then installed in the interstices between the floors and frames already fastened. At this stage two full frames and eight floors had been fastened to the keel at an average spacing of 0.30 m centre to centre. Each floor was fashioned from a crook, the curve of which matched that required for

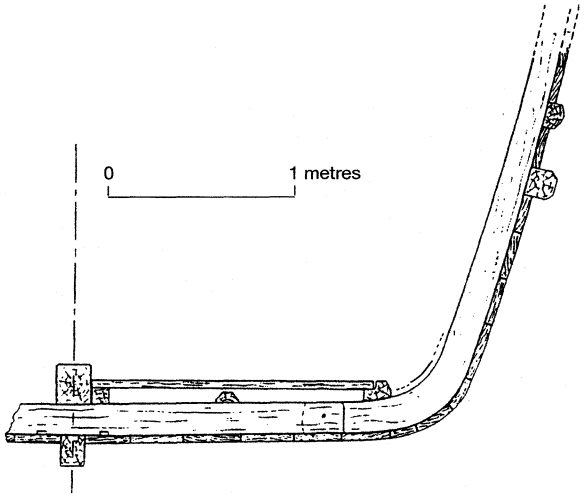


Fig. 4.45. Midship section of the Serçe Limani ship (after Steffy, 1994: fig. 4.10)

the turn of the bilge: these floors were positioned so that the curve of the crooks were alternately to port and to starboard.

6. Although the evidence is limited, Steffy (possibly drawing on his knowledge of later documented practices in the central Mediterranean (4.16) believes that a further pair of floors or frames was fastened to the keel about half-way between the master frames and each post. These two frames/floors would have been much narrower, and have had more rising than other floors and frames; the after one more than the forward one.

7. The bottom was planked with five strakes each side, the planks being spiked to the floors and subsequently treenailed.

8. The lower sides were planked; and then the turn of the bilge.

9. All remaining frames were installed and the upper planking and wales fastened to them.

10. The keelson was bolted to the keel, between the frames, by forelock bolts (similar to those used in Yassi Ada 1).

11. Stringers and removable transverse ceiling were added to the area of the hold; then a fixed ceiling, clamps and deck beams.

4.15.2.3.1 *Designing the frames*

The shape the builder/owner visualized for the Serçe Limani hull was encapsulated in the framing. A key question is, how were the individual frames designed? Steffy believes that an elementary form of geometric projection and ratios were used, and he believes he has identified a unit of measurement upon which the design was based: in our terms this *unit* was 0.16 m, which Steffy believes may have been equivalent to a handspan, or perhaps some proportion of a Byzantine foot. It may be that a smaller unit of a 'palm' (i.e. *c.*80 mm) is more appropriate.

The transverse section amidships (the master frame) of this box-shaped hull can be represented by two straight lines: the bottom rising only a few degrees from the horizontal, equivalent to a rise of a quarter of Steffy's *unit* at the ends; the sides rising at *c.*72° to the horizontal—this angle may be constructed by drawing a simple right-angled triangle since the tangent of 72° is 3. These two straight lines were then joined by a curve representing the turn of the bilge (Steffy, 1994: fig. 4.12).

The shapes of the other active or control frames may have been derived from that of the master frame as is done today in Tamil Nadu (6.7.4.3) when building the traditional wooden sailing *thoni* merchant ship and the *vattai* fishing boat (Blue *et al.*, 1998), and as was done in the later Middle Ages in the Mediterranean and in Atlantic Europe (4.16, 5.9.4). The shapes of the frames in the forward and after parts of the ship, where the hull's transverse shape was changing rapidly, may have been derived from temporary ribbands or planking acting as ribbands (5.6.1.3)—a reversion, in a sense, to plank-first methods.

Other Mediterranean ships that appear to have been frame-first include: Plane 6 (Parker, 1992: no. 821) and Agay (ibid. 8) of the tenth century; Pelagos (ibid. 796) of the twelfth century; and Culip 6 (ibid. 349) of the fourteenth (Palou *et al.*, 1998; Rieth, 1999).

4.15.3 THE CHANGE FROM PLANK-FIRST TO FRAME-FIRST METHODS

From the first century BC to the sixth century AD, there are suggestions that the earlier, dominant importance of the planking to the structural integrity of Mediterranean ships and boats was being reduced. It is not until the seventh century AD, however, that there is clear evidence that the internal structure of framing and longitudinal timbers was significantly improved. During this transitional phase, planking became less important structurally as the mortise and tenon fastenings

became smaller, more widely spaced, and finally not locked: their role now was merely one of aligning strakes (instead of fastening them together in a watertight seam) until they could be fastened to the framing, and the seams caulked. Ironically, the role of the unlocked mortise and tenon joint when it first appeared on the nautical scene—in Egypt in the third millennium BC—was also that of aligning planking before it could be fastened by other means (2.7.1).

By AD 1025, and probably much earlier, edge-fastened planking began to be abandoned entirely. The framing structure was now clearly the most important feature, not only in the realm of structural integrity, but also in the matter of obtaining the shape of hull the builder had visualized. These frames had to be 'designed': precisely how this was done is not clear but the methods may have been similar to those used from the fifteenth century onwards (4.16).

Possibly induced by social and economic changes, this shift to frame-first construction was to have important technological and, indeed, political, effects in the Mediterranean. Frame-first techniques gave builders the ability to build bigger, but more importantly, more seaworthy hulls suitable for long ocean passages, and to build them more quickly. It also meant that, as the art and science of generating hull shapes developed, significant improvements could be built into a design, and a successful design could be repeated again and again.

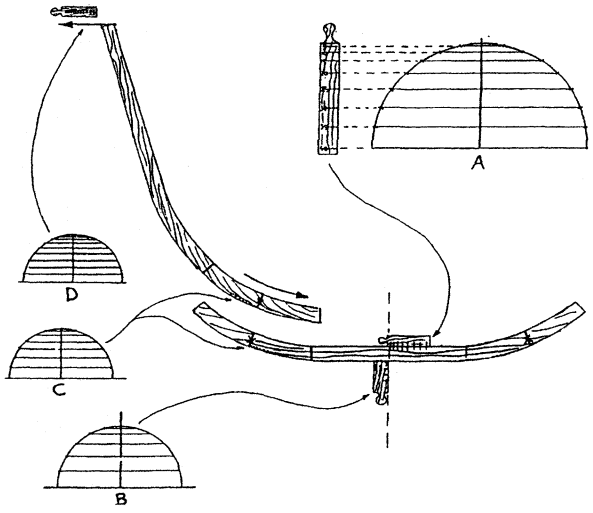


Fig. 4.46. Diagram to illustrate the fifteenth-century Venice method of designing frames A: narrowing the floors; B: rising the floors; C: fairing the junction of futtock and floor; D: widening the futtocks (after Bellabarba, 1993: fig. 4).

4.16
The Design of Medieval Frame-First Ships

It is not until the mid-fifteenth century that the methods of designing the framework of Mediterranean vessels and of building them frame-first appears to have been written down (R. Anderson, 1925; Bellabarba, 1988; 1993; Steffy, 1994: 93–100; Johnston, 1994; Greenhill, 1995*b*: 256–73; Rieth, 1996). The two documents that have received the most critical attention, the *Timbotta* MS. and the *Fabrica di galere*, originated in Venice, and there are indications that design methods similar to those described were used in that region during the thirteenth century, and even earlier (Bellabarba, 1996).

In this Venetian method the main dimensions of the hull were known as proportions of a modular unit, usually the keel length, the length overall (Bellabarba, 1993: 274), or the maximum beam (Steffy, 1994: 93). The dimensions of fittings such as the rudder, the mast, the yards, could also be a proportion of this unit. The shape of the posts was probably obtained by simple geometric construction with measured offsets, or by a batten bent to the required curve through two control points (Steffy, 1994: fig. 4.20A). The shape of the master frame was encapsulated in a 'rule' giving the orthogonal co-ordinates of the required curve at four points (Bellabarba, 1993: fig. 3). A master mould was made from this curve, and a master frame, made from this mould, was set up on the keel near amidships. Geometrically similar frames were set up on either side of this master frame, the number depending upon the length of main hull (of constant transverse section) required. The shapes of the remaining designed frames were obtained from the master mould by simple geometric means—this was the essence of the design system.

A series of horizontal lines was inscribed on a semicircular wooden tablet known as a *mezza luna* (half

moon) using a construction which made the intervals between lines decrease steadily in accordance with a geometric progression (Fig. 4.46). A measuring stick marked with this scale was then used to derive the shapes of pairs of frames (one forward, one aft) from the master mould so that each pair of these frames had the appropriate rising and narrowing to give the shape of the designed part of the hull. These designed frames extended almost to the ends of the keel: beyond this point the hull transverse section changed too rapidly for shapes to be calculated by this Venetian method (Bellabarba, 1993: 282). The bow and stern frames were thus not designed: their shapes were obtained late in the building sequence from ribbands or planking running from post to post—in contrast to the designed frames, these bow and stern frames were passive.

By the sixteenth century similar design methods were used in southern Italy, Spain, Portugal, France, southern Netherlands, England, and possibly elsewhere (Bellabarba, 1993: 286, 290; Rieth, 1996: 177–99; 1998). The ships of the European explorers of the late fifteenth/early sixteenth centuries were probably designed by these methods (5.9.4) since the earliest known Portuguese text on shipbuilding, *Livro da Fábrica das Naus* by Fernando de Oliveira dated *c.*1570, prescribes similar methods to the Venetian (Steffy, 1994: 128–41; Loewen, 1998: 213–14).

5
Atlantic Europe

This chapter deals with the 'Atlantic arc' of Europe: those seas and coastal lands which lie on a broad sweep from the Strait of Gibraltar through maritime Spain, Portugal and France, the British and Irish archipelago, the Low Countries, coastal Germany, and Scandinavia, including the southern shores of the Baltic (Fig. 5.1). This maritime zone extends in latitude from 36° to *c.*63°N, in longitude from *c.*11°W in the Atlantic to *c.*20°E in the Baltic.

This long coastline, much of it open to the Atlantic Ocean, has a diversity of geology and topography. (Cunliffe, 2001) The Baltic and the North Sea are regions of deposition with relatively shallow seas and low-lying coasts. The Baltic is virtually tideless, but numerous tidal rivers flow into the North Sea: for example, the Elbe, Weser, Ems, Schelde/Meusse/Rhine, Thames, Humber, and Forth. By and large these rivers flow relatively slowly through low-lying, easily-flooded landscapes, with reeds and marshes at their margins, and widespread sandbanks on their approaches from seaward.

The coasts of Norway, France (from Normandy to the River Loire), Spain, Portugal, and the western and south-western coasts of Ireland and Britain, on the other hand, are formed of more resistant, compact solid rock: the harder rock has weathered to form headlands, promontories, peninsulas, and capes; the softer rock forms bays and inlets. These are generally rugged, rocky coasts with bold cliffs, and deep water relatively close inshore. Along these coasts, from northern Norway as far south as River Minho (at the Spain/Portugal northern border), with the exception of the south-east part of the Bay of Biscay (Golfe de Gascogne) there are numerous off-lying islands. In certain parts of these coastal lands, the coast is broken into a series of deep-water inlets such as fjords and rias, some of which form spacious, natural harbours: Vigo and Corunna in north-west Spain; Morlaix in Brittany; Falmouth and Plymouth in south-west England; Milford Haven in Wales, Killary in western Ireland; Trondheim, Hardangar, and Stavanger in Norway. In other parts there are great tidal rivers such as the Guadalquivir, Tagus, Douro, and Minho in the Iberian peninsula, the Severn and Clyde in Britain, and the Shannon in Ireland.

The Baltic Sea is a tideless, relatively shallow body of brackish water with a mean depth of *c.*30 fathoms (55 m) The Skagerrak, the channel between Norway and Denmark, and the Kattegatt, between Denmark and Sweden, lead to three entrances to the Baltic: Oresund, in the east between the large Danish island of Sjaelland and south-west Sweden, and the Stora Bält and the Lille Bält which pass through the Danish archipelago. These channels are only *c.*10 fathoms (*c.*18 m) deep and form a sill to the Baltic.

The North Sea is also relatively shallow, since it is part of the continental shelf, as is the Baltic. At the seaward limit of this shelf the seabed plunges precipitously thousands of fathoms down to the ocean bed. Since late-medieval times this outer edge has been recognized as approximating to the 100 fathom line (*c.*180 m). Landward of this line a vessel is said to be 'in soundings' (Waters, 1978: 18). Along the coasts of Norway and of Iberia, and at some points in the west and south-west of Ireland, this 100 fathom line is only 10 to 20 nautical miles from land. Entering soundings when approaching these coasts can thus be a warning of the nearness of land. On the other hand, the 100 fathom line is some hundreds of miles from the coasts of the Irish Sea, the North Sea, the Channel, and the north-