University of Cyprus
Department of History and Archaeology

MA Programme in Field Archaeology on Land and Under the Sea

The evolution of the mast-step in the Mediterranean (7th century BC – 3rd century AD): A structural and functional analysis

Master's dissertation by

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[…] But a wooden ship was, in reality, far more than a lifeless structure. It began as a desire for profit, a hope of victory, or a dream for exploration or conquest in the minds of its originators. The idea moved to the shipyard, where the efforts of shipwrights, carpenters, and smiths – who sometimes left the marks of their tools or signs of their ingenuity – converted hundreds of trees into a variety of shapes and joined them together.

Steffy (1994), *Wooden Shipbuilding and the Interpretation of Shipwrecks*, p. 5

Richard Steffy working on the Kyrenia mast-step (Loren C. Steffy, 2012, *The man who thought like a ship*)

I hereby declare that all opinions in this paper are my own, and that the text does not reflect official opinions of the University of Cyprus.

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Chapter 1: Into the bowels of a ship

One of the most significant breakthrough innovations and changes in the history of ancient seafaring was the moment when shipbuilders conceived the idea to convert a man-powered vessel into a sailing one. Paddling or rowing was the primary form of propulsion until it was set aside in favour of a sailing propulsion system. This fact signified radical changes in the principles of ship construction, since the mast, the sail and the rigging were added to the equation. Shipbuilders had to take into account technical considerations, such as the raising and lowering of the mast, its stabilization during the voyage, as well as its efficiency for the seaworthiness of the vessel.

The resolution of these practical issues was the innovation of an intermediate structure, which would connect the mast and the hull; this structure was the mast-step. Steffy (1994: 275) defines a mast-step as “a mortise cut into the top of a keelson or large floor-timber, or a mortised wooden block or assembly of blocks mounted on the floor-timbers or keelson, into which the tenoned heel of a mast was seated.” In layman’s terms, the mast-step is a large wooden block installed atop the ship’s axis, which receives the foot of the mast (**Fig. 1**). It constitutes one of the longitudinal structures of the hull, along with the keel, the stem and the stern post, the planking and the ceiling. In the course of time, the mast-step concept is inextricably linked to that of the keelson, that is “an internal keel, mounted on top of the floor-timbers and directly above the keel, which provided additional longitudinal strength to the hull” (Steffy 1985: 71).

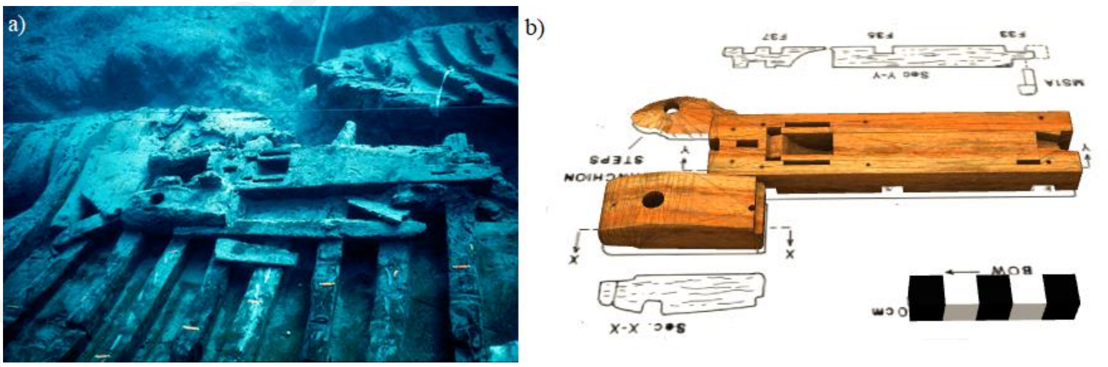


Figure 1: The Kyrenia mast-step: a) in situ, b) 3D model (© 2019 Learning Sites, Inc.)

In the past, the limited number of discovered shipwrecks preserving hull remains had hindered the tracing of shipbuilding development and as a consequence, during the last few decades, scholars have been mainly focused on the examination of the general hull construction. Thus, despite the importance of the mast-step as a structural element for the construction and function of ancient sailing ships, it has received little attention by scholars. In particular, the last decades, the examination of Mediterranean watercrafts has focused on classifying hulls either as shell-first or skeleton- based construction, principles which play a fundamental role in understanding ancient shipbuilding (Pomey 2004; Pomey *et al*. 2012). Additionally, scholars examine hulls according to their planking assembly (i.e. sewn or mortise-and-tenons joints), as well as their form, based on longitudinal or transverse orientation (Steffy 1995: 418–419; Pomey & Rieth 2005).

Shipwreck archaeology has progressed considerably in the last decades, with numerous excavations unearthing well-preserved hulls, permitting valuable insights to be gained regarding ancient shipbuilding, traditions, methods of construction and concepts. This development enables the study and interpretation of individual structural elements. In this respect, the evolution of the mast-step and keelson, their relationship, as well as their association with the structure of the hull, reflects the broader development in the construction of ancient ships. Therefore, the examination and interpretation of these timbers may supplement our knowledge on ancient shipbuilding and, consequently, ancient seafaring.

The archaeological remains of mast-steps, as part of the hull remains, are still very rare. Most Mediterranean shipwrecks which had been discovered until the beginning of 1990s are listed in Parker (1992). A total of 117 wreck sites, dated to *c*. 300 BC or earlier, had been recorded throughout the Mediterranean, up until then (Parker 1992: 10-12). Of them, only 11 had conserved hull remains (less than 10%) (Tejedor 2018: 300; McGrail 2001: 145) and, of those, only 5 preserved the mast-step timber (about 3,5% of the total wreck number and almost one-third of those which had preserved hull remains). These percentages indicate that the mast-step is a very rare discovery. However, it must be taken into account that many excavations are not well documented, recorded or published and these rates should be treated as indicative. After Parker's list, less than a dozen shipwrecks with preserved hull remains, dated before the Roman era, have been recorded in the western Mediterranean (Tejedor 2018: 300), and only one has preserved the mast-step (Mazarrón 2, S001). The same applies to the eastern Mediterranean, where also only one shipwreck with mast-step has been discovered (Thonis-Herakleion/ Ship 17, S005). The corresponding percentage regarding the Roman period is more difficult to be extracted with accuracy, taking into account the great number of shipwrecks dated to this era that preserve hull remains. However, the percentage most likely is still extremely low, as only 15 Roman shipwrecks have preserved their mast-step timbers (**Fig. 2**).

It must be mentioned that these shipwrecks were cargo ships or coastal/fishing boats. Until the Roman period, there is no archaeological evidence of a mast-step as a structural remain of a warship.

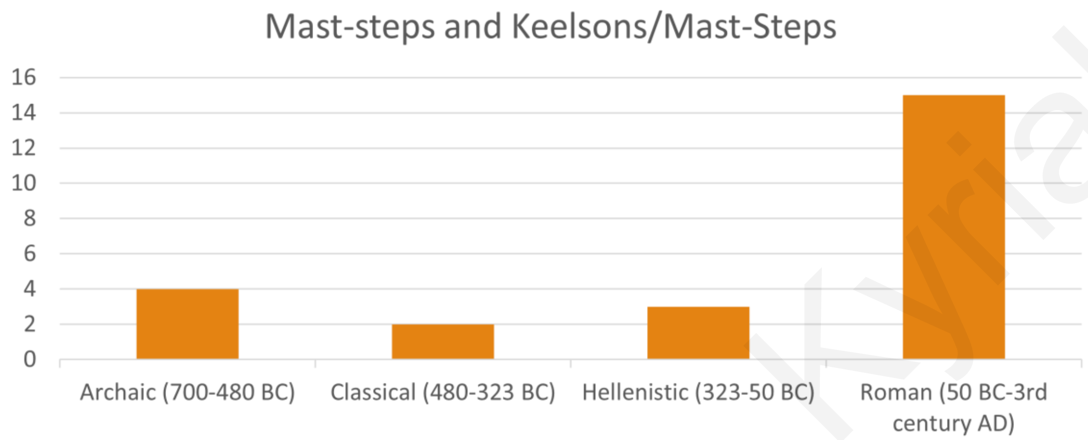


Figure 2: Chronological distribution of shipwrecks that preserve the mast-step in the Mediterranean (7th century BC - 3rd century AD).

The evidence supplied by textual sources concern mainly the terminology of the mast-step, rather than its description (Casson 1971: 47, 153, 233, 237). The iconographic evidence on the other hand, while limited, can contribute significantly to the study of the mast-steps. Even if the mast-step itself is not portrayed (due to its very position into the hull) other information, for instance the position of the mast, can be gleaned from iconographic evidence.

Mark Geannette's MA thesis (1983) was the first research regarding the development of the mast-step and keelson as part of the hull structure. His work was based on published material - up to that time - accompanied by information provided by his personal communication with scholars. His work involved the study of mast-steps from the Mediterranean and Northern Europe, covering a span from 6th century BC until the 11th century AD.

Geannette's thesis formulated the basis for any further examination regarding the mast-step and keelson. Many of his theories on Mediterranean shipbuilding, however, were not sufficiently explained. Furthermore, some of his conclusions could not be answered until subsequent archaeological excavations were carried out. Considering that at the time of his analysis, the archaeologically attested mast-steps in the

Mediterranean until the end of the Roman period (3rd century AD) were not more than ten in number, this subject requires updating as well as further scrutiny.

Research Objectives

The present thesis aims to re-examine and re-evaluate the available data, in order to contextualize the changes in the construction of the mast-step in the *longue durée*. Therefore, the research objectives of this study are as follows:

1. To compile a corpus of the excavated shipwrecks that preserve the mast-steps remains.
2. To affiliate the mast-steps and keelsons into specific shipbuilding traditions.
3. To examine and analyze the mast-steps diachronically, based on their form, function and adjacent elements.
4. To formulate a structural typology.
5. To interpret the form and the function of the mast-step in association with the mast.

Methodology

For the purpose of re-examining and re-evaluating the available data, a corpus of 24 shipwrecks has been created (Chapter 2), which will be the basis of this study. It includes all the available archaeological evidence derived from shipwrecks that preserve the mast-steps and it extends geographically throughout the eastern, central and western Mediterranean. It spans chronologically ten centuries, ranging from the Archaic to Roman period (7th century BC –3rd century AD). Where the archaeological evidence ended, carefully chosen examples provided by iconography and experimental archaeology are used to supplement the missing information. As it can be seen in **Figure 2**, out of the 24 shipwrecks, only 9 are before the 1st century BC, whilst the vast majority (approximately 2/3) are dated to the Roman period. Even though the archaeological evidence prior to the Roman period is limited, they are of great importance for the tracing of the mast-step and keelson evolution. The catalogue lists the shipwrecks in chronological order and includes the dimensions, the main characteristics and the individual features of each mast-step and keelson.

Aiming to contextualize the changes in the construction of the mast-step in the *longue durée*, and in order to draw safe conclusions, different analysis of available evidence has been attempted. The analysis begins with the classification of the mast-steps and the keelsons/mast-steps into specific shipbuilding traditions. From the 24 shipwrecks of the corpus, only 12 (50% of the total) have hitherto been classified into shipbuilding traditions (Pomey *et al.* 2012; Pomey & Boetto 2019). The purpose is to affiliate this timber as a diagnostic structural element of each known shipbuilding tradition (Chapter 3). Moreover, a chronological development has been presented and the material has been contextualized based on the known shipbuilding traditions (Chapter 4).

Based on these, a comparative analysis along with a structural typology is suggested, associated with the different types of mast-step placement, its position into the hull and its relationship with the mast (Chapter 5).

The Mast

The examination of the mast-step is inextricably linked to that of the mast. Therefore, before the corpus of the shipwrecks that preserve mast-step remains and the analysis of the structure, a brief introduction about the mast is of vital importance for any further analysis and interpretation.

Information regarding the form and the location of the ancient masts is based mainly on iconographic evidence.

1. Single-masted vessels

The earliest sailing vessels, as it is inferred from the iconographic evidence, has a mainmast set – initially - amidships, carrying a square or rectangular sail (Casson 1971: 239). The single-masted square-rigged vessel is seen as the most ancient type of a sailing vessel in the Mediterranean (Whitewright 2016: 879-882).

Early representations of single-masted vessels can be seen on three Cypriot jugs, dated to the 8^{th}-7^{th} century BC. A single mast is placed amidships and is held in place by a triangle-shaped mast-step or by two oblique braces. The mast carries a horizontal yard, sometimes with a furled sail (A, C) (Karageorghis & des Gagniers 1974: 38, 122-123; Westerberg 1983: 43-45, Catalogue no. 53, 54, 55) (**Fig. 3**).

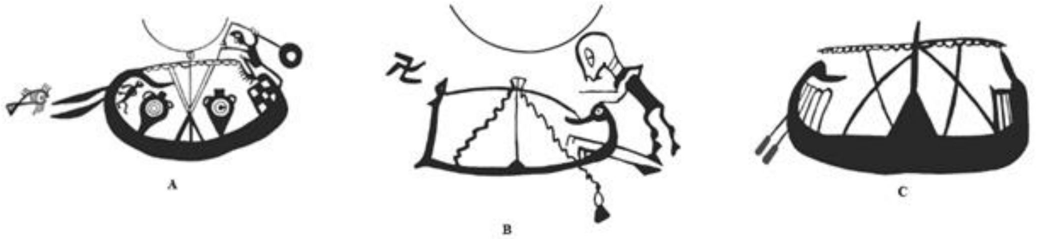


Figure 3: Cypriot jugs with early representations of single-masted vessels (Karageorghis & des Gagniers 1974: 122-123).

In this study, 22 out of 24 shipwrecks under discussion were single-masted vessels – as it is inferred from the mast-step remains – which, most likely, carried a square or rectangular sail.

2. <u>Two-masted vessels</u>

So far, the earliest depictions of two-masted merchantmen in the Mediterranean, dated to the Archaic period, have been discovered in Greece, engraved on rocks. They are depicted with a mainmast in the centre of the hull and a straight or slanting *artemon*, which was a small mast in the bow, carrying a square sail (Van de Moortel & Langdon 2017: 397-400) (**Fig. 4**).

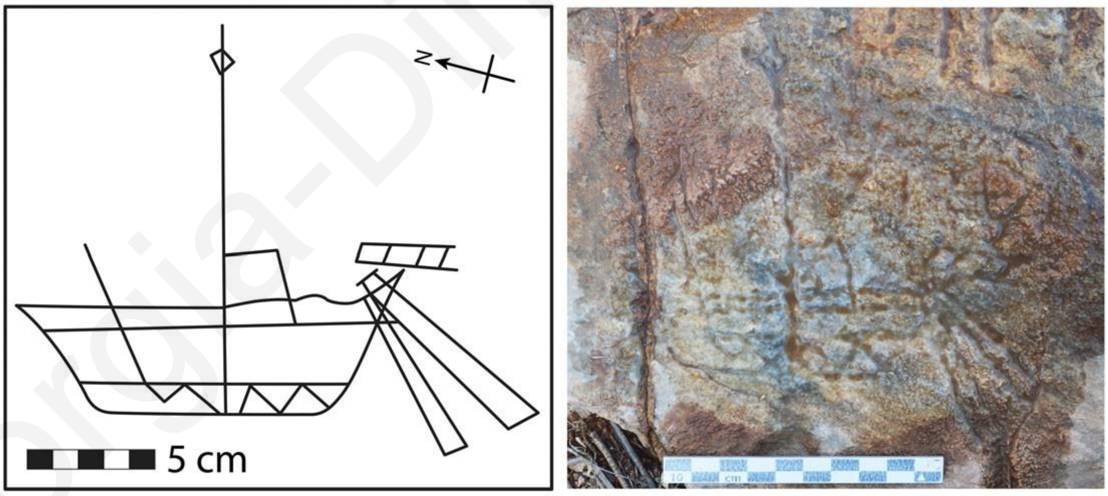


Figure 4: Merchantman with two masts (Van de Moortel & Langdon 2017: 400, fig. 26)

The first archaeological evidence of two-masted vessels – as it is inferred from the mast-step remains – is dated to the Roman period, revealing information both for a slanting (Madrague de Giens, S010) and a straight (Saint-Gervais 3, S021) foremast (see Chapter 5 for further analysis).

Archaeological Evidence

As an archaeological remain, the mast is an extremely scarce discovery. During the wrecking event, the vast majority of the sailing ships lose their mast because it detaches violently from the hull; as a matter of fact, the discovery of an ancient mast is exceptional. So far, the archaeological evidence reveals only four examples.

a) The mainmast of the Albenga shipwreck (100-80 BC, **Table 6, No. 4**) survived in place (Beltrame 1996: 135; Lamboglia 1952). It was squared up to the main-beam level and circular above. The opening (mast-box) into the main-beam was also preserved, indicating that the ship was undecked at this point (Parker 1992: 50).

b) Excavations at the 1st century AD site in Olbia (**Table 6, No. 6**), Sardinia, unearthed a possible mast, which was broken at one end but its longitudinal section (it tapered in width from the bottom to the top) led scholars to interpret it as a mast (Riccardi 2002; Gavini *et al.* 2014) (**Fig. 5**).

Figure 5: The Olbia mast (Riccardi 2002: 268, fig. 2)

c) A portion of a mast was found *in situ*, at the Dramont E shipwreck (425-455 AD, **Table 6, No. 10**). Only the foot of the mast had survived, set into the mast-step. It is a smaller in comparison to the Olbia mast. So far, it is the only example of an ancient mast that was found stepped into the mast-step.

d) The Shipwreck D (5th century AD, **Table 6, No. 9**) was found at a depth of about 100m by side scan sonar and remotely operated vehicles (ROVs). It preserves a single-pieced mast in place, with the associated spars and deck structures. It is a unique case where the mast is completely preserved, due to the anoxic waters of the Black Sea, without a trace of erosion (Ward & Ballard 2004: 6-12) (**Fig. 6**).

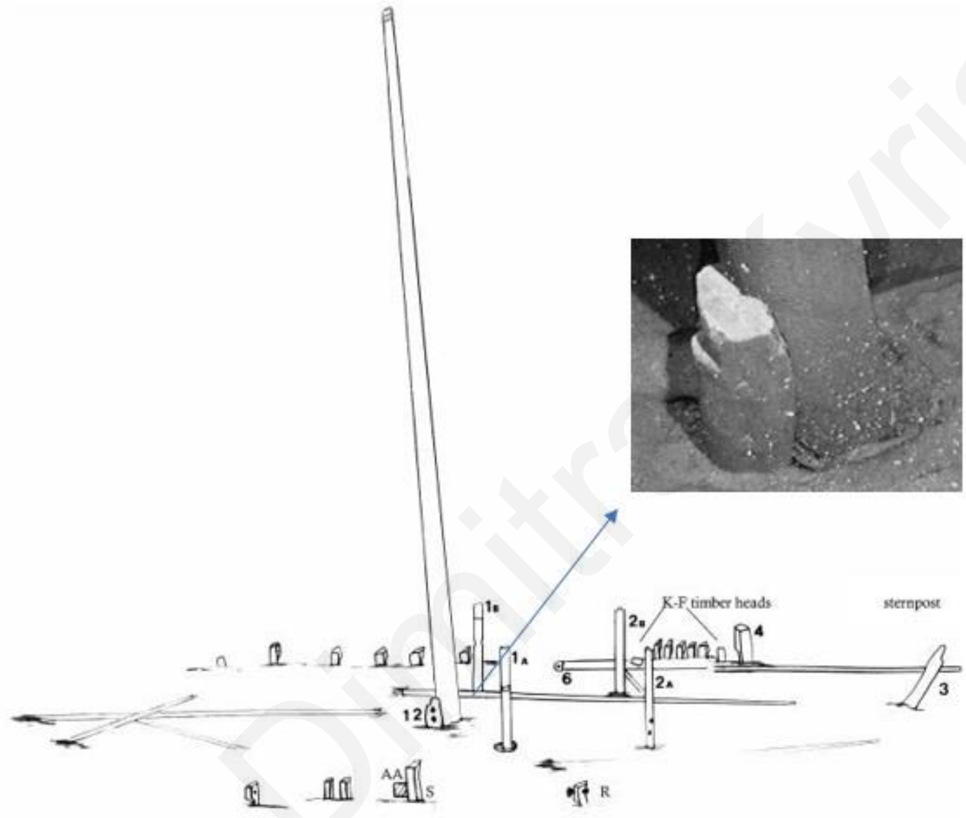


Figure 6: Sheer view of the Shipwreck D. Note the mast and its bracing timber (Ward & Ballard 2004: 9, fig.9; 10, fig. 12a).

It becomes obvious that, as the mast-step does not ordinarily survive in the archaeological record, the examination and interpretation of the mast-step is of vital importance for the research regarding the ancient sailing vessels. Its study undoubtedly serves on the one hand, to a better understanding of the shipbuilding development as part of the hull but, on the other hand, it reflects evidence regarding the missing mast, the driving force of any sailing ship. The archaeological examples of the surviving masts will be discussed in detail towards the end of the analysis, in relation to the structure and the function of the mast-step.

Chapter 2: Excavated Shipwrecks that preserve mast-step remains

2.1 Archaic Period (700-480 BC)

S001. Mazarrón 2 (625-570 BC), Cartagena, Spain

The earliest example of a surviving mast-step in the Mediterranean, comes from the Mazarrón 2 shipwreck, dated to the end of the 7th or the beginning of the 6th century BC (625–570 BC). The mast-step was found *in situ*, as part of the fully preserved hull (Pomey & Boetto 2019: 19). A slight deviation between the measurements in different publications is observed, as Negueruela (2004: 241) refers to 0.98m long mast-step, whilst Miñano (2014: 7) describes a 1.04m long mast-step, adding the width (10cm) and the height (6cm). It is rectangular, placed amidships and set over the cylindrical floor-timbers which passed through two semicircular recesses. Furthermore, it is fastened to and in direct contact with the keel with five mortise-and-tenon joints; four of them are arranged in a straight line and a fifth is orientated perpendicular to the others (Negueruela 2004: 241; Miñano 2014: 7; Pomey & Boetto 2019: 20). The largest cavity (9cm long and 4cm wide) was employed for the housing of the mast (Dell' Amico 2008: 21; De Juan 2018: 97). It contains a secondary groove for a blocking wedge on its bow side **(Figs. 7 and 8)** (Pomey 2012: 25). The position of the mast-step allowed the identification of the bow and stern of the boat (De Juan 2017: 70; Tejedor 2018: 309-310) (**Fig. 8**).

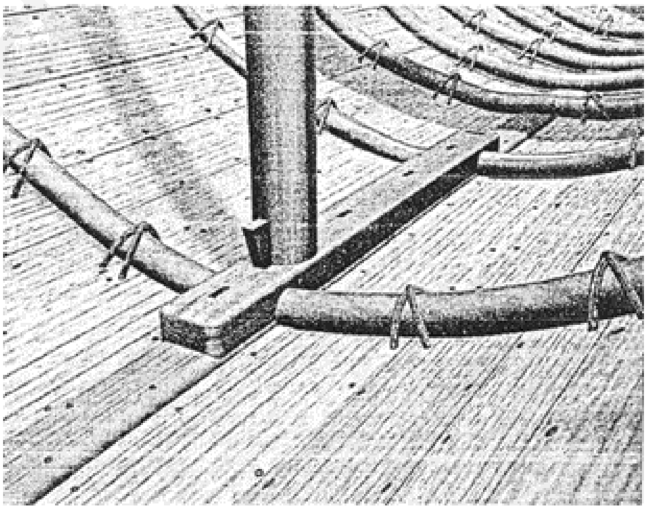


Figure 7: Axonometric view of the Mazarrón 2 mast-step (Pomey 2012: 25, fig. 17).

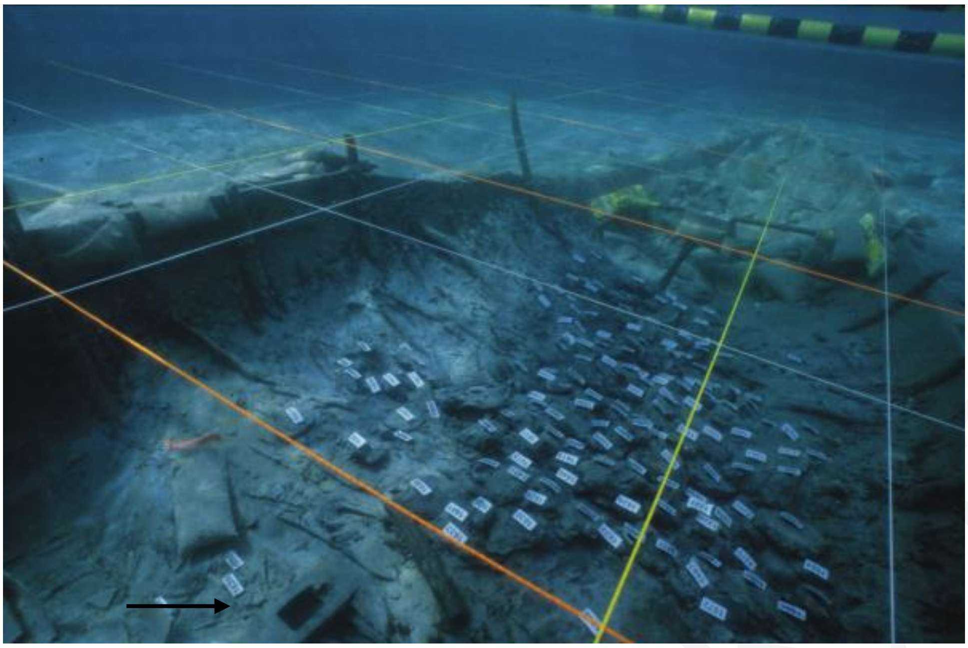


Figure 8: The Mazarrón 2 mast-step, in situ. Note the fore extremity of the timber, including the mast cavity and the groove for the blocking wedge, which allowed the identification of the bow (Miñano 2014: 2, fig. 1).

S002. Golo (6th century BC), Corsica, France

In contrast to the other cases presented in this thesis, the Golo mast-step does not survive today. Nevertheless, the thorough documentation of the boat permits the assumption, that at the time of its discovery, it was in a very good state of preservation and, consequently, can provide important information to the study of the ancient mast-steps. The Golo boat was discovered in Corsica in 1777 by a local scholar, but the text and the drawings were published a century later (1888) to Admiral Paris's *Souvenir de marine conservés*. Basch (1973: 329-331, 342) re-examined the boat, based on this publication. The boat has been recorded and designed from bow to stern and from bottom to deck level and represents a completely symmetrical boat. Among the other parts of the hull, crucial details and layouts for the mast-step are provided.

According to the dimensions of Admiral Paris's Souvenir de marine conservés (folio 8), the mast-step (2.56m long, 16-24cm wide and 16-26cm high) was placed over the floor-timbers and its underside was in direct contact with the keel. The three notches on its under surface permitted the floor-timbers to pass through. The strong similarities that preserve with the Mazarrón 2 mast-step, reinforce the credibility of Admiral Paris's layouts (Pomey 2012: 23-24; Dell'Amico 2008: 17; De Juan 2017: 71-72) (**Fig. 9**).

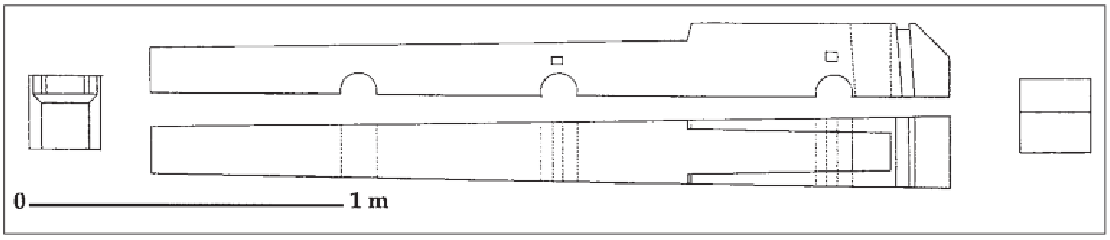


Figure 9: Drawing of the Golo mast-step (Dell' Amico 2008: 16, fig. 5).

Presumably, the upper surface of the mast-step timber had eroded to such a degree, that it was not possible to design or measure the pattern of mortises. The form that they would have had can only be hypothesized, based on the traces that remained.

The interpretation of the two square holes horizontally crossing the mast-step timber remains problematic. Basch (1973: 332-333) contests the assumption that these were used for the attachment of ropes, since the deck was exactly above them and most probably prevented such an operation. Since this boat exists only through the publication, the existence of a deck and, in general, the credibility of the description is disputable. On the other hand, Dell' Amico (2008: 17) has interpreted the two square holes as passages for ligatures of fastening of the mast-step.

Lastly, there are no indications of the existence of a keelson as an extension of the mast-step, either towards the fore or towards the aft part of the boat (Dell' Amico 2008: 17; Pomey 2012: 24).

S003. Bon-Porté 1 (540-510 BC), Saint-Tropez, France

The Bon-Porté 1 mast-step (1,05m long, 12.5cm high and 19cm wide) was found resting above the frames (Liou 1975: 595-596; Joncheray 1976: 33; Pomey 1981: 225; Kahanov & Pomey 2004: 14). Its underside – much thinner than its upper one – has a tenon in the middle of two parallel notches to fit on corresponding rabbets on the frames (Joncheray 1976: 33; McGrail 2001: 134) (**Fig. 10**). The mast-step is totally devoid of bolts, nails or pegs in the tenons and, therefore, is not fastened at all to the keel or the frames. This weak wooden assemblage and the spreading of the notches make the mast-step essentially mobile (Joncheray 1976: 34; Geanette 1983: 9). The upper surface of the mast-step presents six mortises. The main cavity was undoubtedly destined for the housing of the foot of the mast, although it has a rather peculiar profile; the bottom is rounded and the back face is not vertical, as is most common, but is angled several degrees forward. It has been suggested that the curvature of the bottom serves for the rotation of the mast during its insertion. The shallow depth and the length of the elongated cavities, on either side of the main one, indicates that they could not have a substantial support role, but they could be used as a durable sliding mechanism – now lost – essentially guiding the mast (Joncheray 1976: 33-34; Pomey 1981: 225).

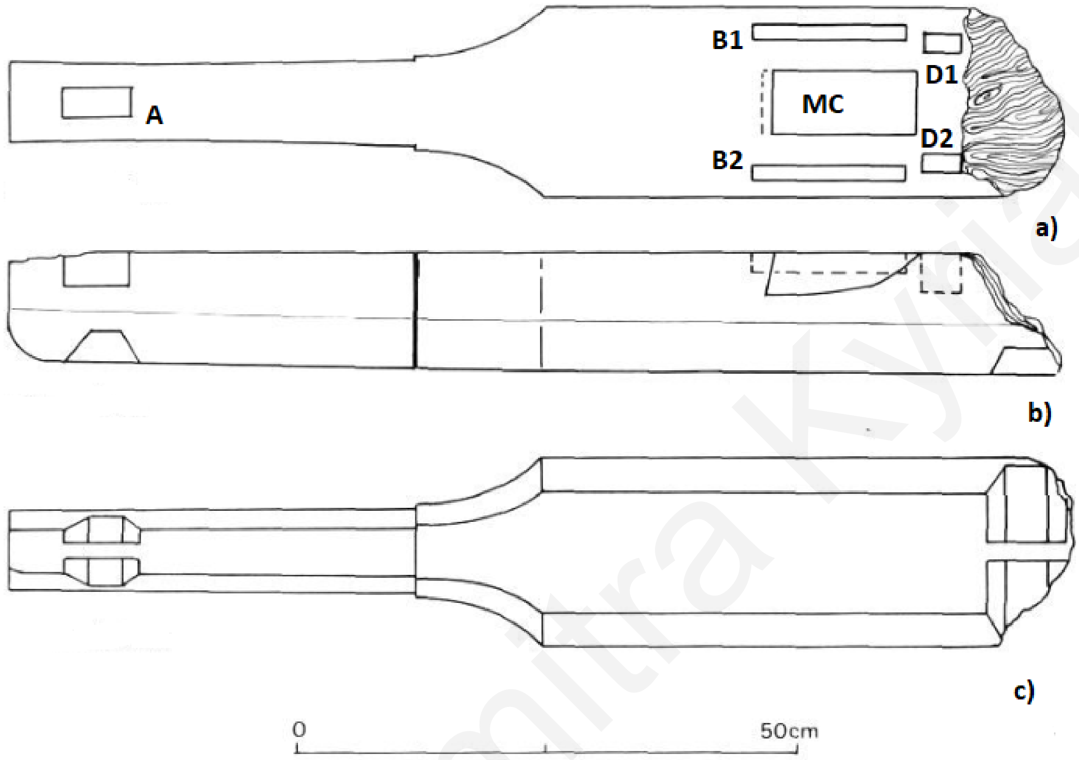


Figure 10: The Bon-Porté 1 mast-step: a) the upper extremity. (MC) Main Cavity; (B1, B2) elongated cavities; (D1, D2) deep and narrow mortises; (A) Isolated cavity. b) side-view; Note the curvature of the main cavity. c) The underside (thinner than the upper one) with the notches for the placement on the frames (After Joncheray 1976: 32).

The two deep and narrow mortises, slightly forward and out of the main cavity, are capable of receiving tenons, also related to the sliding mechanism mentioned above (Joncheray 1976: 33-34). Lastly, at the time when Joncheray analyzed the mast-step, he did not reach an interpretation for the isolated cavity, at the narrow end of the timber. However, the discovery of the Ma'agan Mikhael shipwreck, some years later and the interpretation of the mortises on the aft end of the mast-step as *stanchion* bases, led to the assumption that the cavity of the Bon Porté I mast-step may have been used for the same function (Mark 2005: 47).

S004. Gela 1 (500-480 BC), Sicily, Italy

The Gela 1 shipwreck, dated to the end of the Archaic period, preserved a complete mast-step in its original position, lying in the central and forward section of the ship

(Panvini 2001: 19, 21; Benini 2017: 410). Two pieces of roughly square-sectioned wood, round-shaped at the ends, created a mast-step (**Fig. 11**) of considerable size (6m long, 58cm wide and 20cm thick) (Panvini 2001: 24), almost 1/3 of the length of preserved hull. It was placed above the floor-timbers, like that of Bon-Porté 1, but in this case, it is attached to the keel with vertical wooden keys. Additionally, it has four sister-keelsons beside it, as auxiliary elements for its support (Kahanov & Pomey 2004: 18; Benini 2017: 410; Pomey & Boetto 2019: 30). Based on the archaeological record, this is the first occurrence of such a structural element.

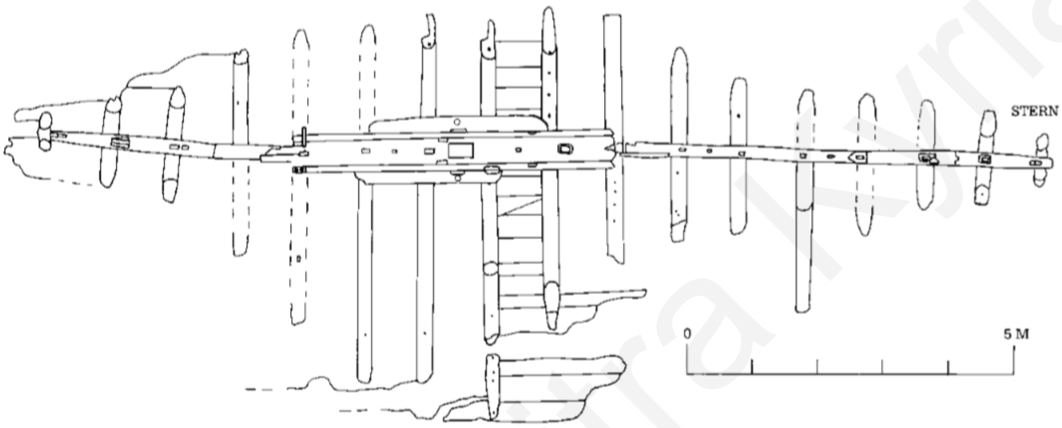


Figure 11: The mast-step of Gela 1 ship (Mark 2005: 46, fig. 16).

The Gela 1 mast-step has several recesses (the exact number is not mentioned) on its widest upper surface, the largest of which served for the housing of the mast. The rectangular and circular recesses were presumably intended for stanchion poles, which served to support the mast and provide the necessary counter thrust during navigation. They also must have contributed to the lowering and raising of the mast (Panvini 2001: 24). The mast-step is connected fore and aft with a longitudinal stringer, placed on the ship's axis and is, essentially, along with other three pieces, part of this stringer, running along the 16 of 17 frames of the hull (Mark 2005: 46).

This structural element has been characterized by the scholars as a keelson, due to its form and position in the hull. Its underside has notches in order to be fixed on the rabbets on the floor-timbers (Panvini 2001: 24; Benini 2017: 410; Pomey & Boetto 2019: 30). The recesses on the upper face of the stringer may have served the same purpose with those of the mast-step, but they could also be interpreted as stanchion holes to support deck beams (Panvini 2001: 25; Mark 2005: 46). The keelson terminates towards the stern on the same floor-timber as the mast-step, and towards the bow, it extends further than the mast-step, reaching the first preserved floor-timber (Panvini 2001: 24-25).

2.2 Classical Period (480-323 BC)

S005. Thonis-Herakleion/ Ship 17 (mid-5th – early 4th century BC), Egypt

The Ship 17 has been identified as *baris,* a type of vessel which was, until the discovery of this shipwreck, only known by Herodotu's descriptions (Belov 2014: 3; Belov 2015: 76). This Egyptian sailing vessel presents a totally different and alternative method for stepping the mast, which is unique and unprecedented. Instead of a mast-step, a notch on the keel itself was intended for the mast. Although, it must be noted that this is not a true keel, as is known from other ships' hulls because, in this case, the keel is actually a central longitudinal element, whose width is greater than its thickness (sided vs moulded dimension), protruded into the hull. Pulak (2008: 302; 2010: 873) characterized a similar timber, found at the Late Bronze Age Uluburun Shipwreck, as a *proto-keel*, thus demonstrating its rudimentary structure.

The 'keel' consisted of 12 segments (K1 – K12) made of acacia, ranging in length from 1.63 to 3.05 metres (Belov 2014: 2, 3; Belov 2015: 76). The central segment (**Fig. 12**) has a mortise of elongated shape (46cm x 13cm) which essentially function as the "mast-step" of the ship (Belov 2014: 7; Belov 2015: 76). Considering that the segment is eroded, the depth of the mortise (5cm) was presumably greater originally, to receive the foot of the mast (Belov 2019: 93).

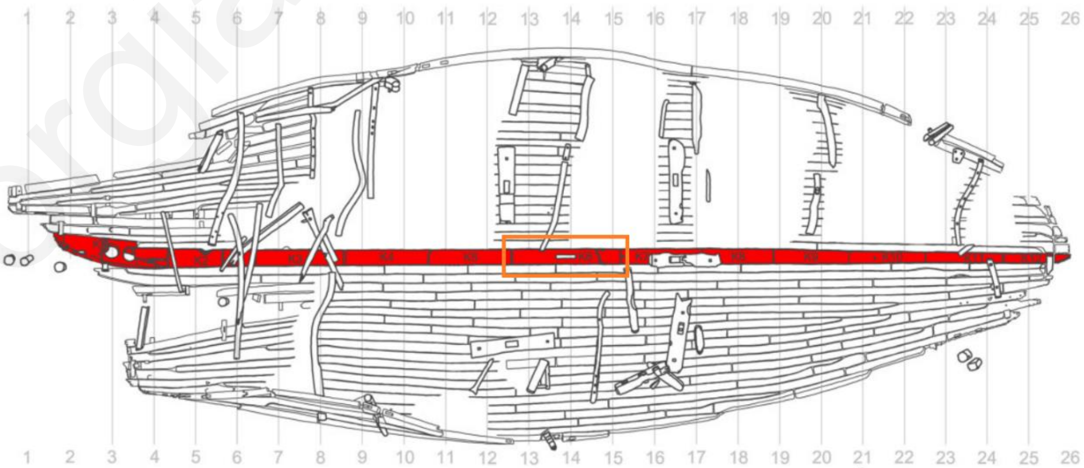


Figure 12: Plan of the keel of Ship 17 of Thonis-Herakleion. In the rectangular frame: K6, the central segment of the 'keel' that functioned as a mast-step (Belov 2015: 77, fig. 3).

Ship 17 was an undecked vessel, but the remains of ten bracing timbers indicate that they were used to reinforce the hull transversally, according to the choice of shipwrights or the crew, during the voyage. Only a pair of such bracing timbers were attached to the proto-keel and it was at the point of the “mast-step”; the rest of them were not joined to the ‘keel’ (Belov 2014: 3, 7, 14; Belov 2019: 104). It would seem that, the displacement of the mast was blocked by these bracing timbers, as well as due to the greater depth of the cavity in which was placed in.

S006. Ma‘agan Mikhael (c. 400 BC), Israel

Kahanov (2003) has analyzed in detail the form of this ship’s mast-step and its position in the hull. It was found *in situ*, about amidships and rested on four frames (F12, F9, F8, F7 from bow to stern). It is made of a half pinewood log and is 2.44m long, 29,5cm wide and 14,5cm high. The mast was stepped slightly towards the bow and at the fore end of the mast-step timber (Kahanov 1998: 158; 2003: 99; Kahanov & Pomey 2004: 11) (**Fig. 14**).

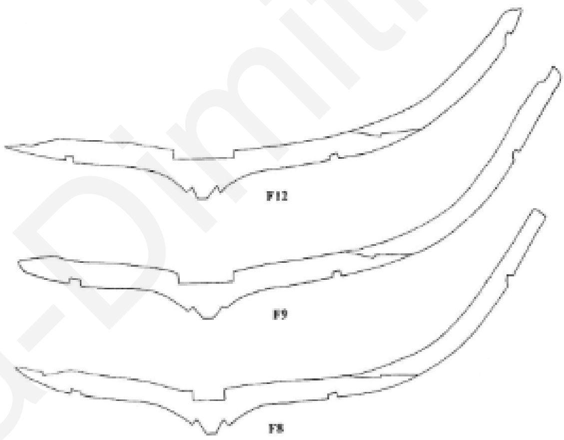


Figure 13: Ma‘agan Mikhael, Floor-timbers 8, 9, 12. Detail of the framing pattern by T. Levi (Kahanov 2003: 95, fig. 68).

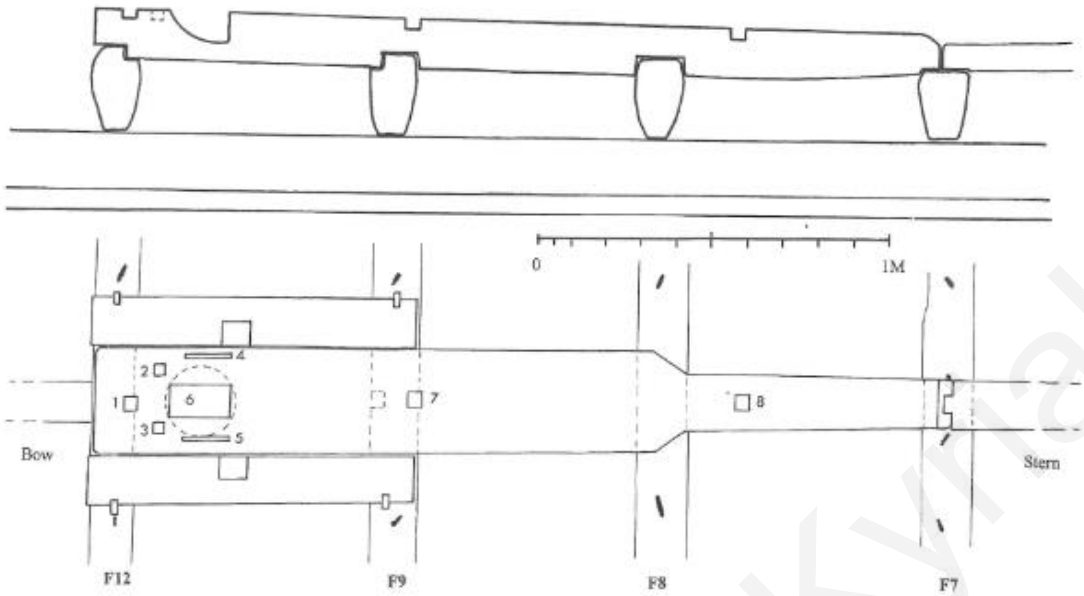


Figure 14: The Ma'agan Mikhael mast-step plan. No. 6 (Main Cavity); No. 4 and 5 (elongated mortises); No. 1, 2, 3, 7, 8 (cavities for stanchions) (Kahanov 2003: 102, fig. 78).

Three of the floor-timbers (F8, F9 and F12) has rabbets on their upper surface to fit the mast-step (**Fig. 13**) (Kahanov 2003: 92). Thus, the mast-step has recesses on its underside, fitting with the corresponding ones of the floor-timbers F8 and F9, to prevent any longitudinal movement. A smaller recess in the upper part of F12, matches with the corresponding one at the forward edge of the mast-step and serves for additional stability towards the bow (Kahanov 2003: 102; Kahanov & Pomey 2004: 11).

Towards the stern, the mast-step demonstrates a distinct feature. Despite the fact that the keel and the false keel are leveled amidships, the form of the mast-step differentiates on the longitudinal axis; its forward edge is higher than the aft edge (**Fig. 14**). It narrows gradually above the floor-timber F8 and it is dovetail-scarfed to the stringer on the F7. From this point the stringer extends towards the stern (Kahanov 2003: 92, 99, 102). This stringer might be considered as an extension of the mast-step timber and is similar to the stringer which runs along the first five floor-timbers, starting from the bow (F17 – F13) (Kahanov 2003: 99; 2011: 162) (**Fig. 15**). The similarity between these two stringers, leads to the question of whether these pieces should be considered as an extension of the mast-step (like the case of Gela 1 mentioned above) or not.

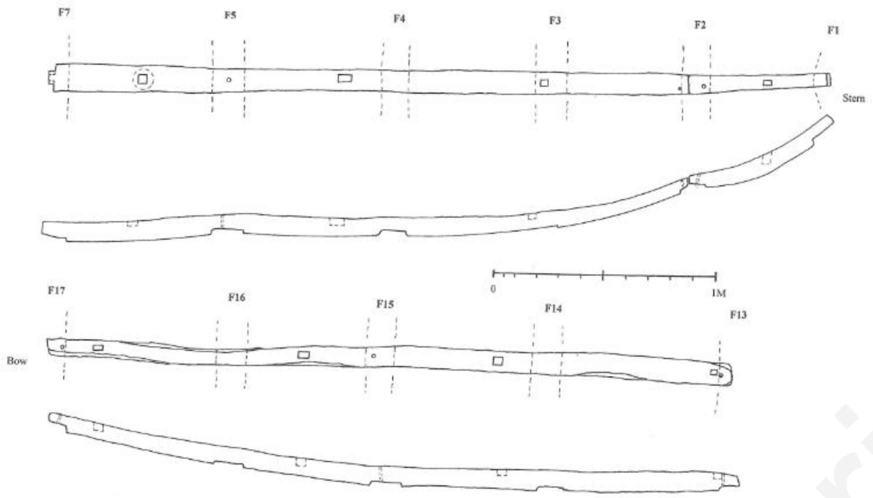


Figure 15: Ma'agan Mikhael, The stringers a) the aft part (towards the stern), b) the front part (towards the bow) (Kahanov 2003: 100, fig. 55).

The auxiliary timbers on either side of the mast-step have been interpreted by Kahanov (2003: 102) as sisters, served to strengthened further its stability. They secured it from moving laterally by having two large wooden rectangular tenons on their external sides, which were paired with mortise sockets in floor-timbers F9 and F12 respectively (**Fig. 14**) (Kahanov 2003: 99; Kahanov & Pomey 2004: 11).

The transverse/cross-beams found within the wreck have been interpreted as mast partner beams; the first one was nailed to the futtock of F9 and the other to this of F12 at the level of the first wale. Both partner beams have rabbets in their horizontal plane which fitted on the frames and were secured by two copper nails respectively (Kahanov 2003: 105; 2011: 162; Kahanov & Pomey 2004: 11;) (**Fig. 16**).

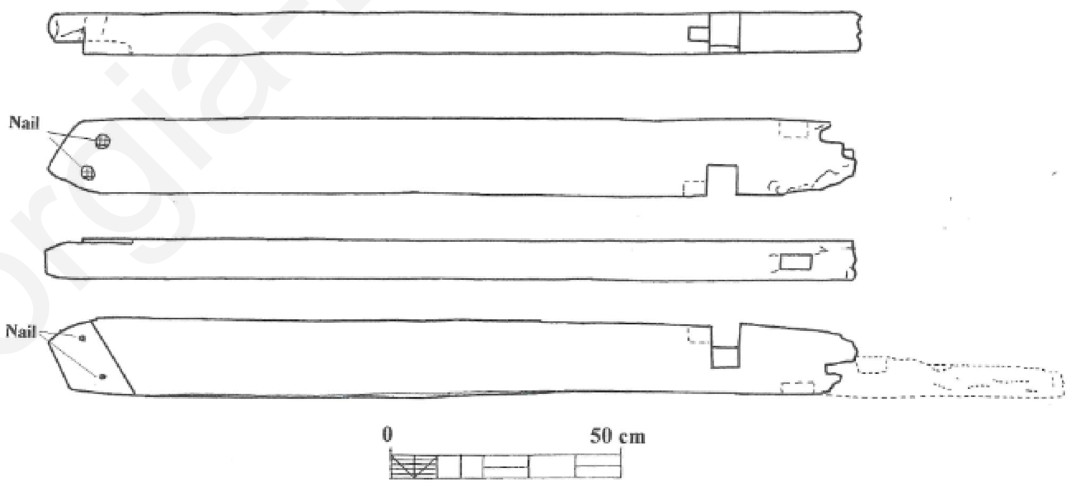


Figure 16: Ma'agan Mikhael, Mast partner beams (Kahanov 2003: 105, fig. 83).

Four vertical stanchions have also survived. They were made of the central part of a branch, with a varying length of 47 to 66 cm. All stanchions have a rectangular protrusion to emplace vertically into the shaped sockets on the mast-step and the stringer. They had been used for the supporting of the lateral mast partners, to which they were joined. The existence of the stanchions, the fact that they were joined with the mast partners, along with the mast's own weight and the load upon it, contributed to the stability of the mast step and precluded any upward movement (Kahanov 2003: 102, 104; 2011: 162; Kahanov & Pomey 2004: 11). The fact that during the restoration process of the hull one of the mast partners matched perfectly with its corresponding support stanchion, confirmed the accuracy of the hull's reassembly (Kahanov 2011: 167).

Two mast boards of the same dimension, one on the port and one on the starboard side, were fitted into the elongated mortises alongside the main socket of the mast-step (**Fig. 14 and 17**). The mast boards were situated 20cm apart and were used to support the raised mast. This information may provide an indication of the form, the diameter and the thickness of the mast (Kahanov 2003: 105).

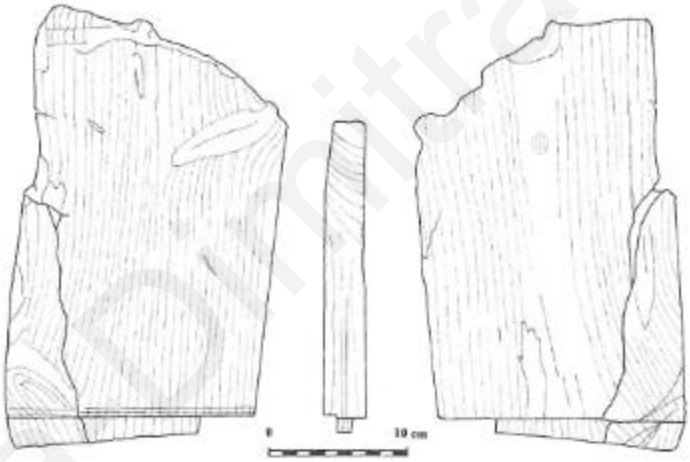


Figure 17: Ma'agan Mikhael, A mast-board (Kahanov 2003: 104, fig. 82).

2.3 Hellenistic Period (323 – 50 BC)

S007. Kyrenia (310-275 BC), Cyprus

The pinewood-made mast-step (1.2m long, 24cm wide and 10cm high) was one of the surviving internal structures of the Kyrenia ship, along with two stanchion steps, port and starboard ceiling strakes and transverse-beams (Geannette 1983: 12; Steffy 1985: 72, 87). It was found in the forward part of the vessel, about one-third of the length of the vessel from the bow (Casson 1971: 245). On the upper side, it consists of a complex of cavities and a closing device (**Figs. 1 and 18**) related to the unusual cutting in the after end of the timber. Additionally, as the mast-step has four notches on its underside, one would expect that it would have been placed atop four frames. It was found atop three rabbeted frames, however (F37, F35, F33), instead of four. Similar rabbets are present on two other frames (F44, F47), further to the fore of the ship. Steffy (1985: 86, 95) interprets this fourth notch cut on the bottom of the mast-step timber, and the rabbeted frames as evidence that the mast-step was reversed and placed across F37, F35, F33 when the ship sunk; or that it could also be placed further forward in the ship, on F44 and F47 or F44 and F40 (in a reversal of its *in situ* direction), when needed (**Fig. 19).** The reversing ability of the mast-step that Steffy refers to has not been sufficiently explained.

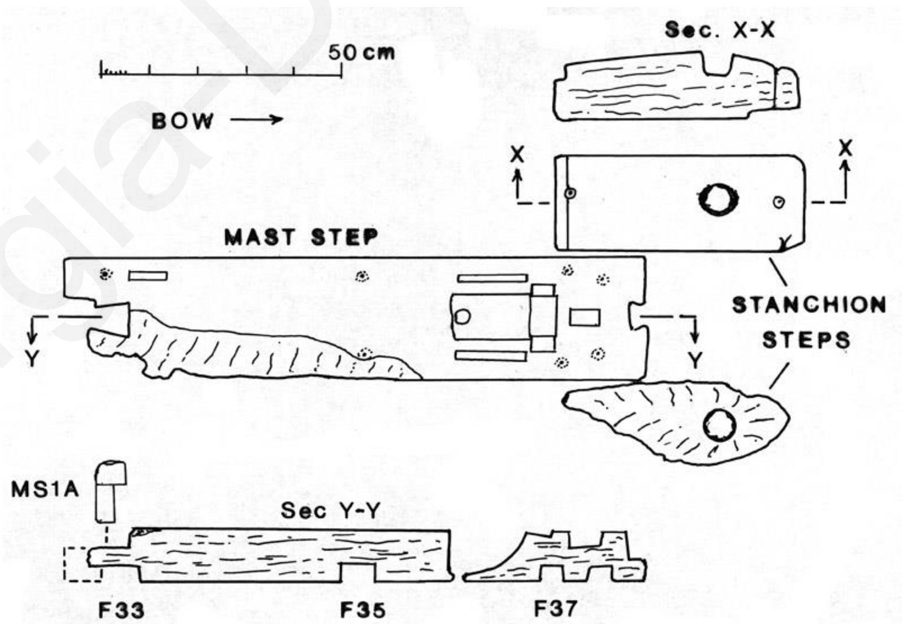


Figure 18: The Kyrenia mast-step complex. (MS1A): the closing device. (Steffy 1985: ill. 12, p. 89).

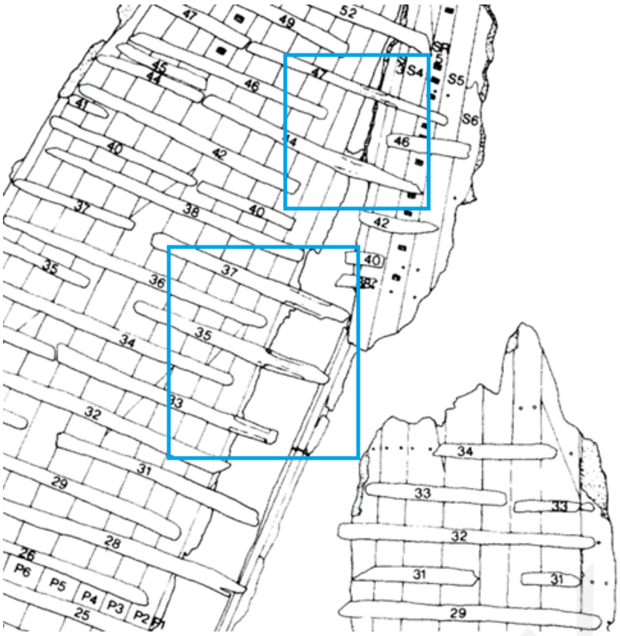


Figure 19: Detail of the Kyrenia's hull plan. Note the rabbets on timbers F47, F44, F37, F35, F33 (based on Steffy 1985:74, fig. 2).

In any case, he concluded that at least three, or even four locations could thus be used for the mast-step's placement, during or before the voyages, which presumably served practical issues of navigation. The ability of its readjustment perhaps also served to create space for a bilge pump, used to remove the seawater from the hull or to close gaps in the ceiling. Steffy doesn't explain, however, how the mast-step was capable of closing these gaps. In any case, the partner beams ought to be easily modified to create space for the mast (Steffy 1985: 86, 95). Based on the shape of the mast-step, Dell' Amico (2011: 59) suggests that it could have been a reused mast-step timber, recovered from another ship.

S008. Chrétienne A (150-100 BC), Anthéor, France

The preserved mast-step measures 4.71m in length and it is damaged at its southern edge; its original length would have been over 5m (Dumas 1964: 156; Basch 1973: 333; Geannette 1983: 22). For the first 2.40m of the mast-step timber, its width is 22-24 cm but towards the southernmost part it almost doubles to 48cm and remains this wide for 2.31m (Casson 1971: 208) (**Fig. 20**). On the upper surface of the mast-step timber, the main cavity (31cm long, 21cm wide with a 15.5cm maximum depth) presents an "wavy/undulant" form, as it curves firstly upwards and then back down, creating a second shallower groove. A peculiar characteristic is that the two parallel mortises

(18cm long, 4.5cm wide and 4cm deep) are essentially part of the main cavity, the first appearance of such a form (Geannette 1983: 22).

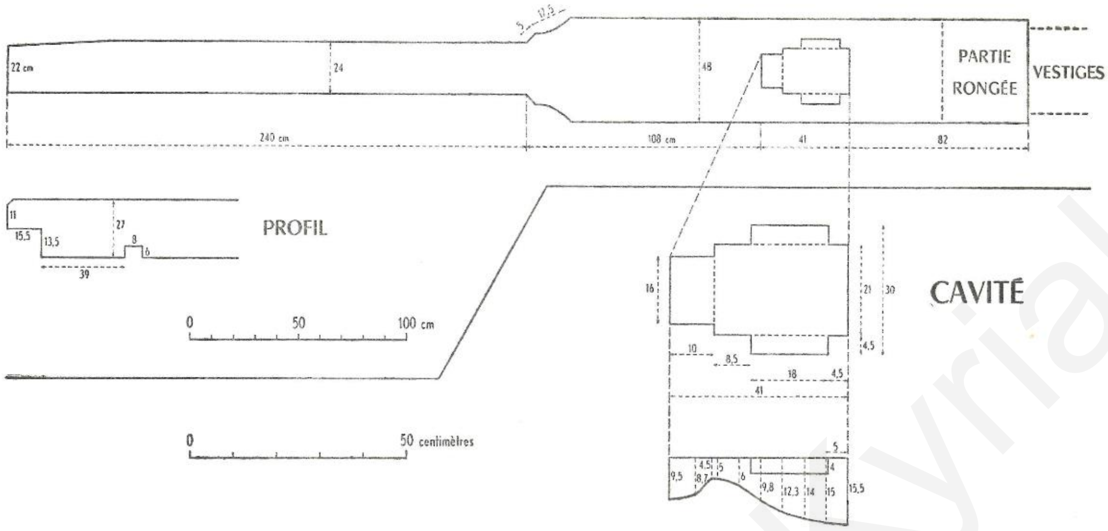


Figure 20: The Chrétienne A mast-step (After Dumas 1964: 124, fig. 14).

On the under surface, the narrower part of the mast-step timber (northern extremity) is placed on rabbeted floor-timbers, but in its widest (southern extremity) it is the mast-step itself which has notches on the underside, in order to allow ten of the floor-timbers, distanced 39cm apart from each other, to pass through (Basch 1973: 333; Gennette 1983: 26, 77).

As the Chrétienne A hull has not been fully excavated, it has yet to be ascertained which of the extremities of the vessel is the bow and which the stern and for this reason the position of the mast-step into the hull remains uncertain. Dumas (1974: 166-167) made an attempt to identify the orientation of the hull, based on the curvature of the main cavity, and wavered among three possibilities:

- The mast-step was intended to receive a single mast and was located at the central part of the hull. This possibility would not provide any information about the vessel’s orientation.
- The mast-step was intended to receive a single mast, which was located at the front part of the ship (so the northern part of the wreck corresponds to the bow)
- The mast-step was intended for one of the masts of a two-masted ship, and as such it may well correspond to either the front mast or a rear mast.

Casson (1971: 208) slants towards the hypothesis that the mast-step is located towards the stern of the hull, and definitely not amidships. If this is true, the mast-step was intended to receive a *mizzenmast*, that is a third mast placed at the vessel’s stern to further improve maneuverability (Casson 1971: 243; Whitewright 2016: 881). If this is the case, then this is the first archaeological evidence of a mizzenmast in antiquity.

S009. Cavalière (110-90 BC), Le Levandou, France

A 3,5m long mast-step was preserved within the Cavalière's hull. Its rather peculiar form is an almost rectangular shape, beginning with a width of 18cm and a height of 16cm from the floor-timber 41 and moving on to floor-timber 31 to a width of 26cm and the height from 15-21cm (**Fig. 21**) (Liou 1975 591; Charlin *et al.* 1978: 74). The effects of teredo navalis caused major erosion to the mast-step timber, damaging much of it. Thus, the reconstructed total length was based on the cut rabbets on the upper side of the frames and estimated of being 7.5m. On the upper side, the main cavity for receiving the mast resembles a square shape (10,5cm long,10,5cm wide, preserved depth of 3cm and restituted depth of 7cm or 9cm) and internally has a "half-bowl" cross section (Geannette 1983: 18; Charlin *et al.* 1978: 74, 77). The two parallel mortises on either side reflect an arrangement already seen on previous mast-steps, serving to stabilize the mast (Charlin *et al.* 1978: 74). Their depth (7cm) is almost double in comparison to the equivalent parallel mortises of the Kyrenia's mast-step, for a cavity of only two-thirds the area (Geannette 1983: 18). In a distance of circa 3cm there is a second, badly eroded, also symmetrical cavity (10cm long and 10cm wide, with a conserved depth of 2cm) (Liou 1975: 591; Charlin *et al.* 1978: 77). Similarly to other cases (S003), when the descriptions of the mast-step were published (Liou 1975; Charlin *et al.* 1978), the second cavity was hardly defined. The analysis as part of the present study demonstrates that the second cavity was likely intended for a stanchion pole.

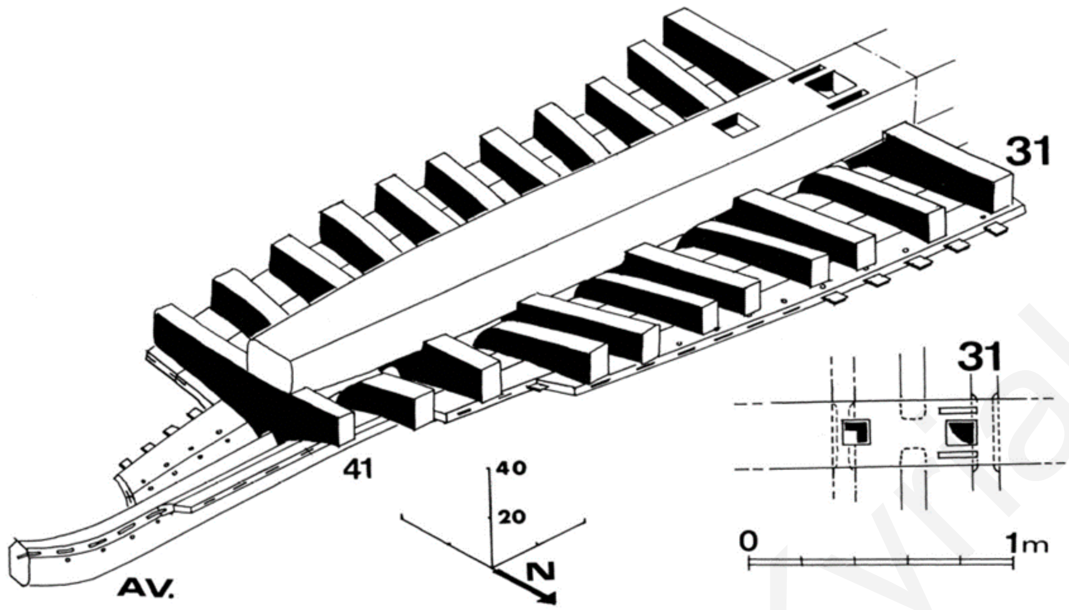


Figure 21: Axonometric view of the Cavalière mast-step (Charlin et al. 1978: 75, fig. 52).

The mast-step was found in the front part of the ship, set in between the alternated floor-timbers and half-frames. Its underside has notches, 27cm apart to each other, in order to be placed on the back of the floor-timbers. (Liou 1975: 591; Geannette 1983: 18).

2.4 Roman Period (50 BC – 3rd century AD)

S010. Madrague de Giens (75-60 BC), Giens peninsula, France

The largest ancient shipwreck that has hitherto been excavated in the Mediterranean provides the first archaeological evidence of a two-masted sailing ship.

The mast-step (**Figs. 22 and 23**) (4m long, 55cm wide, 45cm high), made of oak, was found to the west part of the wreck and it was set over the alternated floor-timbers and half-frames (Liou 1975: 588; Tchernia *et al.* 1978: 83; Pomey 1978: 89 Geannette 1983: 26). Seven frames, from M100 to M116, have a rabbet on their upper surface (55-57cm long, 2-3cm wide and 5cm in height) to receive the mast-step timber. The rabbets are cut on the edges of each frame in such a manner that they face each other. The mast-step on its underside has eight notches, 5cm apart, so that it could be placed on the floor-timbers. At intervals of these notches, the timber is chamfered in the arc of a circle in order to allow the half-frames to pass (Tchernia *et al.* 1978: 83; Geannette 1983: 27).

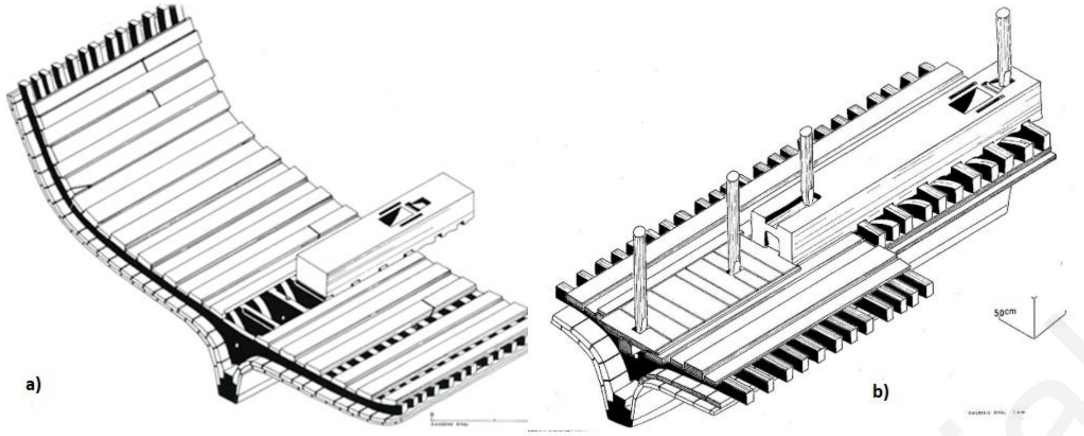


Figure 22: Madrague de Giens: a) General and b) axial axonometric view. Note the insertion of the mast-step on the alternated floor-timbers and half-frames and the notches to be placed on them (Pomey 2020: 35, Fig. 3.8 and 3.9).

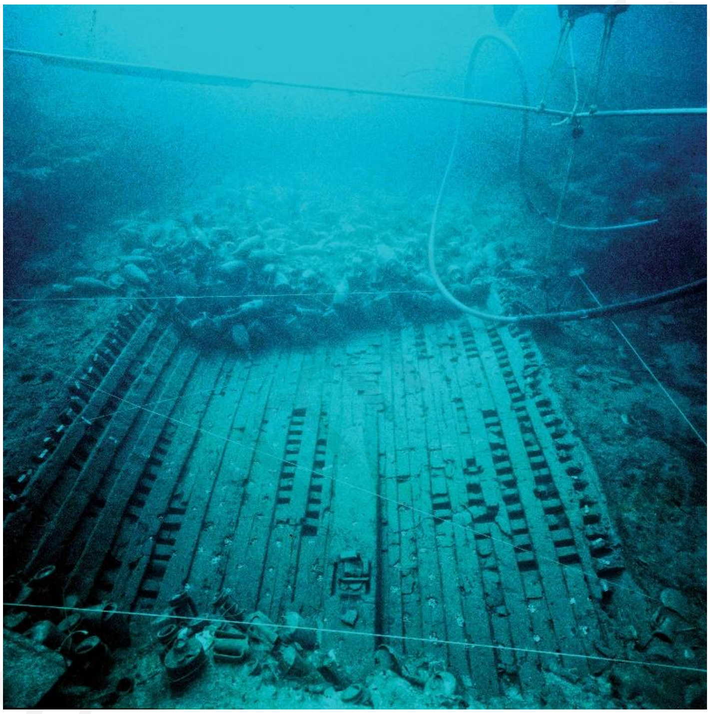


Figure 23: The Madrague de Giens mast-step, in situ (Pomey 1978: 87).

Regarding the upper surface, a series of five cavities is located 2,85m from the west extremity of the mast-step (**Fig. 24**). The main cavity (41cm long, 25cm wide and 24cm deep) has two parallel long mortises on either side (39cm long, 4cm wide and 10cm deep). Two other cavities are spaced about 6cm from the main one; these two cavities are located exactly adjacent to each other, with no space between them. Although they are of different size, (the first is 8cm long, 23cm wide, 6 cm deep; the second one is 20cm long, 12cm wide, 7cm deep), they have the same profile and their orientation is inversed in comparison to the principal cavity (Tchernia *et al.* 1978: 96) (**Fig. 24**).

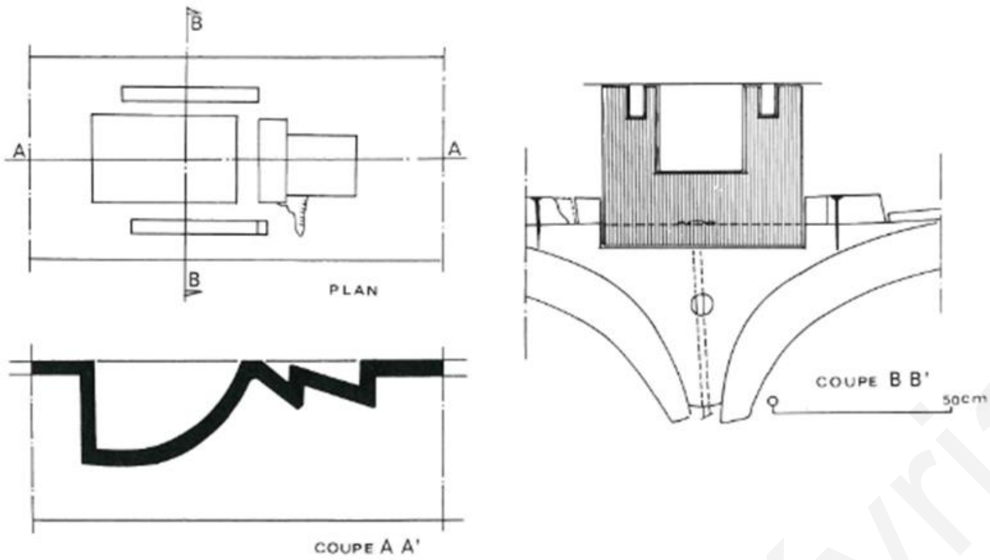


Figure 24: Plan and sections (AA', BB'), depicting the layout of the cavities of the Madrague de Giens mast-step (Tchernia et al. 1978: 97, Fig. 13).

To the east part of the wreck, the mast-step is joined with a keelson (19cm wide and 15,5cm high), which is extended aft of the mast-step. The keelson is also curved on its underside to be placed over the floor-timbers which, however, are not rabbeted. Both the mast-step and the keelson contributed to the longitudinal connection and stability of the floor-timbers (Tchernia *et al.* 1978: 84; Pomey 1978: 89).

On the front extremity of the mast-step timber, a smaller cavity was detected. It was presumably intended to receive a vertical post on which an *artemon* mast was placed. This mast, when titled, could be placed on the deck (Pomey 1982: 141-142; Geannette 1983: 27; Liou & Pomey 1985: 561-562) (**Fig. 25**).

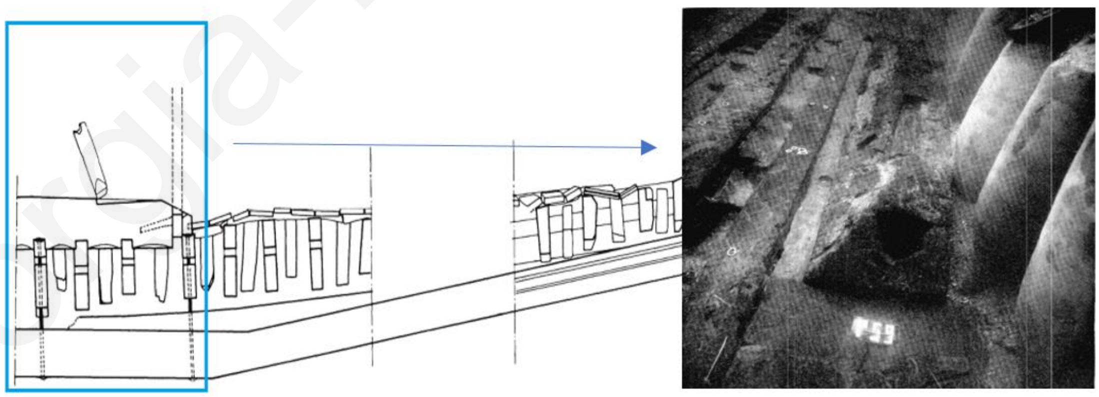


Figure 25: Madrague de Giens's artemon mast-step. Note the cavity on the front part of the mast-step (Pomey 1982: 143, Fig. 7; Liou & Pomey 1985: 561, Fig. 14b).

S011. Plane 1 (mid-1st century BC), Marseilles, France

The Plane 1 shipwreck was only partially excavated. The mast-step (4.2m long, 22cm high and 30-14cm wide) was amongst the few parts of the hull that were recorded, drawn and published (Charlin *et al*. 1978: 76-77; Geannette 1983: 37, 39-40; Liou & Pomey 1985: 556). The keel is missing, possibly lost during the sinking (Pomey & Boetto 2019: 39), thus the position in which the mast-step was found is not the original one.

On the upper surface, the main cavity (14cm long, 10cm wide and 11cm deep) is flanked by two parallel mortises on either side (12cm long and 2.5cm wide), and a perpendicular groove exactly next to it (6cm long, 12cm wide and 4cm deep); this groove has the inverse orientation of the main cavity, in a similar manner to the aforementioned mast-step (S010). A third cavity (10cm square and 6cm deep) is located 12cm forward from the other cavities, probably intended for a stanchion pole. On its underside, the mast-step has notches (50 cm apart) in order to precisely fit on the framing.

The most intriguing fact regarding the mast-step timber is that it would become narrower - its width gradually decreasing from 30 to 14 cm – towards the front part of the ship, and not towards the aft, which is usually the case (Geannette 1983: 37-39). This is inferred by the curvature of the main cavity and the reverse groove in front of it, which is a clear indication of the orientation of the mast-step. Unfortunately, since the mast-step was not found *in situ*, the orientation that the vessel would have had is unknown.

By closely inspecting the plan (**Fig. 26**), one can count a total of seven notches and one “half” on its one edge (probably the aft one), planned to fit with the consequent number of frames. Based on the distance between the notches and in accordance to the plan and the scale depicted (**Fig. 26**), it can be deduced that the preserved length of the mast-step was just over 4 metres, so its original length could have reached 5 metres.

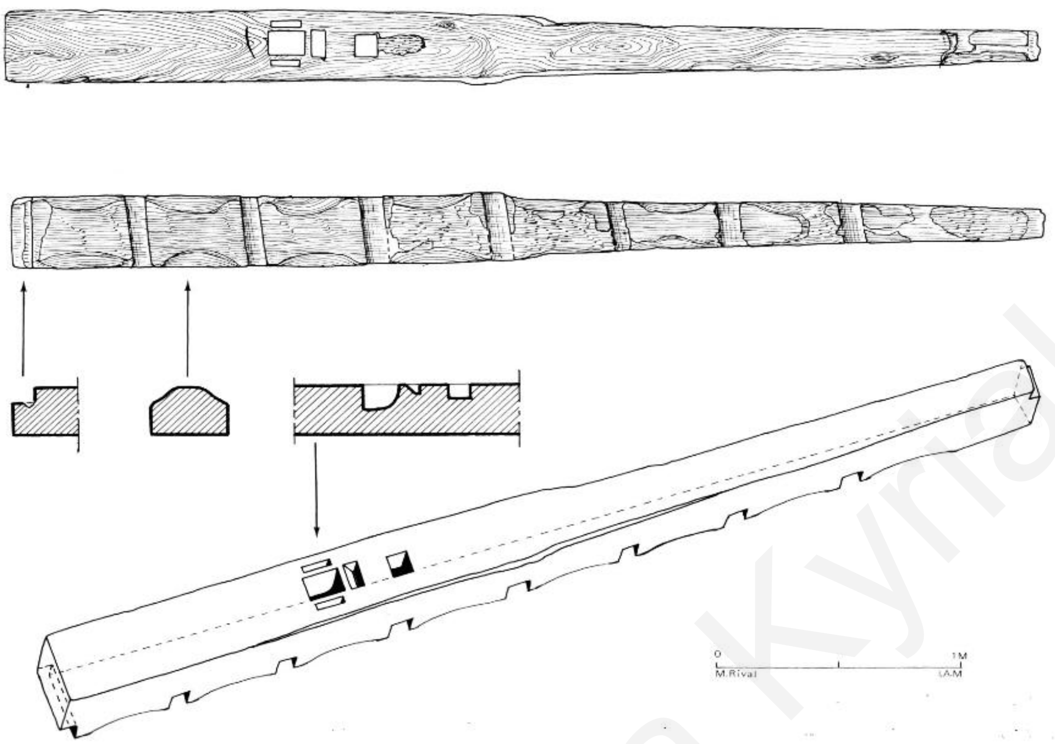


Figure 26: Plane 1: The mast-step schematic (Charlin et al. 1978: 76).

S012. Cap Béar 3 (50-25 BC), France

Very little is known regarding the Cap Béar 3 mast-step. It was discovered in place, with a preserved length of 3.24m and a narrowing width from 20cm in its southern part to 13cm to its northern one. It is placed directly on the floor-timbers through the notches on its under surface and rabbets on the back of the frames. As its upper surface was badly preserved, the pattern of cavities for the mast fixation could not detected. The mast-step is extended by a small keelson (1.50m long, 12cm wide and 7cm thick) towards its northern part (Marlier 2005: 298; Pomey & Boetto 2019: 36).

S013. Cap del Vol (end of the 1st century BC – beginning of the 1st century AD), Catalonia, Spain

The Cap del Vol's keelson/mast-step (9.2m in length, 12cm in height and ranged from 22 to 38cm in width) was not found intact but broken on its one edge, due to the action of looters. It was constructed from an entire pine tree trunk, which justifies its considerable size and the tapering in its width (from 22cm to 38cm). The length (reconstructed to 9.5m for a boat of a total length of 18m), as well as the form of the mast-step timber, led scholars to interpret it as a keelson (Foerster 1980: 247; Geannette 1983: 27, 31).

Regarding the upper surface of the keelson/mast-step, the arrangement of the mortises related to the mast support system begins at 7.15m from the aft end of the timber, at the point where the width from 17cm starts to widen until it reaches 34cm. It consisted of the main cavity (14.5cm long and 9.5cm wide), two parallel narrow mortises (13cm long and 3.5cm wide) and a fourth one slightly forward and transversally to the others (4.5cm long and 15cm wide). Inside the main cavity, the southern plane is vertical and the northern one is inclined, suggesting that the southernmost part of the vessel is the stern and the northernmost one is the bow. An opposite arrangement is observed to the transverse mortise, where the northern surface is vertical and the southern one (i.e. the point directed towards the aft) is inclined (Nieto 1982: 165; Geannette 1983: 31; Vivar *et al.* 2014: 99) (**Fig. 27**).

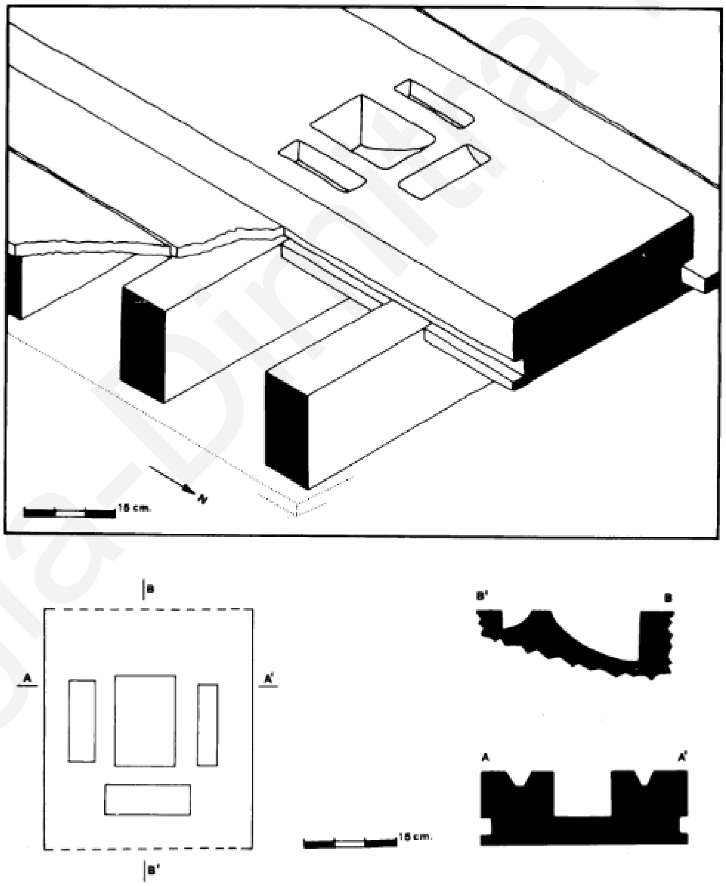


Figure 27: Plan and sections of the Cap de Vol keelson/mast-step, at the point of the cavities for the mast (Nieto 1982: 166, Fig. 1).

A series of notches are cut on the underside of the keelson/mast-step, with a distance of 19 cm between them, in order for it to be fixed on the alternated half-frames and floor-timbers (Foerster 1980: 247; Nieto 1982: 167). Although it was fastened neither to the frames nor to the keel, any upright or longitudinal movement was prevented by firstly, the great distribution of different forces coming from the mast across the boat (Nieto 1982: 167) and secondly, by the ceiling planks which were nailed to the frames on each side of the keelson/ mast-step (**Fig. 27**). The mortise which is located at the very rear of the keelson was intended for a mast *crutch* or a stanchion (Geannette 1983: 31, 34).

The Cap de Vol keelson/mast-step is an excellent example of the combining of two different elements in the ship's construction that merge into one but continue to act as before; as the step of the mast but also as an elongated timber which reinforced the longitudinal structure of the hull.

S014. Diano Marina (25-75 AD), Liguria, Italy

The keelson/mast-step of Diano Marina shipwreck was badly preserved due to the extensive erosion caused by teredo navalis, which prevented it from being sufficiently studied and interpreted. The surviving timber preserves the arrangement of the cavities for the mast installation.

Firstly, what little is known concerning the principal dimensions of the keelson/mast-step, is mainly provided by the published plan (**Fig. 28**). The overall length is not possible to be measured, but the width is 25cm and the height is about 44cm. The main cavity was 37cm long and 36-38cm wide (Dell'Amico & Pallarés 2005: 71, 75; Marlier 2008: 157). The dimensions of the adjacent cavities are unknown.

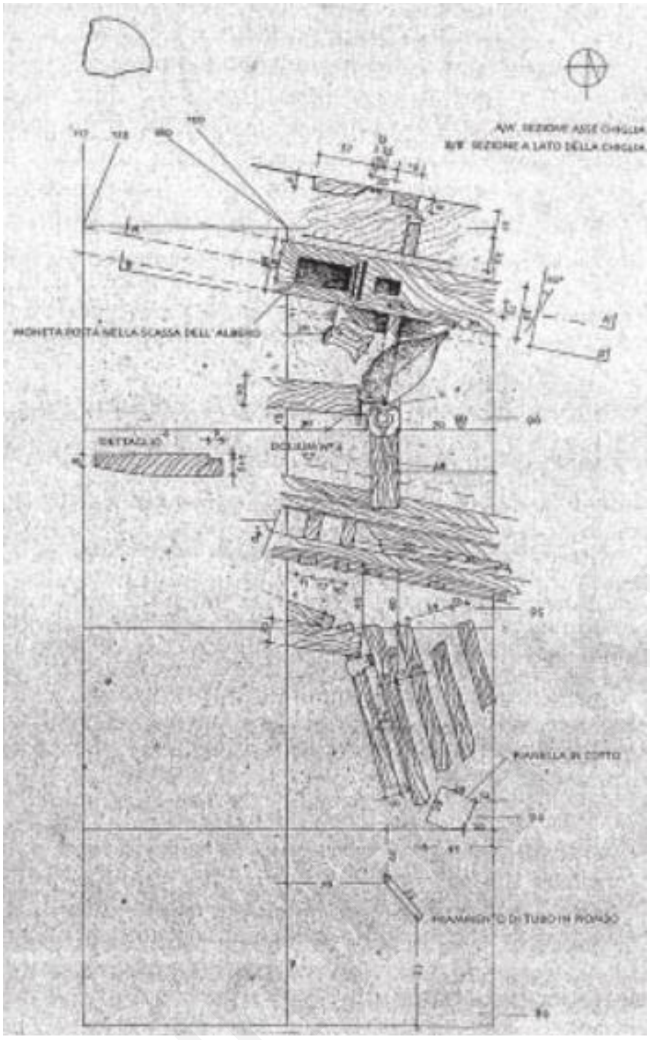


Figure 28: Plan and longitudinal section of Diano Marina (Dell' Amico and 2005: 72, fig. 4).

Based on the published figure, scholars were able to extract some additional information regarding the mast-step and its placement into the hull. The mast-step was wedged on the floor-timbers, and this is nothing new; what is surprising is the fact that the notches of the joint are as high as the floor-timbers themselves (the overall height of the mast step would be 44 cm), so the underside of the mast-step timber seems to be in direct contact with the upper side of the keel. Such an arrangement of the mast-step timber may prevent the flow of bilge water into the central area of the ship (where the main cargo would have been located), as would the lateral *limber holes* as well. If the above are correct, this mast-step would constitute, at the moment, a unicum (Dell'Amico & Pallarés 2005: 71). What is not specified in the publications, however, is whether the mast-step was embedded directly on the floor-timbers or indirectly with the assistance of a pair of sister-keelsons (Marlier 2008: 157).

S015. Caska 2 (1st century BC – 1st century AD), Pag Island, Croatia

The pinewood-made keelson/mast-step (6.75m long, 15cm wide and 11,5 -14cm high) was found in place, as part of a very well-preserved hull. It was placed on the frames, from F15 to F28.

At its central part the timber is wider (20-22 cm) and rectangular, at the point of the frames F21 and F22, where the cavities arrangement is located. The main cavity for the mast is rectangular (15-15.5cm long, 8-9cm wide and 5,5cm deep) and has the inclined plane towards the bow. It is flanked by two parallel mortises (17cm long, 2-3cm wide and 2-2.8cm deep) and one forward (17,5cm long, 3.8cm wide and 2cm deep), which serve to house the mast-partners. At a distance of 26cm from the main cavity, towards the stern, two quadrangular mortises (5.7x 5.1cm and 5.6x4.7cm; 2-2.8cm deep) are cut to house the stanchions, which reinforced the supporting of the mast (**Fig. 29**).

Figure 29: Caska 2: The main and the adjacent cavities for the mast, and the mortises for stanchions on the keelson/ mast-step (Rossi & Boetto 2020: 24, fig. 28c).

The notches on the underside of keelson/mast -step vary in shape and in depth (from 2 to 8cm) in order to accurately match with the rabbets (1–2cm deep) cut on the upper part of the frames (Boetto & Rossi 2015: 285; Rossi & Boetto 2020: 18).

S016. Sud-Lavezzi 2 (mid-1st century AD), Lavezzi reef, France

The mast-step was found underwater damaged, broken in several places and moved from its initial position. An attempt was made to retrieve the piece from the site, in order to be further studied but during its ascent, it was swept away and almost completely dissolved (Liou & Domergue 1990: 121) (**Fig. 30**). The preserved timber (5.50m long, 30cm wide and maximum 15cm high) has been characterized by scholars as a relatively thin mast-step timber; this statement is disputable, due to the bad preservation of the timber. The probable mast cavity (13cm wide and 6cm deep) is located 2.15m from the fore and 3.20m from the aft end of the preserved mast-step timber. The exact length of the main cavity is unknown, although it must have been greater than 15cm. Liou & Domergue (1990: 115) argued that the mast-step would had originally been a square piece of wood of an unsophisticated form, embedded on the frames.

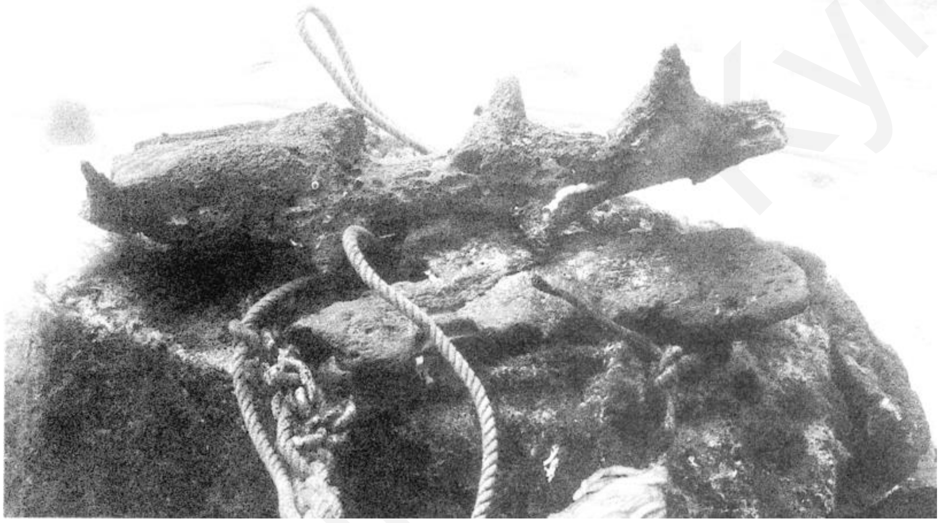


Figure 30: Fragments of the Sud-Lavezzi 2 mast-step deposited at the site, after its surfacing attempt. The overturned piece is the one that contains the probable mast cavity. Note the notches for the placement on to the frames (Liou & Domergue 1990: 116, fig. 86).

S017. Rabiou (50 AD), Saint-Tropez, France

The mast-step timber of the Rabiou shipwreck was found intact and in a very good state of preservation. It is 4.20m in length, made up of two portions of different widths (a front part of 30cm wide, over approximately 2.50m, and a rear part, 16cm to 18cm wide, over approximately 1.60 m). Various notches are cut on the underside of the timber to fit on the floor-timbers (Joncheray & Joncheray 2005: 91-92). It seems that the cavities for the supporting of the mast are located to the forward end of the mast-step. The main cavity is flanked by three mortises, which were intended to receive the mast-partners (**Fig. 31**).

Figure 31: Detail of the Rabiou mast-step. Note the arrangement of cavities (Joncheray & Joncheray 2005: 91, fig.74).

S018. Calanque de l' Âne (end of the 1st century AD), Marseilles, France

The Calanque de l'Âne shipwreck presents complex longitudinal elements of a robust construction. Two lateral sister-keelsons (11.68m long, 11cm wide and 9.5cm high), both made of oak, support a keelson/mast-step (9.10m long, 42cm wide and 29cm high). The sister-keelsons are cut on their underside in order to fit on the frames and are nailed at their ends, thus reinforcing the attachment to the hull (Ximénès & Moerman 1998: 299). The main cavity has two parallel elongated mortises on either side, to house the mast-partners, as well as two mortises for stanchions on either side of the mast base, in the longitudinal sense (Ximénès & Moerman 1998: 300).

The entire complex of the keelson/mast-step and the sister-keelsons is buttressed by two elements with a triangular profile, which also rest on the sister-keelsons. These pieces, also made of oak, have their highest end on the side of the keelson (120cm long, 31 to 32cm wide and 14cm high to the side of the sister-keelson) and are nailed at their ends on the frames. Each buttress element is pierced by a circular mortise (10 to 11cm in diameter) for the insertion of a stanchion pole. The stanchion poles would have been of smaller diameter than that of the mortise, as no indentation marks were left on the buttresses. They are located 15cm from the sister-keelsons (**Fig. 32**). These buttress elements are unprecedented in ancient naval architecture. Their presence can be associated with the great robustness of the ship, which would probably provide additional support on the mast-step's point. No comparable example has been found on other known ancient wrecks (Ximénès & Moerman 1998: 299- 300).

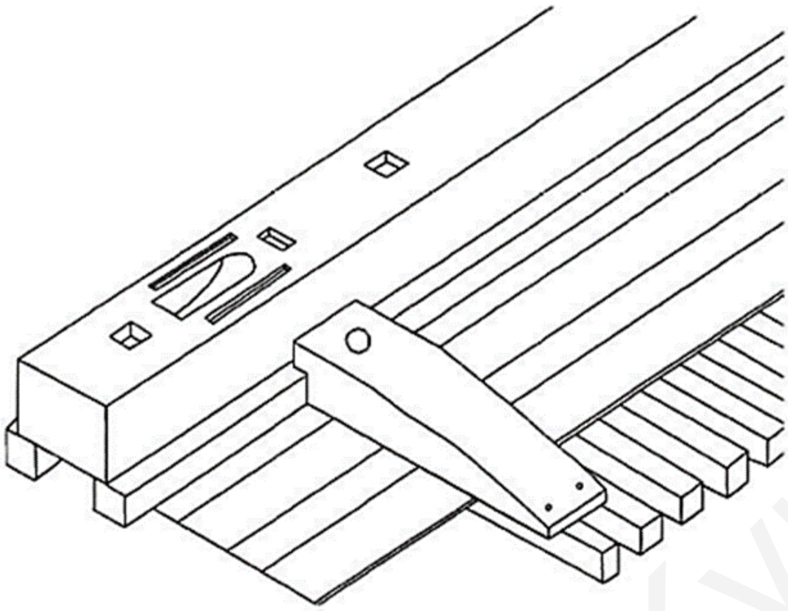


Figure 32: Axonometric view of the Calanque de l'Âne keelson/mast-step and adjacent pieces (Ximénès & Moerman 1998: 302, fig. 3).

<u>S019. Napoli A (end of the 1st century AD), Naples, Italy</u>

The 5.63m-long keelson/mast-step narrows as it proceeds towards the aft, varying both in width (24cm to 20.5cm) and in thickness (9cm to 12.5cm). It is placed parallel to the keel and rests on the back of twenty-seven frames (M14 to M40, from stern to bow) (**Fig. 33**). In order to fit on them, its lower surface is notched with corresponding rectangular recesses, between 8 and 13 cm wide and 2.8cm high on average (between 2cm and 4.5cm).

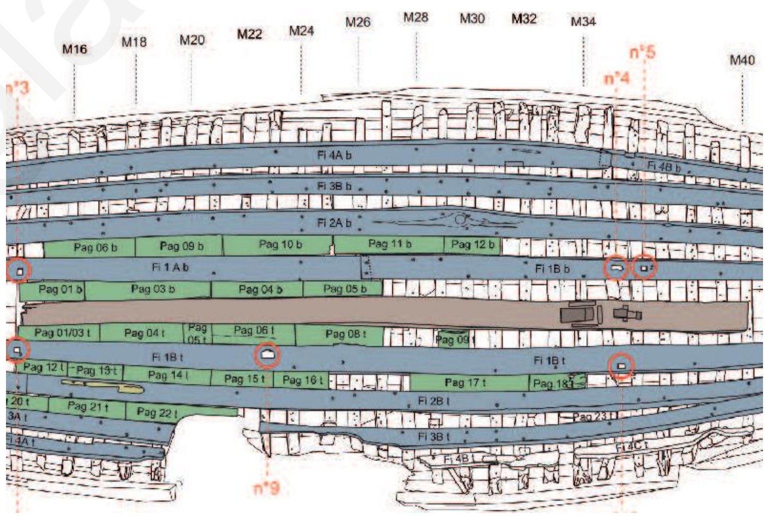


Figure 33: Detail of the Napoli A hull plan. Note the keelson/mast-step and its placement on the frames (Boetto & Poveda 2018: 34, fig. 25).

On the upper side, towards its front end, the timber presents five recesses. At the level of frame M34, the largest cavity (25.4cm long, 10cm wide and 6cm deep) was intended to receive the foot of the mast and has the characteristic side sloping towards the bow, for the lowering of the mast. Two parallel mortises (20cm long, 3cm wide and 1.5cm deep) and a third one (14cm long, 2.3cm wide and 1.8cm deep) slightly forward to the main cavity were intended to house the mast-boards, creating a frame for the base of the mast (Boetto & Poveda 2018: 33).

At the level of frame M36, a mortise of a faintly cruciform form (length 21.7cm, maximum width 12.7cm and depth 4 to 5.8cm) was intended to accommodate a stanchion pole (Giampaola *et al.* 2005: 68; Boetto & Poveda 2018: 35) (**Fig. 34**).

Figure 34: The notches on the upper face of the Napoli A keelson/ mast-step (Boetto & Poveda 2018: 35, fig. 26).

Towards the stern, the keelson/mast-step has on either side an additional level of planks, which are laid on the ceiling, on either side of the keelson/mast-step (Boetto & Poveda 2018: 33).

S020. Grado (117 - 150 AD), Adriatic, Italy

The shipwreck is also named «Julia Felix» but has prevailed as Grado shipwreck. The keelson/mast-step (8.02m long and 30cm wide) (**Fig. 35**) of the Grado shipwreck is embedded on two lateral sister-keelsons (6.5m long). Five notches of a quadrangular section (5-6 x 6cm) are curved on its underside in order to fit on the frames. Inside the second and fourth notch, small wooden elements were found, which have been interpreted as "stoppers" to prevent any longitudinal movement. The presence of only two such wooden elements has led scholars to suggest that either the keelson could be moved along the ship's axis, or it was retrieved from another vessel and reused.

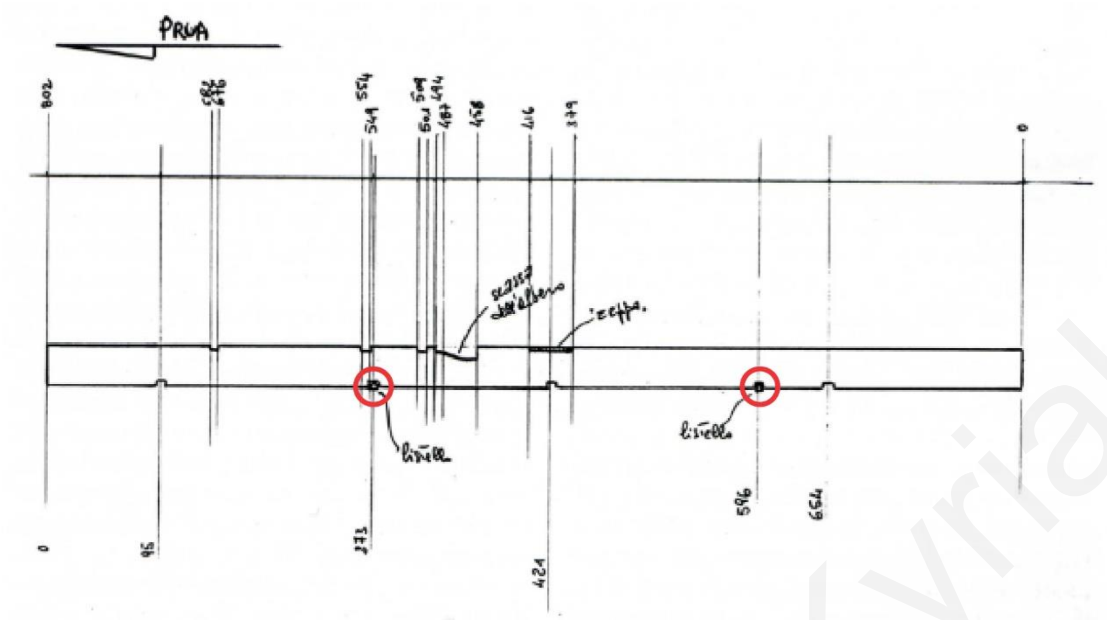


Figure 35: The Grado keelson/mast-step. Note the wooden elements in the second and fourth notch on its underside (based on Dell' Amico 2001: 39, fig. 4).

The sister-keelsons are also notched on their underside to be fitted on the frames, but they are also joined to them by metal nails. The cross-section represents a T-shaped keelson/mast-step - the first appearance of such a form (Dell' Amico 1997: 111-112; 2001: 39-40; Beltrame & Gaddi 2007: 138-141).

S021. Saint-Gervais 3 (mid-2nd century AD), Golfe de Fos, France

The Saint-Gervais 3 shipwreck presents a mast-step and a keelson of a totally different concept to the cases so far examined. The long mast-step timber is installed above a large keelson (10.5m long, 47cm wide and 27cm thick) which, in turn, is fitted onto a pair of sister-keelsons (18–20 cm wide and 11–13 cm thick). It is a unique example of a mast-step as an element independent of the keelson (Pomey *et al.* 2012: 240) (**Fig. 37**).

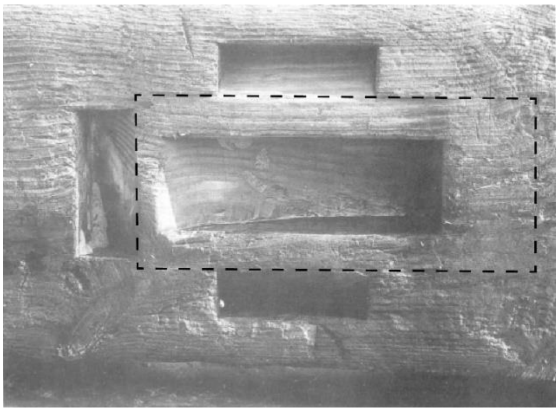


Figure 36: The Saint-Gervais 3 mast-step: the arrangement of cavities. Adjusted to note the footprint of the mast (dashed-lines) (based on Liou et al. 1990: 243, fig. 109).

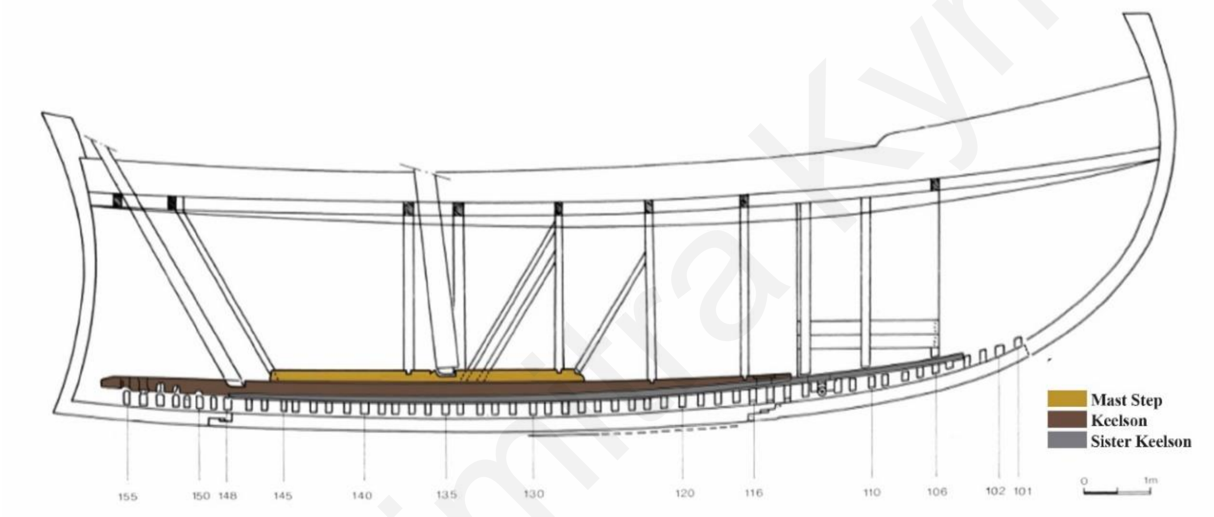


Figure 37: The Saint-Gervais 3 longitudinal section (based on Liou et al. 1990: 85, fig. 223).

The mast-step (4.80m long, 38cm wide, 21cm thick) extends from frame M127 to frame M145 (from stern to bow) and is located to the front part of the vessel. The arrangement of the cavities is located to 2.45-2.80m before the end of the mast-step timber, at the point of frames M135-M136. The main cavity (30cm long, 10cm wide, 9cm deep), which was intended to receive the mainmast, has the usual form of a right angle towards the rear and a rounded one towards the front. It is flanked by three mortises for the housing of the mast-partners. The footprint of the mast (30cm long and 17.5cm wide), which is of rectangular section, is preserved and it is longer and wider than that of the tenon which entered the cavity (Liou *et al.* 1990: 234, 237) (**Fig. 36**). The mast-step is secured on the keelson by a series of sixteen keys (18cm long, 10cm wide and 6mm thick) on its underside, joined with the corresponding mortises along the upper surface of the keelson. A large tenon of a square section (18cm and 2cm thick) corresponds to a mortise of the same section and of the same depth on the upper surface of the keelson, with the result of further strengthening the attachment between the latter and the mast-step. All these adjustments are extremely precise (Liou *et al.* 1990: 240).

The pinewood-made keelson is a large timber (10.5m long, 47cm wide and 27cm thick), which extends from the first preserved floor-timber M155 to the floor-timber M115, about 4m below the preserved end of the hull. Its upper surface is totally flat and at 1.40m from its front end presents a cavity (30cm long, 10cm wide) with a rounded slope towards the bow and a right-angled towards the stern (10cm in depth). Thus, this cavity is similar in shape to that which was destined to receive the mainmast and, according to Liou *et al.* (1990: 245) is undoubtedly the step of an *artemon* mast (**Fig. 38**).

Figure 38: The mast-steps of Saint-Gervais 3. Note the similarity for the stepping of the masts (Gassend et al. 1986: 25, fig. 10).

Additionally, the keelson has the aforementioned mortises, for the purpose of placing the mast-step timber (**Fig. 39**). Several mortises for the stanchions are cut along the upper side of both longitudinal timbers (Liou *et al.* 1990: 240, 245; Pomey *et al.* 2012: 241).

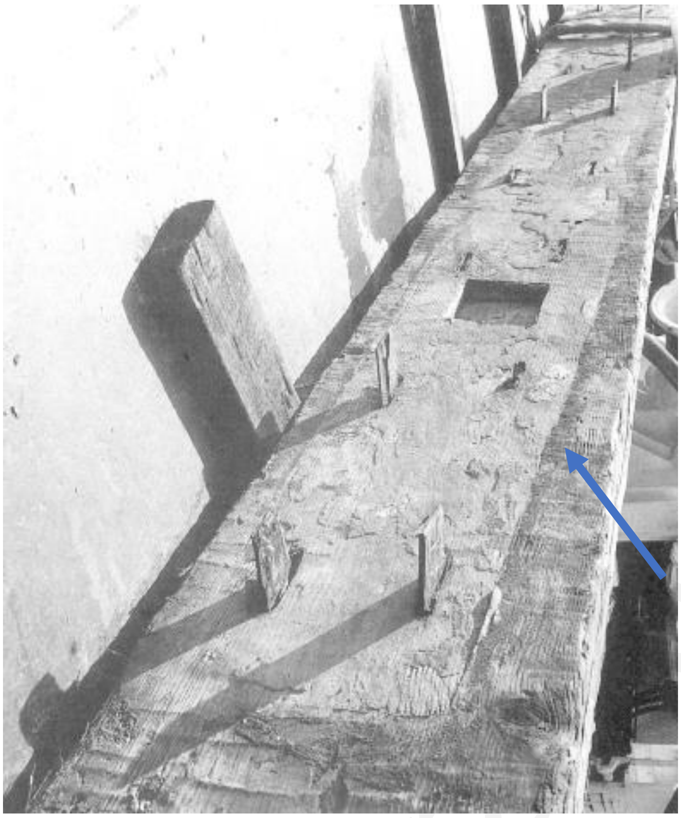


Figure 39: The upper side of the Saint-Gervais 3 keelson. Note the area of contact with the mast-step, of which the imprint is visible (blue arrow) (Liou et al. 1990: 249, fig. 118).

Towards the stern, the sister-keelsons are curved to a crescent shape, in order to permit the placement of a *bilge pump*. Stringers on each side have mortises for stanchions, also related to the system of the bilge pump (**Fig. 40**).

Figure 40: Saint-Gervais 3: View from the back but towards the front of the ship's axis, the location of the bilge pump (Liou et al. 1990: 244, fig. 111).

S022. Laurons 2 (end of the 2nd – 3rd century AD), Golfe de Fos, France

The Laurons 2 keelson/mast-step has been reconstructed to a 7.75m long timber, which was installed on a pair of sister-keelsons (**Fig. 41**). The preserved timber (5.20m, 22cm high and 26-28cm wide) was found bottom-side-up across the hull, due to the wrecking event (Gassend *et al.* 1984: 100; Pomey *et al.* 2012: 242).

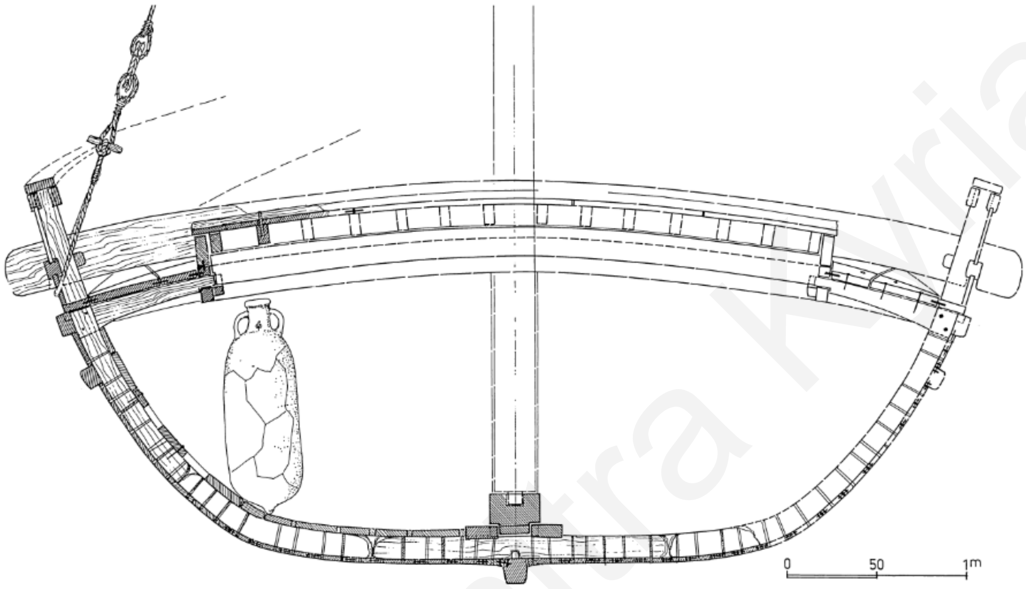


Figure 41: Laurons 2: Cross section amidships. Note the placement of the mast-step onto the sister-keelsons (Gassend et al. 1984: 94, fig. 17c).

On its upper surface, 2.60m from the front edge of the mast-step timber, the cavities arrangement for supporting the mast is detected. It consists of the main cavity for the mast (21cm in length, 8cm in width and maximum 6cm in depth), with the inclined plane towards the front part and the straight one towards the aft part of the vessel, as well as the adjacent mortises for the mast partners (14cm wide).

Regarding its underside, the mast-step has notches (5cm by 6cm in section) in order to fit on the sister-keelsons. Furthermore, on the front third, the timber is staggered in such a way to fit precisely on the back of half-frames (**Fig. 42**). The rectangular section of the mast-step becomes thinner at this point, with no more than 8cm in height at its end. Three notches (at the level of M114, M127 and M136) are curved in such a manner to fit into transverse braces, connecting the two sister-keelsons. All these notches on the underside of the mast-step made it possible to understand its initial position and to graphically reconstruct it.

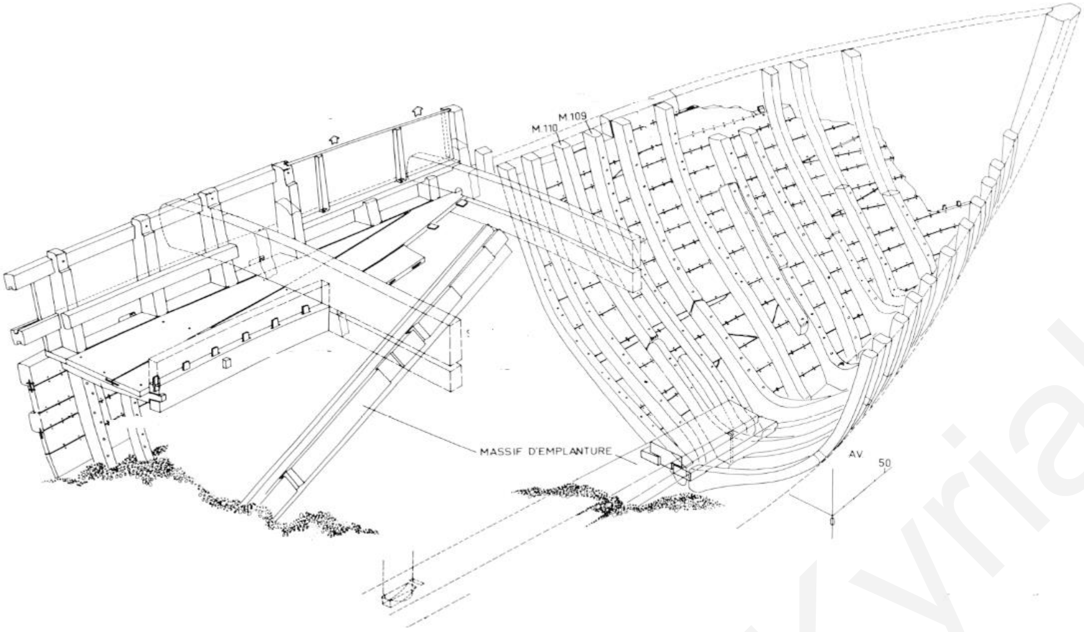


Figure 42: Axonometric view of Laurons 2 ship. Note the shape of the mast-step on its underside (Liou & Gassend 1984: 84. fig. 12).

Sister-keelsons running parallel on either side of the keel, extend from frame M109 to frame M140. They were made of two pieces of wood, of trapezoidal section (7.9 m long, 15cm wide and 6cm to 10cm of a variable thickness). The undersides of the sister-keelsons have notches to fit on the backs of the half-frames (Gassend *et al.* 1984: 100).

S023. Fiumicino 4 (2^{nd} – 3^{rd} century AD), Rome, Italy

The pinewood-made mast-step (1,17m long, 14,6cm wide and 12cm high) was found in place, slightly forward towards the fore part of the hull. It presents a rather unsophisticated form, at least in comparison to other examples of the same period; the main cavity, intended to receive the mast, is accompanied only by a mortise towards the stern for the housing of a stanchion. The mast-step is flanked by two lateral elements and present two semicircular mortises in which the *bilge pump* (not preserved) would have been fitted (Boetto 2001: 124; Boetto: https://www2.rgzm.de/navis/Ships/Ship054/Fiumicino4engl.htm) (**Fig. 43**).

Figure 43: The Fiumicino 4 mast-step area (retrieved from the website).

S024. Conque des Salins (15-236 AD), Hérault, France

The Conque des Salins mast-step has a totally different form when compared to the other cases. It is not a longitudinal structure but a transversal one, composed of two timbers made of oak. In fact, the first one is a floor-timber, reinforced by a second timber which is joined to it with horizontal nails (2,4 cm in diameter), forming together this peculiar mast-step (Pomey *et al.* 2013: 435). An irregular square cavity (10cm by 12 cm) completely penetrates the frame, intended to house the foot of the mast. It is located exactly at the point where the keel (V6) is. A second rectangular groove (2cm by 6cm and 4cm deep) is cut on the parallel reinforcement timber, 30cm from the main cavity in the starboard side (**Fig. 44**). It is hard for someone to interpret this groove as the base of a stanchion pole due to, firstly the weakness of its section and secondly, the absence of a corresponding groove to the portside, the presence of which would reflect the existence of a deck (Jézégou 2011: 171; Jézégou *et al.* 2009: 81).

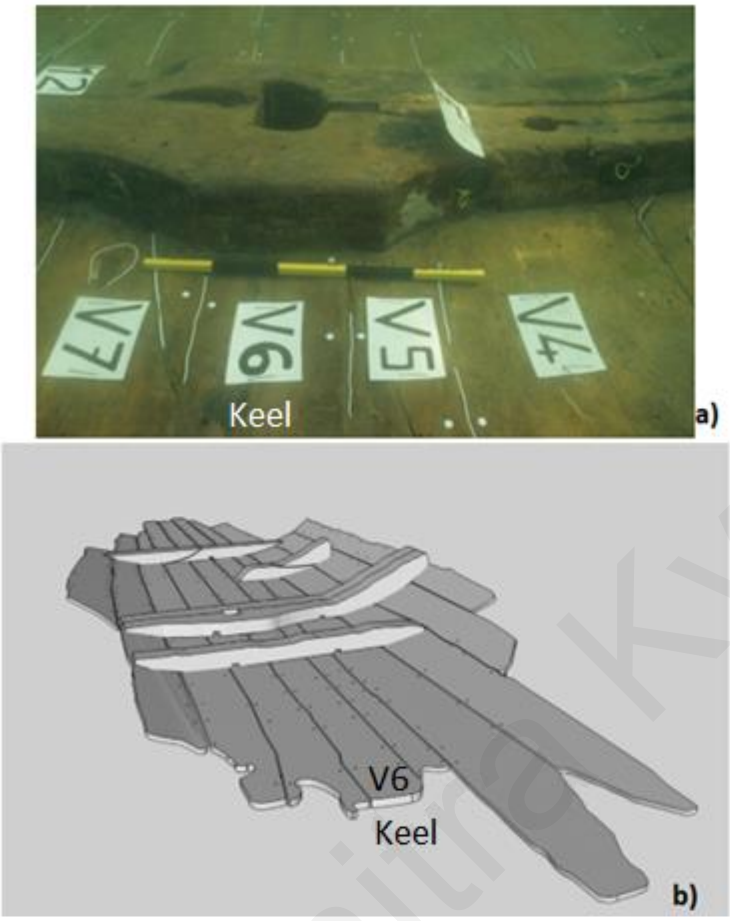


Figure 44: Condue des Salins mast-step: a) in situ b) axonometric 3D restoration (based on Jézégou 2011: 173, fig. 10; 174, fig. 12).

Mast-Step and Keelson

Before the affiliation of the mast-step in the Mediterranean shipbuilding traditions and the analysis of its chronological development, the distinction between mast-step and keelson and the interpretation of their relationship is of key importance for this study.

The significance of the mast-step lies in the fact that it is the point of connection between the rigging and the hull and in the evidence it reveals regarding the form and the function of an essential part for the sailing ships, i.e. the mast. The main role of the mast-step is to support the mast and secure it in place but is also used for the stanchions, i.e. the necessary poles for the supporting of the deck. The primary form of the mast-step, as evidenced from the Archaic period, comprises of a structurally isolated timber that is placed on the ship axis, which is slightly prolonged fore and/ or aft. Currently, the Bon-Porté 1 mast-step (S003, 540-510 BC) could be considered as the precursor of the later development.

The 'keelson' during the Archaic and Classical period is essentially a stringer that extends fore or/and aft of the mast-step, without any significant structural supporting role. The proper form of keelson as a continuous longitudinal timber placed on the ship axis, spanning over a large part of the vessel, appears during the Roman period. The large ship dimensions in this period most probably required a strong internal backbone that would reinforce the internal structure of the hull. A primary form of a keelson is already attested in the Gela 1 (S004), a shipwreck of a much earlier period (500-480 BC), demonstrating that the shipwrights conceived this idea and used this concept centuries before the Roman period.

The main discussion amongst scholars is focused on the point of change from the mast-step to keelson/mast-step. Starting from the end of the Hellenistic and the beginning of the Roman period (1st century BC), the distinction between keelson and mast-step becomes more difficult, given that the length of the latter considerably increases, while continuing to be more dimensioned at the point of cavities arrangement (Dell'Amico 2002: 176). Steffy (1990: 317) supports that the keelson was an uncommon element in the Mediterranean before the 2nd- 3rd century AD, considering the earlier form as an extended mast-step and not a proper keelson. It seems that other scholars also agree with this view (Tchernia *et al.* 1978: 83-84; Pomey 1978: 89).

Dell'Amico (2002: 176-177) opposingly, detects the occurrence of this element already in the 1st century BC.

Indeed, the first occurrence of this structural fusion can be seen in the Cap de Vol shipwreck (S013), dated to the turn of the millennium (Geannette 1983: 78-79). The mast-step and the keelson, both positioned at the same part of the hull, gradually merged into a single member (Geannette 1983: 75-76) and, consequently, the keelson became a component of multiple purposes, reinforcing the hull longitudinally and providing the necessary support to the mast.

Sister-Keelsons

During the Roman period, the concept of sister-keelsons, which were auxiliary elements placed alongside and on either side of the keel, also appears. They essentially function as intermediate structures between the keelson/mast-step and the frames. It stands to reason that the increase in the size of the keelson/mast-step would require additional longitudinal support that would reinforce the stability and structural coherence. The sister-keelsons remain parallel to each other by transverse braces distributed at regular intervals over their entire length (Gassend and Roman 2010: 76) (**Fig. 45**). These crosspieces also prevent the keel from breaking off from the hull (Gassend *et al.* 1984: 100). An earlier form of sisters is encountered in the Ma'agan Mikhael (S006, *c.* 400 BC), albeit not spanning the entire length, but located only on either side of the mast-step area.

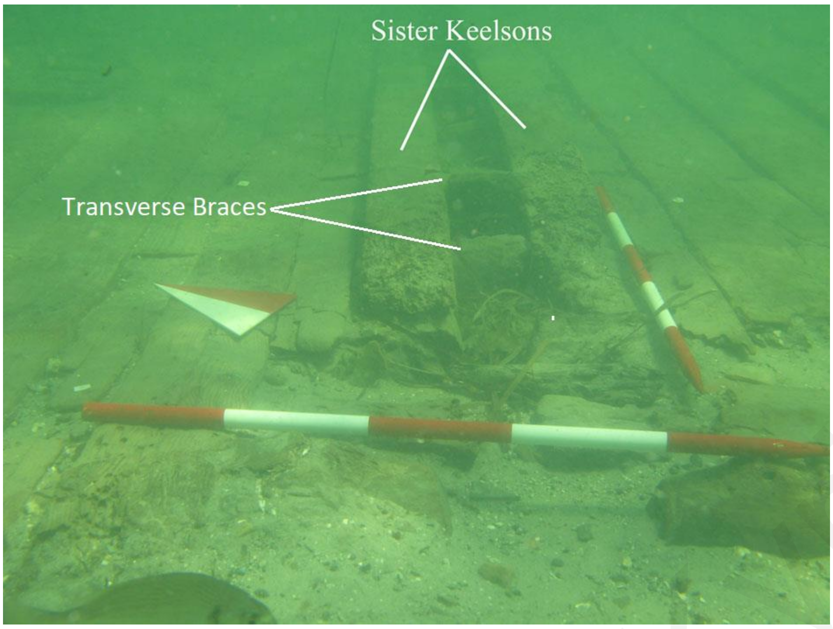


*Figure 45: Marausa shipwreck (**Table 6, No.8**). Note the pair of sister-keelsons, joined with transverse braces (based on Tiboni & Tusa 2016: 8, fig. 12).*

The Grado shipwreck (S020, 117-150 AD) is a great example of the occurrence of the sister-keelson system, spanning over a large part of the vessel. The Grado keelson/mast-step was curved on its underside in order to be rested over two sister-keelsons, which were also curved on the underside to be fitted on the frames. The result is a "T" cross-section of a keelson/mast-step and sister-keelsons (**Fig. 46**), noted in many shipwrecks from the 2nd century AD onwards (Dell' Amico 2011: 61).

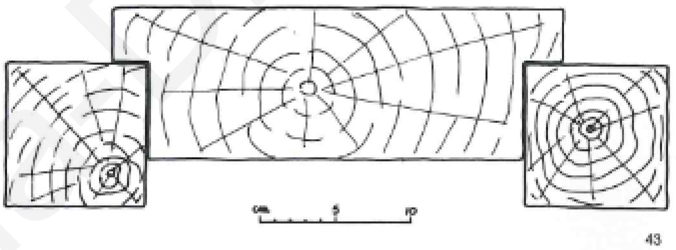


Figure 46: T-shaped cross-section (Dell'Amico 1997: 111, fig. 43).

Chapter 3: Shipbuilding Traditions

The maritime archaeological research during the last 30 years has shed light on the ancient Mediterranean shipbuilding traditions. Different traditions have been identified throughout the Mediterranean, based on the archaeological remains of vessels which present common structural characteristics and/or have the same origin. In some cases, the shipbuilding traditions are subdivided into architectural families, which include vessels of similar construction but of different type (for instance, small coastal boats and fluvio-maritime ships). From the 24 shipwrecks of the corpus, only 12 (50% of the total) have hitherto been classified into shipbuilding traditions (Pomey *et al.* 2012; Pomey & Boetto 2019). The following section is a first attempt to affiliate the mast-steps as a diagnostic structural feature with distinctive shipbuilding traditions. What follows concern a general morphological and conceptual evolution of the mast-steps.

3.1 The Iberian Tradition with Punic Influence

The earliest examples of seagoing vessels that preserve parts of their wooden hull in the Mediterranean, come from the Uluburun (*c.* 1320 BC) (Bass 1989; Pulak 1998; 1999) and Cape Gelidonya (*c.* 1200 BC) shipwrecks (Bass 1967; 1999). They demonstrate an early use of mortise-and-tenons joints, used on shell-first built vessels, and have been attributed to an eastern Mediterranean origin and construction tradition (Pomey et al. 2012: 291; Pomey & Boetto 2019: 22). Half a millennium later, Mazarrón 2 (S001, 625-570 BC) seems to have followed a similar tradition. The use of mortise-and-tenon joints for its planking assembly and the use of the lashing for the framing assembly subsume the Mazarrón 2 shipwreck to the *Iberian tradition with Punic influence* (Pomey 2012: 24-28; Pomey *et al.* 2012: 292; De Juan 2014: 32-33; 2018: 98-100; Pomey & Boetto 2019: 19-22, 43-44). The importance of this shipwreck for this study lies in the fact that it constitutes the first evidence of a surviving mast-step in the Mediterranean.

The mast-step timber does not survive in other boats of this group, except from the Golo 'wreck' (S002, 6th century BC), a contemporary boat to the Mazarrón 2 and of similar construction (Pomey & Boetto 2019: 20-22). Both vessels present similar mast-step placement and form. Given that for the boat of Golo only the text and the layouts of the 19th century publication are available, the inclusion of the mast-step as a characteristic to this tradition must be treated with caution (Dell'Amico 2008: 22). Nevertheless, the strong similarities that the mast-step of Golo presents with that of Mazarrón 2, reinforce the opinion that both boats must be included in the same architectural tradition (De Juan 2017: 72).

Based on the evidence provided by these two wrecks, the mast-step of this group is:

- a rectangular timber,
- located amidships,
- placed over the frames, but in direct contact with the keel,
- fastened to the keel (through tenons) but not to the frames, and
- with a secondary groove, where a blocking wedge for the mast would be fit.

3.2 The Greek Tradition

The Greek tradition includes boats or small merchantmen, the distinguishing feature of which is the sewn assembly system, used partially or for the entire vessel (Pomey 1981; McGrail 2001: 134; Pomey & Boetto 2019: 24, 28). Vessels of this tradition are detected throughout the Mediterranean due to the Greek colonization (Kahanov & Pomey 2004: 24). Pomey and Boetto (2019: 22-36) divided the Greek tradition into four phases based on the interpretation of the vessels' structural evolution. The phases correspond to the gradual transition from the widespread use of sewing to the use of mortise-and-tenons joints.

At the current state of research, only 4 of the 14 shipwrecks ascribed to this tradition have preserved their mast-step and, as it happens, each shipwreck belongs to a different stage of evolution of the Greek tradition.

- The *original phase*: <u>Sewn-constructed vessel</u> (Bon-Porté 1, S003, 540-510 BC). The mast-step is placed over the floor-timbers, unfastened to either keel or frames (Joncheray 1976: 34; Kahanov & Pomey 2004: 14; Pomey & Boetto 2019: 28).
- The *transition phase*: <u>Sewn vessel, mortise-and-tenons on the extremities</u> (Gela 1, S004, 500-480 BC). The mast-step is fitted over the floor-timbers but, for the first time, it is attached to the keel by vertical wooden keys. Moreover, it is extended towards the bow and the stern by a keelson and supported on both

sides by sister-keelsons (Kahanov & Pomey 2004: 18; Pomey & Boetto 2019: 30).

- The *development phase*: Mortise-and-tenon built vessel, sewn at the bow and the stern (Ma‘agan Mikhael, S006, *c.* 400 BC). The mast-step does not present any new characteristic and resembles that of Gela 1 (Pomey & Boetto 2019: 31).
- The *final development*: Mortise-and-tenon built vessel, sewn repairs on the ceiling (Kyrenia, S007, 310-275 BC) (Steffy 1985: 95; Pomey & Boetto 2019: 31, 33). The mast-step is almost rectangular in shape and it is not prolonged by a keelson (Pomey & Boetto 2019: 34).

All hulls of this group are characterized to a greater or lesser extent by a sewn assembly system. The Ma‘agan Mikhael and Kyrenia are fully mortise-and-tenons constructions, but the sewing at the bow and the stern of the former, as well as the sewn repairs on the ceiling of the latter, is consistent with a Greek origin (Steffy 1985: 95; Pomey & Boetto 2019: 31, 33). In fact, the Kyrenia shipwreck represents the final development of the Greek sewn-vessel tradition and the beginning of a new tradition of shipbuilding, where the use of the mortise-and-tenons joints becomes commonplace (Kahanov & Pomey 2004: 23; Pomey & Boetto 2019: 35).

Despite the changes in the general construction, the form and the placement of the mast-step does not represent any remarkable development at all, except the fact that Gela 1 (S004) presents an early attachment of the mast-step to the keel. This fact demonstrates that the structure of the mast-step deemed sufficient and functionable throughout the evolutionary phases of Greek tradition.

In broad terms, the mast-step of the Greek tradition can be described as a timber which:

- is rectangular or extends fore or/and aft,
- is located about amidships or slightly forward in the vessel’s hull,
- is directly placed on the back of the floor-timbers,
- has various recesses on its upper side intended for the mast, the mast boards, and stanchions (Kahanov 1998: 158).

3.3 The North-western Mediterranean Tradition

An important number of shipwrecks preserves the practice of sewing the frames, through the use of internal lashing for their attachment, alongside the use of mortise-and-tenon joints for the planking assembly. This practice is detected in shipwrecks from the northern part of the western Mediterranean and integrates them into a separate tradition. Four of those shipwrecks preserve their mast-steps and some common characteristics could be observed. Two architectural families of boats are found within this tradition.

The first one includes small boats used for coastal trade, characterized by a more-or-less sharp bottom (Pomey & Boetto 2019: 36). The Cavalière (S009, 110-90 BC), Plane 1 (S011, mid-1st century BC) and Cap Béar 3 (S012, 50-25 BC) shipwrecks are included in this family. The second architectural family is associated with fluvio-maritime ships, a type characterized by a flat keel and/or a flat bottom (Pomey & Boetto 2019: 40). From this group, only the Cap de Vol (S013, 10-5 BC/ beginning of the 1st century AD) shipwreck preserves its keelson/mast-step.

Taking the common characteristics into account, it seems that the mast-step of the North-western Mediterranean tradition is:

- an elongated timber,
- located in the forward part of the vessel,
- placed on alternated floor-timbers and half-frames,
- gradually tapered in width.

These four shipwrecks are on the threshold of the development in the mast-step construction, i.e within the process of the transition between the mast-step and the keelson/mast-step.

The Conque de Salins shipwreck (S024, 25-236 AD) is also discussed at this point, due to its relevance to some aspects of the shipbuilding tradition. Jézégou (2011: 175) supports that the Conque de Salins shipwreck is reminiscent of that of Cap de Vol, because both vessels have a flat keel. Pomey *et al.* (2013: 435) disagreed and strongly supported that the two shipwrecks do not belong to the same architectural family. The Conque de Salins wreck has, on the one hand, typical characteristics of the Romano-Celtic tradition attested to vessels of northwestern Europe (for instance, keel as part of the planking and mast-step in the floor-timbers) and, on the other hand, characteristics that remind a Mediterranean tradition (for instance, the use of mortise-and-tenons joints). Pomey (2011: 14) suggested that this shipwreck must be affiliated with the Romano-Celtic tradition presenting, however, strong Mediterranean influences. In any case, this shipwreck has an important position in the discussion for the transition process in the Mediterranean vessels (Pomey *et al*. 2012; 304-305; 2013: 435-436).

3.4 The Western Roman Imperial Tradition

From the 2nd century AD, a new architectural type appears in the western Mediterranean, exemplified by hulls with flat floor-timbers, alternated with half-frames, and a keelson/mast-step placed on two lateral sister-keelsons. These vessels incorporate technologies that demonstrate the gradual transition from shell-first to skeleton-first principle for the ship construction (Pomey *et al.* 2012: 237, 302, 306-307; Pomey 2020: 47). The Saint-Gervais 3 (S021, mid-2nd century AD) and Laurons 2 (S022, end of the 2nd- 3rd century AD) shipwrecks are dated to the dawn of this tradition and preserve their keelson/mast-step.

According to the primary evidence provided by these two shipwrecks, the keelson/mast-step traced to this tradition is:

- a long and large timber,
- supported by two sister-keelsons which, in turn, are:
    - placed on the floor-timbers and
    - connected by transverse braces.

This strong complex of the keelson/mast-step and sister-keelsons significantly reinforces the longitudinal axis and plays an important role in the structural coherence of the hull (Pomey *et al.* 2012: 300).

The abovementioned concern the general morphological and conceptual evolution of the mast-steps. The intensive analysis which follows will present a number of exclusive characteristics which are of vital importance in the study of the mast-step's evolution.

Chapter 4: Chronological Development

The evolution of the mast-step must not be interpreted as a linear development, but as a long and complex process that involves various techniques, different forms and structural diversities. The examination in terms of chronological development is necessary to detect changes that occurred in the principles of the mast-step construction in antiquity. The analysis which follows will present a number of exclusive characteristics which are of vital importance in the study of the mast-step's evolution. The shipwrecks are presented in chronological order and their characteristics are summarized in **Table 1**.

4.1 Archaic period (700-480 BC)

During the Archaic period, the mast-step was a short timber, that did not span the length of the hull and was located exactly amidships. A noticeable difference between the archaic mast-steps is the manner in which they were placed on the hull; directly into contact with the keel in the Phoenician boats of Mazarrón 2 (S001, 625-570 BC) and Golo (S002, 6th century BC) but over the floor-timbers in the Greek boat of Bon-Porté 1 (S003, 540-510 BC). In the first case the mast-step was fastened to the keel, but in the latter it was unfastened to either keel or the frames. It remained in place because of its own weight and the vertical pressure of the mast (Joncheray 1976: 34; Pomey 1981: 229; Geannette 1983: 9). The difference between the mast-step placements within the Archaic period is, most probably, associated with the different shipbuilding traditions (see Chapter 3).

4.2 Classical period (480-323 BC)

Moving from the Archaic to the Classical period, the mast-step seems to have moved slightly towards the bow and such a forward placement became gradually a commonplace from this period onwards. The Gela 1 shipwreck (S004, 500-480 BC) constitutes the first evidence of an attached-to-the-keel mast-step, belonging to a vessel of the Greek tradition (Kahanov & Pomey 2004: 18; Pomey & Boetto 2019: 30). This wreck also introduces for the first time the concept of sister-keelsons, as an additional auxiliary element for the integrity of the mast-step complex (Benini 2017: 410). The stringer that spans the length of the Gela 1 hull has been interpreted by Panvini (2001: 24-25) as a keelson, which is prolonged fore and aft of the mast-step and is attached to the keel. If this view is accepted, then this is the first occurrence of the keelson as such in the Mediterranean wrecks. Mark (2005: 47), however, opposes the view that the longitudinal stringer could be characterized as a keelson, explaining that "it does not extend the length of the vessel, it is not attached to the keel, and it is too small to give the ship the structural support we associate with a keelson".

The same issue is encountered in the case of the Ma'agan Mikhael 's mast-step assembly (S006, *c.* 400 BC). On the one hand, if the interpretation of the stringer as a keelson is accepted, this characteristic does not surprise us, since it has also been seen in Gela 1 and both mast-steps look quite similar (Kahanov 1998: 158; Mark 2005: 47; Pomey & Boetto 2019: 31). On the other hand, the 'interrupted' and non-constant structure of the Ma'agan Mikhael 's stringer (noticeable between the frames F13 and F12) perhaps does not permit it to be classified as a keelson. The extension of the mast-step could be interpreted as an attached-to-the-frames stringer, which acts as a stanchion holder for supporting deck beams (Mark 2005: 47; Dell' Amico 2011: 59). The mast-step of the Ma'agan Mikhael mostly resembles that of Gela 1, in more than one ways: it rests on the frames, its wider part is forward and the narrower towards the stern and it has sister-keelsons on each side (Kahanov 1998: 156, 158; Mark 2005: 47; Pomey & Boetto 2019: 31). Ma'agan Mikhael 's mast-step is also reminiscent of that of Bon-Porté 1, in regards to the shape, the way in which it is attached to the frames and the pattern of cavities at the top of the timber (Kahanov 1998: 156, 158; Mark 2005: 46-47).

The mast-step of the Kyrenia ship (S007), dated a century later (310-275 BC), resembles that of Ma' agan Mikhael in its form, function, placement over the floor-timbers and pattern of mortises on their upper side (Kahanov 1998: 156, 158; Kahanov & Pomey 2004: 20; Pomey & Boetto 2019: 34). Moreover, the interpretation of the cross-beams acting as mast-partners, present in both the Kyrenia and Ma'agan Mikhael wrecks, and their similar arrangement at the level of the first wale, is an additional common feature between them (Steffy 1994: 40-41; Kahanov 2003: 105; Kahanov & Pomey 2004: 6-8). As the Kyrenia is the closest parallel to the Ma'agan Mikhael hull in many ways (Kahanov 2003: 119; Kahanov & Pomey 2004: 19-20), the fact that these mast-step complexes resemble each other is consistent with their overall construction.

However, no "keelson" has been found associated with Kyrenia's mast-step (Steffy 1994: 52; Dell' Amico 2011: 59) and, although it is fitted over the floor-timbers, it appears to be interlocked by an alternation of half-frames and floor-timbers (Kahanov 1998: 158; Pomey & Boetto 2019: 34). To sum up, it is not surprising that such similarities exist amongst these four mast-steps, since they belong to different phases of the same shipbuilding tradition (Greek Tradition, see Chapter 3).

These resemblances notwithstanding, the Kyrenia shipwreck is considered a watershed in the evolution of mast-steps due to its unique characteristic of having a movable and reversible mast-step. Casson (1971: 245), writing before Steffy (1985: 86, 95) formulated the theory of a shifting mast-step, noting that such a far forward placement of the timber (as indicated by the *in situ* location of the find), may be indicative of a second sail (*artemon*/ *spritsail*). Geannette (1983: 11-12) adds that the ability to relocate the mast-step may reflect a more advanced technology of shipbuilding.

The alternative method of stepping the mast amidships and directly onto a proto-keel found in Ship 17 of Thonis - Herakleion (S005, mid-5th – early 4th century BC), confirms the general assumption that the Egyptian ships had a central mast, but there is no other archaeologically attested parallel (Belov 2014: 7; 2015: 76; 2019: 93; 2020: 173).

4.3 Hellenistic period (323-50 BC)

The Kyrenia shipwreck belongs to the final phase of the Classical period and signals the transition to the Hellenistic era (Pomey 2020: 43, 45). During the Hellenistic period, the mast-steps gradually increase in size. The mast-step of the Cavalière shipwreck (S009, 110-90 BC) has been reconstructed as a 7.5m long timber, for a vessel only 13m-long, spanning over about 3/5 of the total vessel's length. The length of the timber is remarkable, especially if we take into account that the Kyrenia's mast-step is 1.2m long for a vessel of approximately the same length. The form is also different, since the Kyrenia's mast-step is almost rectangular in shape, whilst that of Cavalière tapers in width. Both these two mast-steps, however, were placed on alternated floor-timbers and half-frames and notched on their underside to allow the floor-timbers, and not the half-frames, to pass through.

The Chrétienne A shipwreck (S008, 150-100 BC) has a distinctive mast-step that presents two types of placement: in its widest part it is notched to be fixed on the floor-timbers (as seen in the Hellenistic shipwrecks of Kyrenia and Cavalière, above), but in its narrower part it was the floor-timbers that were rabbeted to receive the mast-step timber (as seen in the Classical shipwreck of Ma'aghan Mikhael) (Basch 1973: 333).

4.4 Roman period (50 BC – 3rd century AD)

Moving to the Roman period, the surviving examples of mast-steps are more numerous (**Fig. 2**). The Madrague de Giens mast-step (S010, 75-60 BC) yields the first archaeological evidence of a two-masted ship and could be considered one of the major milestones of the Mediterranean nautical archaeology. For the first time, the mast-step is bevelled on its underside to be fitted both on floor-timbers and half-frames, a feature encountered in many shipwrecks from the Roman period onwards. The 4m-long mast-step of the Madrague de Giens might seem incompatible with the reconstructed length of the vessel (40m) - with the timber occupying only 1/10 of its length – however, the mast-step timber is massive in cross-section (55x45 cm), thus sufficiently able to distribute the pressure of the mast.

Geannette (1983: 39) compares the Madrague de Giens mast-step with that of Plane 1 (S011, mid-1st century BC) and supports that the latter does not represent any technological evolution but instead constitutes simply an "economy version" of that of the Madrague de Giens. This statement can only be explained by the difference in size, because the two compared mast-steps are approximately the same length, whereas the Plane 1 mast-step is half as large as that Madrague de Giens in cross-section. Plane 1 is shares similarities with the Cavalière (Charlin *et al.* 1978: 75-77) and Chrétienne A mast-steps. The particularity of the Plane 1 mast-step is that it narrows towards the front, instead of the aft of the vessel (Geannette 1983: 39). This peculiar feature is unique of this mast-step, since it is not encountered in any of the earlier nor later shipwrecks.

At the turn of the millennium, the Cap de Vol shipwreck (S013, 10-5 BC/ beginning of the 1st century AD) presents a primary type of an unfastened keelson, consisting of an entire tree trunk, placed atop the floor-timbers. This may constitute the first example of a ship designed to employ a longitudinal member for the purpose of structural support (Geannette 1983: 78); as the timber occupies half of the vessel's total length, what can be concluded is that it should not be considered as an extended mast-step but as a proper keelson. From this period onwards, the concept of the keelson/mast-step is used alongside.

The information regarding the keelson/mast-steps of the Cap Béar 3 (S012, 50-25 BC) Caska 2 (S015, 1^{st} century-BC- 1^{st} century AD), Sud-Lavezzi 2 (S016, mid-1^{st} century AD), Rabiou (S017, 50 AD) and Napoli A (S019, end of the 1^{st} century AD) shipwrecks is either fragmentary, or still in the course of being studied. Based on the data available up to this point, they do not represent any signs of evolution but are instead consistent with the design already discussed for the Roman keelson/mast-step. The Diano Marina shipwreck (S014, 25-27 AD), however, has a keelson/mast-step is fixed over the floor-timbers, like the other examples of the Roman period but with the notches on its underside, as high as the floor-timbers themselves. In this case, the mast-step timber seems to be in direct contact with the upper side of the keel (but it is not fastened to it)**,** a feature unprecedented so far (Dell'Amico & Pallarés 2005: 71). Since it is currently the only example of a mast-step belonging to a *dolia* shipwreck, it is not known if this arrangement is typical of this specific type of ship or whether it is unique. Another *dolia* ship, the Ladispoli, also preserved its mast-step but it was destroyed before it could be studied (Carre 1993: 9; Marlier 2008: 157).

By the end of the 1^{st} century AD, the Calanque de l'Âne shipwreck (S018, end of the 1^{st} century AD) yields information of a keelson/mast-step that is not fixed directly on the floor-timbers, but instead embedded on a pair of sister-keelsons. What is surprising about this case is the fact that the complex of the keelson/mast-step and sister-keelsons is reinforced by a pair of buttresses (also called crutches or transverse sisters) on each side - elements unprecedented in naval architecture up to this time (Ximénès & Moerman 1998: 299- 300).

The placement of the keelson/mast-step on two lateral keelsons becomes commonplace from the 2^{nd} century BC, up to the 7^{th} century AD. The Grado (S020, 117-150 AD) and Laurons 2 (S022, end of the 2^{nd} - 3^{rd} century AD) shipwrecks represent a T-shaped keelson/mast-step, a form that is encountered in many shipwrecks from this period onwards (Dell' Amico 2011: 61, 74). The Grado shipwreck, however, is noteworthy because it presents a mast-step which can be moved and placed in a different location along the axis of the vessel (Beltrame & Gaddi 2007: 138-139). The only known parallel is the Kyrenia mast-step of a much earlier period, a fact that demonstrates the possibility of a shipbuilding technique to survive for centuries.

It is necessary at this point to discuss the Fiumicino 4 shipwreck (S023, 2nd – 3rd century AD), which is an exception amongst the Roman shipwrecks according to which the keelson/mast-step appears to be placed on two sister-keelsons. However, the following factors must be taken into account. Firstly, its dating is still uncertain. Secondly, there are two sister-keelson on either side of the mast-step, but they do not support it. Lastly, this mast-step has also some 'archaic' characteristics, such as the simplistic design of cavities arrangement. All these characteristics have led to the hypothesis that the mast-step was reused from another ship (Boetto 2001: 124; Dell' Amico 2011: 74).

The Saint-Gervais 3 (S021, mid-2nd century AD) also presents a system of sister-keelsons but, in this case, the keelson and the mast-step constitute independent elements, fastened together through mortise-and tenons joints. This is very similar to the Mazarrón 2 mast-step (S001, 625-570 BC), which is fixed through tenons on the keel. As these two shipwrecks are eight centuries apart, belong to different shipbuilding traditions and types, this structural similarity is surprising. However, it is perhaps indicative of shipbuilders employing a similar method to stabilise the mast-step. This method has proven to be effective over time, a demonstrably effective solution to address practical issues in the shipbuilding process.

In any case, the Saint-Gervais 3 shipwreck is exceptional, as is a two-masted vessel; the mast-step acts as the supporting element for the mainmast, whilst the keelson acts in a bidirectional way, as a longitudinal member which reinforces the hull and as the step for the foremast.

The Conque de Salins shipwreck (S024, 15-236 AD) mainly bears the characteristics attested on northwestern European vessels, which do not belong to the geographical context examined in this dissertation. It is included in the present thesis however, for two reasons; firstly, it was discovered in Mediterranean waters (South France) and, secondly, it has Mediterranean influences regarding its construction. This shipwreck – of uncertain date - presents an entirely different concept in terms of the design of the keelson/mast-step. The unusual feature of this mast-step is that it does not constitute a longitudinal structure but is instead transversal to the ship's axis (Jézégou 2011: 171), a fact most probably associated with the different origin and shipbuilding tradition of the vessel, which is discussed in Chapter 3.

<table>
<tr><th>Period</th><th>CN</th><th>Shipwreck</th><th>Shipbuilding Tradition</th><th>Mast supporting Timber</th><th>Position in the hull</th><th>Placement on other hull timbers</th><th>Special Features</th></tr>
<tr><td rowspan="4">Archaic (700-480 BC)</td><td>S001</td><td>Mazarrón 2</td><td rowspan="2">Iberian Tradition with Punic influence</td><td rowspan="4">Mast-step</td><td rowspan="3">Amidships</td><td rowspan="2">In contact with the keel</td><td rowspan="2"></td></tr>
<tr><td>S002</td><td>Golo</td></tr>
<tr><td>S003</td><td>Bon-Porté 1</td><td rowspan="2">Greek Tradition</td><td rowspan="2">Over the floor-timbers</td><td></td></tr>
<tr><td>S004</td><td>Gela 1</td><td rowspan="14">Forward part</td><td>Primary form of keelson</td></tr>
<tr><td rowspan="2">Classical (480-323 BC)</td><td>S005</td><td>Thonis-Herakleion/ Ship 17</td><td></td><td>Keel</td><td>On the keel</td><td></td></tr>
<tr><td>S006</td><td>Ma‘agan Mikhael</td><td rowspan="2">Greek Tradition</td><td rowspan="7">Mast-step</td><td rowspan="12">Over the floor-timbers</td><td>Primary form of sisters</td></tr>
<tr><td rowspan="3">Hellenistic (323- 50 BC)</td><td>S007</td><td>Kyrenia</td><td>Movable mast-step</td></tr>
<tr><td>S008</td><td>Chrétienne A</td><td></td><td rowspan="2"></td></tr>
<tr><td>S009</td><td>Cavalière</td><td>North-western Mediterranean Tradition</td></tr>
<tr><td rowspan="8">Roman (50 BC – 3rd century AD)</td><td>S010</td><td>Madrague de Giens</td><td></td><td>Mast-step intended to receive two masts</td></tr>
<tr><td>S011</td><td>Plane 1</td><td rowspan="3">North-western Mediterranean Tradition</td><td>The keelson/mast-step narrows towards the front part of the vessel</td></tr>
<tr><td>S012</td><td>Cap Béar 3</td><td></td></tr>
<tr><td>S013</td><td>Cap del Vol</td><td rowspan="5">Keelson/ mast-step</td><td>First occurrence of a proper keelson</td></tr>
<tr><td>S014</td><td>Diano Marina</td><td></td><td>Over the floor-timbers and in contact with the keel</td></tr>
<tr><td>S015</td><td>Caska 2</td><td></td><td rowspan="3"></td></tr>
<tr><td>S016</td><td>Sud-Lavezzi 2</td><td></td></tr>
<tr><td>S017</td><td>Rabiou</td><td></td></tr>
</table>

	S018	Napoli A					
	S019	Calanque de l'Âne				Over the sister-keelsons,	Buttresses on each side of the keelson mast-step and sister-keelsons
	S020	Grado					Movable keelson/mast-step & First occurrence of the sister-keelsons
	S021	Saint-Gervais 3	Western Roman Imperial Tradition				Independent keelson and mast-step/ mast-step for the mainmast, keelson for the foremast
	S022	Laurons 2					
	S023	Fiumicino 4		Mast-Step		Over the floor-timbers, flanked by two sister-keelsons	
	S024	Conque des Salins		Mast-step		On the keel	Transverse mast-step

Table 1: Summary of mast-step and mast-step/keelson construction details.

Chapter 5: Types and Function

5.1 Size

Having established the basic components of the mast-step and keelson structure, as well as their development over the centuries, the following comparative analysis concerns individual features that can be used as a basis of a structural typology.

In order to compare and interpret the different dimensions of the mast-steps and keelsons, it is of key importance to distinguish different groups of ship sizes: boats, small ships, medium-sized ships and large ships (**Table 2**).

Type	Length (m)	Beam (m)
Boats	Up to 10	Up to 3
Small ships	10-15	3-5
Medium-sized Ships	15-20	5-7
Large Ships	20 and upwards	7 and upwards

Table 2: A comparative table of the vessel's' sizes, according to the shipwrecks of the catalogue.

Only for 13 of the 24 shipwrecks discussed in this thesis (almost 50% of the total) are the data satisfactory to make size comparisons (**Table 3**).

The size of the mast-step was determined by the size of the ship, the technological knowledge of the shipbuilder, as well as the available material. The last is of particular importance, considering that the tree trunks used for the mast-step construction, had predetermined to a great degree the shape and the size of the timber.

The mast-step or the keelson/mast-step increases in size in proportion to the size and the type of the ship; small boats required a smaller in size mast-step, bigger ships required a bulkier mast-step and so on. This is an expected result, considering that the length of the mast-step would have acted to distribute the pressure of the mast (Dumas 1974: 56; Geannette 1983:22), which would be bigger and heavier in large ships.

From the comparative dimensional analysis, it is inferred that the similarity in size does not equal to the similarity in design of the mast-step timber, even in cases where the vessels belong to the same shipbuilding tradition. A good example is the comparison of the Ma'agan Mikhael (S006, *c.* 400 BC) and Kyrenia (S007, 310-275 BC) mast-steps, which belong to the same type of vessel (small ships) and shipbuilding tradition (Greek tradition, see Chapter 3), but their mast-step designs present differences. Accordingly, the similarity in design is not equal to the proximity in size; the Ma'agan

Mikhael (S006) and Gela 1 (S004, 500-480 BC) mast-steps are of similar design, but their dimensions vary significantly. Therefore, it is plausible to suggest that any attempt for the formulation of a linear pattern would be misleading.

Type	**CN**	**Shipwrecks**	**Estimated ship length (m)**	**Mast-step or Keelson/ Mast-step**		
				Length (m)	**Width (cm)**	**Height (cm)**
Boats	S001	Mazarrón 2	8.15	1.04	10	6
	S003	Bon-Porte 1	10	1.05	19	12
	S023	Fiumicino 4	10	1,17	14,6	12
Small Ships	S006	Ma'agan Mikhael	13.5	2,44	29,5	14, 5
	S007	Kyrenia	14	1.2	24	10
	S009	Cavalière	12.98	3.5	26	21
	S022	Laurons 2	15	5.20	28	22
Medium-sized Ships	S013	Cap de Vol	18-20	9.2	38	12
	S021	Saint-Gervais 3	17	4.8 (mast-step) 10.5 (keelson)	38 (mast-step) 47 (keelson)	21(mast-step) 27 (keelson)
Large Ships	S004	Gela 1	22-25	6	58	20
	S008	Chrétienne A	24-32	4.71	48	27
	S010	Madrague de Giens	40	4	55	45
	S018	Calanque de l'Âne	25	9.1	42	29

Table 3: Scantling Dimensions of the mast-steps and keelsons/mast-steps.

5.2 Systems of Placement

The study of the available evidence seems to signify three distinct types for the mast-step placement into the hull throughout the period under examination: in direct contact with keel (S001, S002), over the floor-timbers (S003, S004, S006, S007, S008, S009, S010, S011, S012, S013, S014, S015, S016, S017, S018, S023) and on a pair of sister-keelsons (S019, S020, S021, S022) (**Table 1**).

In the first type, as seen in the earliest example of Mazarrón 2 (S001, 625-570 BC), the mast-step is placed in direct contact with the keel, through tenons on its underside and corresponding mortises on the keel's upper side. In addition, the mast-step has rectangular slots, which allow the floor-timbers to pass through (Negueruela 2014: 241; Miñano 2014: 7) (**Fig. 47**).

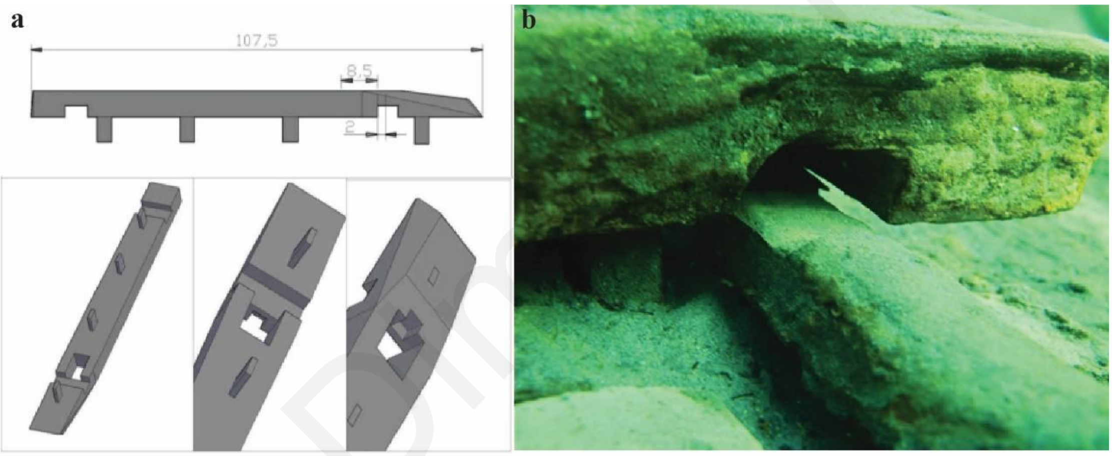


Figure 47: The Mazarrón 2 mast-step. a) 3D model. Note the mortises on its underside (Rodríguez 2012: 101, fig. 80); b) in situ. Note the placement on the keel and the slots for the floor-timbers (Miñano 2014: 8, fig.5).

In the cases where the mast-step is not preserved, the presence of mortises on the upper side of the keel constitutes a clear indication for the position that the timber would have had. This, in turn, can lead to additional information about the vessel. For instance, the mast-step of Mazarrón 1 (a shipwreck which is contemporaneous to Mazarrón 2 and is affiliated to the same shipbuilding tradition, **Table 6, No. 1**) is missing, but the mortises on the keel's upper surface indirectly reveal the position that the mast-step would have had. The four fore mortises reflect the position where the main cavity was curved, hence the position of the mast (**Fig. 48**). Therefore, it is possible for someone to identify the bow and stern of the vessel and, consequently, to determine which side corresponds to the starboard and which to the port side (Pomey & Boetto 2019: 19; Tejedor 2018: 308).

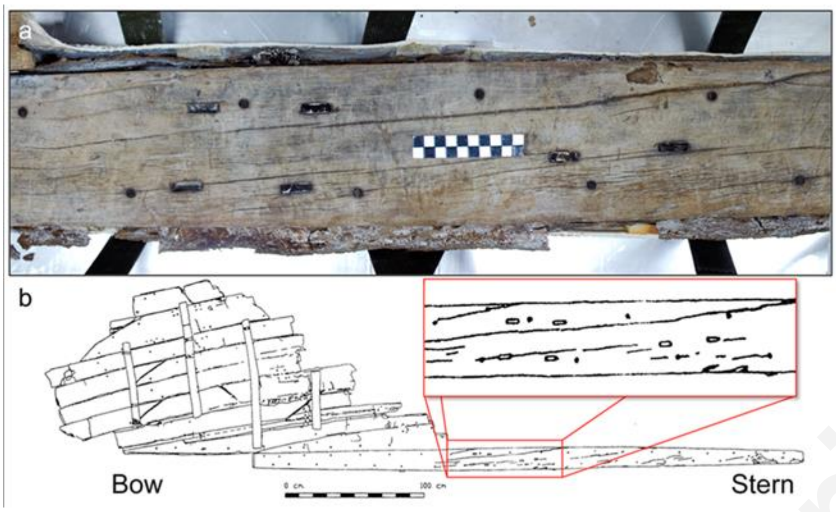


Figure 48: Mazarrón 1 a) Upper face of the keel. Note the mortises b) drawing of the preserved hull and detail of the keel (Tejedor 2018: 309, fig.14).

The second type is associated with the placement of the mast-step on the floor-timbers and can be divided into three subtypes, based on the framing system and the form of the mast-step's underside. Evidence of this method range from the Archaic to the very beginning of the Roman period (6th century BC - 1st century BC). The first subtype was found in the Bon-Porté 1 shipwreck (S003, 540-510 BC). In this case, the mast-step has two notches on its underside, with a tenon in the middle, in order to be placed on the corresponding rabbets on the upper surface of the floor-timbers (**Fig. 49**). It seems that the shipwrights relied on a system of notches along the underside of the mast-step timber, in order to prevent it of moving backward and forward. Respectively, the vertical displacement from port to starboard was prevented by the tenons in the middle of these notches, which correspond with the rabbets on the floor-timbers (Joncheray 1976: 34).

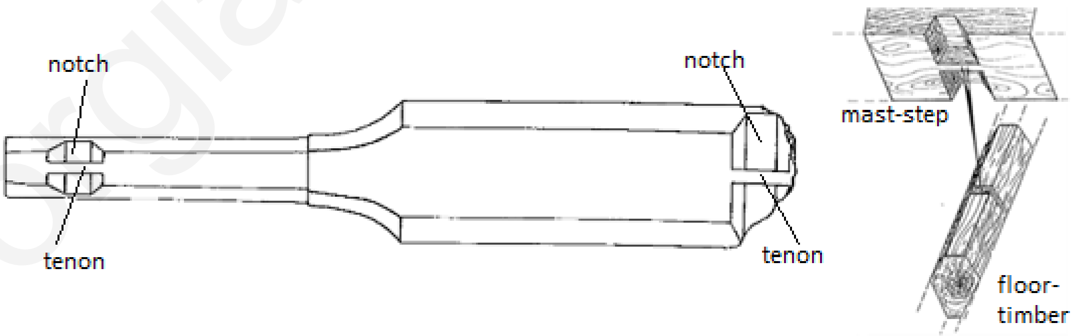


Figure 49: Bon-Porté 1 mast-step. Note the notches with the tenon in the middle, as well as the rabbet on the floor-timber (After Joncheray 1976: 32, 34).

A mast-step of a similar form was constructed and used for the sailing replica of the Jules-Verne 9 wreck (**Table 6, No. 2**), *Gyptis* (**Fig. 50**). In this case, the mast-step was missing but the comparative data allowed the reconstruction of the timber, as the Bon-Porté 1 and the Jules-Vernes 9 shipwrecks are contemporaneous and belong to the same type of vessel (small boats) and shipbuilding tradition (Greek tradition/ original phase, see Chapter 3) (Pomey 2003: 63-64; Pomey & Poveda 2018: 48; Pomey & Boetto 2019: 24-26).

Figure 50: General view of the internal structure of Gyptis. Note the mast-step in the foreground (Pomey 2018: 52, fig. 11).

The second subtype has notches on the underside of the mast-step (without a tenon in the middle) which is placed on the rabbets/ recesses carved on the back of the floor-timbers, as seen in Ma‘agan Mikhael mast-step (S006, *c.* 400 BC) (**Fig. 51**). It is inferred that this method was enough to secure the mast-step from moving longitudinally, but, in this example at least, it seems that auxiliary elements (i.e. the sisters) were necessary to prevent it from moving transversally.

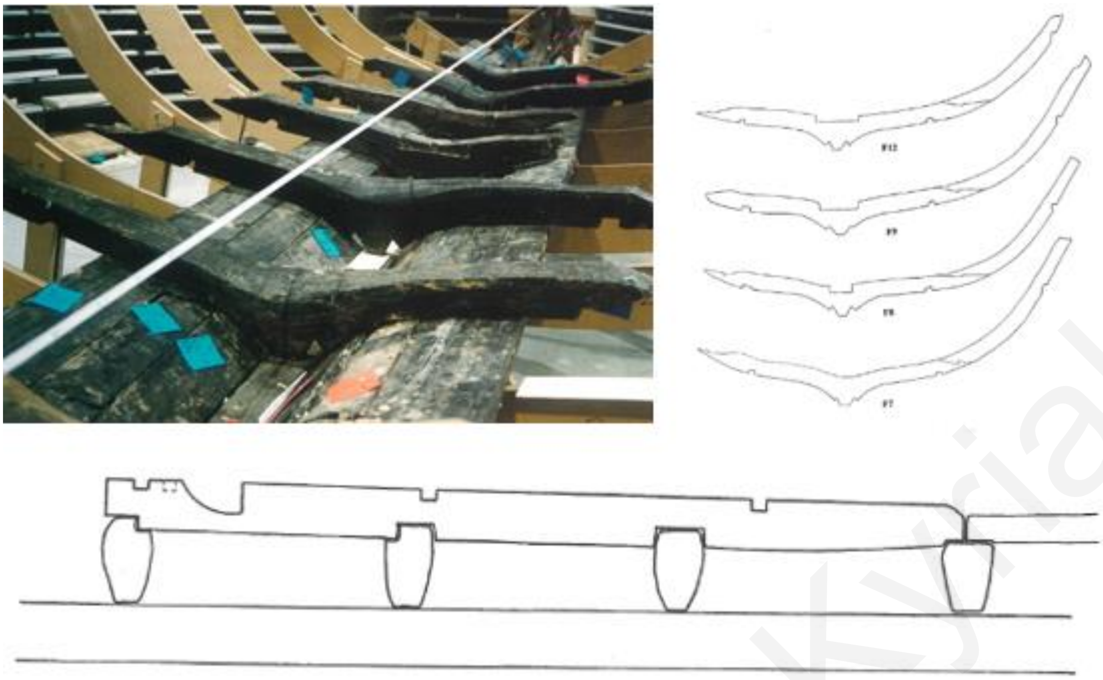


Figure 51: Ma'agan Mikhael mast-step. Note the notches on its underside and the rabbets on the floor-timbers (Kahanov 2003: 89, fig. 60; 95, fig. 68; 102, fig. 78).

The third subtype pertains to vessels in which the framing system is based on an alternation of floor-timbers and half-frames. Only the floor-timbers have rabbets to be matched with the corresponding notches on the mast-step's underside. This method is first seen in the Kyrenia shipwreck (S007, 310-275 BC), where the increased number of the rabbets demonstrated the sifting ability of the mast-step.

The number of notches on the underside of the mast-step expectantly increases from two (Bon-Porté 1) or four (Ma'agan Mikhael, Kyrenia) in smaller crafts to eight (Madrague de Giens) or ten (Chrétienne A) for larger ships. Nevertheless, the proportional correlation between this increase of notching to the vessels' size or to the number of frames, would be misleading; it seems that, even with less notching, the stability of the keelson/mast-step timber was secured. Furthermore, the mast-steps of the Hellenistic shipwrecks have notches designed to match only the floor-timbers and not the half-frames, while those from the Roman period onwards differ: their underside was chamfered to also match with the half-frames (**Fig. 52**) (Geannette 1983: 76-77).

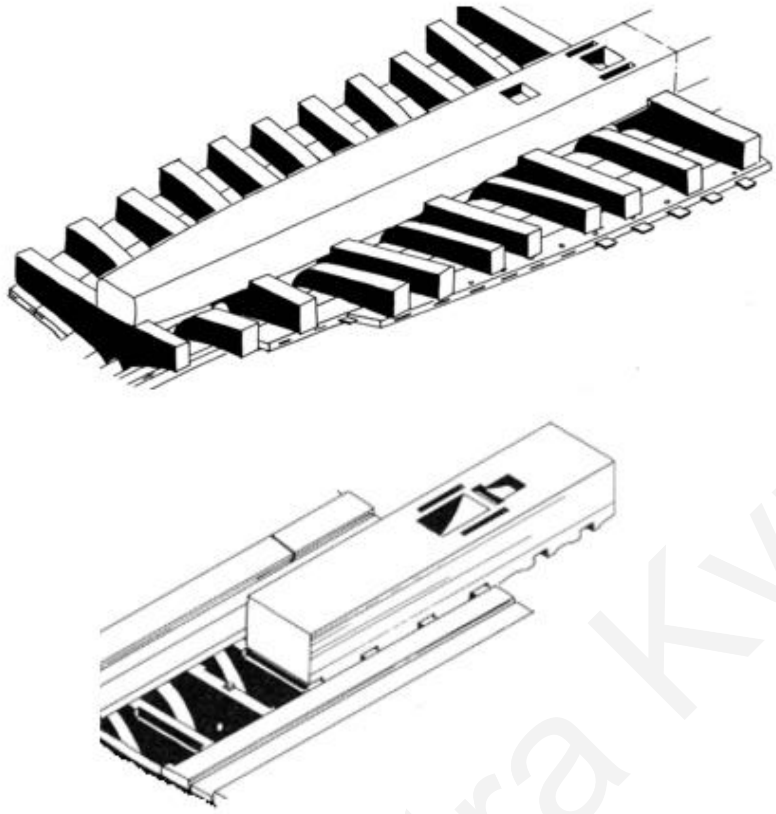


Figure 52: The placement of the mast-step on the alternated floor-timbers and half-frames. a) Cavalière (Charlin et al. 1978: 75, fig. 52) and b) Madrague de Giens (Pomey 2020: 35, Fig. 3.8).

In cases where the mast-step of a ship is either not preserved or badly eroded, the presence of the rabbets reflects the position and the length of the missing timber. For example, in the case of Cavalière (S009, 110-90 BC), where the mast-step is only partially preserved (3,5m), the missing timber has been reconstructed to a length of 7.5m, due to the rabbets on the back of frames.

This way of placement remains unchanged for centuries. The radical change comes with the appearance of the sister-keelson system (during the 2nd century AD), over which the keelson/mast-step is now embedded. This is the third and last type regarding the period under consideration. These auxiliary elements (sister-keelsons) are notched to the frames, in the same manner as the mast-step was during the previous centuries, in order to prevent any lateral movement (Dell'Amico 2011: 61). One might recognize the point of change to the Grado shipwreck (S020, 117-150 AD) the mast-step of which is set on a pair of sister-keelsons. The underside of the keelson has notches to fit on the frames. On each side, the underside is chiseled in such a way to be embedded over and supported by the two sister-keelsons (**Fig. 53**).

Figure 53: The underside of the Grado keelson/mast-step (Beltrame & Gaddi 2007: 141, fig. 6).

In the cases where the mast-step/keelson timber does not survive, its reconstruction is possible. For instance, in the case of the La Bourse (Lacydon) shipwreck (France, 190–220 AD) (**Table 6, No. 7**), "the existence and connections of the mast-step/keelson could be reconstructed based on extant marks and assembly evidence. Sections of keelson could be restored on each end of the hull, as an extension of the mast-step, according to long projecting bolts that formed the keel/frame/keelson connection" (Pomey *et al*. 2012: 243).

It should be noted, however, that these three different types of placement do not represent a linear chronological development, although some involve shipwrecks that signal the transition to a different construction method (see **Table 1**). A method of construction can survive or be identified on shipwrecks dated centuries apart, depending on the available material, the type of the vessel or the need of each construction.

5.3 Fastenings

Throughout the examined period, a few examples present an early attempt at fastening the mast-step or keelson to the keel and frames. As noted above, the earliest examples of mast-steps (Mazarrón 2, Golo) are fastened to the keel through tenons on their underside. The next indication comes from the Archaic shipwreck of Gela 1 (S004, 500-480 BC), where the mast-step is attached to the keel with vertical wooden keys.

The same joinery between the mast-step and the keel was used to the reconstruction model of the Jules-Verne 7 wreck (**Table 6, No. 3**), a vessel of a similar type, shipbuilding tradition (Greek tradition/ transition phase, see Chapter 3) and slightly contemporaneous to that of Gela 1 (Pomey 2003: 61; Pomey & Boetto 2019: 28-30). After this, no evidence of fastening to either the keel or frames has been detected, for a long time span. Mast-steps and keelsons remain in place due to their own weight, the notching on their underside and the vertical pressure of the mast. In the early Roman period, only the single case of the Titan wreck (mid-1st century BC, **Table 6, No. 5**) – where the mast-step was not found - presents an early attempt of fastening the keelson into the keel, but not to the frames, through treenails (Basch 1972: 29; Tchernia *et al.* 1978: 83; Geannette 1983: 37).

It seems that sister-keelsons were only sporadically bolted or nailed to the frames, as is the case of the Grado (S020, 117-150 BC), La Bourse/ Lacydon (190–220 AD) (Gassend & Cuomo 1982) and Marausa (late 3rd–early 4th century AD) shipwrecks (Tiboni & Tusa 2016). No keelson/mast-step was found in the last two examples (**Table 6, No. 7 and 8**), but the preservation of the sister-keelsons allowed the observation that they were iron nailed to frames. This may be in correspondence with the gradual use of fastenings as a major component in ship construction – rather than a reinforcing one- which become commonplace in the Late Antiquity, in the skeleton-first constructions (Pomey *et al*. 2012: 236-237).

5.4 Position into the hull

Iconographic evidence usually concerns masts placed amidships (Casson 1971: 239). This, however, is only partially confirmed by the archaeological data. The earliest archaeological evidence from the Archaic period constitutes a clear indication that the mast-step is initially placed exactly in the middle of the vessel. But from the Classical period onwards, the mast-step moves slightly towards the bow and this forward placement remains the same in the following periods. Casson (1971: 245) reports that the Kyrenia's mast-step (S007, 310-275 BC) is located about ⅓ of the length of the vessel from the bow. The excavation data and the reconstructions of the ancient shipwrecks, however, have revealed more precise information regarding the proportion between the mast-step and the hull. From the Hellenistic era, the location of the mast can be precisely calculated to 3/8 of the length of the vessel from the bow (or 5/8 from the stern). This proportion is applicable to the Hellenistic ship of Cavalière (S009, 110-90 BC) (Charlin *et al.* 1978: 79), as well as to the Roman ships of Madrague de Giens (S010, 75-60 BC) (Pomey 1982: 146-150), Saint-Gervais 3 (S021, mid-2nd century AD) (Liou *et al.* 1990: 258-259) and Laurons 2 (S022, end of the 2nd – 3rd century AD) (Gassend *et al.* 1984: 103-105).

In addition, the Madrague de Giens provides evidence for the existence of a foremast. The proportions of this shipwreck demonstrate that the location of the foremast can be calculated to ¼ of the length of the vessel from the bow (or ¾ of the length of the vessel from the stern) (Pomey 1982: 146-150) (**Fig. 54**). This conclusion arises from the comparative study that has been made between the roman shipwreck and a ship depicted on a mosaic (*frigidarium* of the baths at Themetra, Tunisia, 3rd century AD) (Pomey 1997: 180; Pomey & Rieth 2005: 68). It is a unique example of iconographic evidence which matches perfectly with the archaeological finding, revealing such precise information.

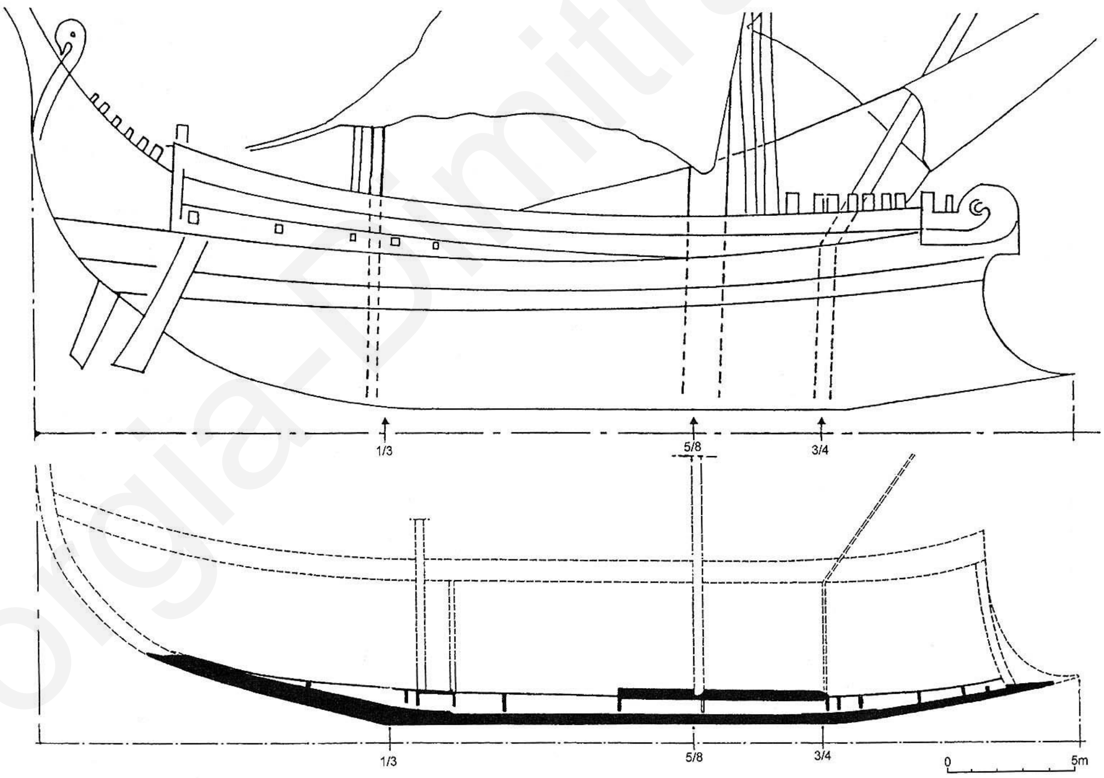


Figure 54: Above: Longitudinal profile of a merchantman (mosaic from the frigidarium of the baths at Themetra Tunisia) after the restitution of the bottom line of the hull. Below: Longitudinal profile of the Madrague de Giens, with reconstructed elements dashed (preserved parts are in black). Note the form and the precise analogy of the ships' masting that attributes the two ships to the same type (Pomey 1997: 68).

However, these transitions do not reflect a definite and linear process. For instance, the Caska 2 (S015, 1^{st} century BC-1^{st} century), Rabiou (S017, *c.* 50 AD) and Grado (S020, 117-150 AD) shipwrecks, all dated to the Roman period, seem to have a mast-step placed near the central part of the vessel rather than in its forward part. The first two cases are smaller boats in comparison to the aforementioned vessels where the mast is stepped such forward. There is reason to believe that in the smaller vessels the mast was still placed amidships, most probably for stability reasons.

5.5 Movable Mast-Steps?

The deliberate movement of the mast-step during the course of a voyage seems to be impossible. Firstly, the pressure exercised on the mast by the wind, as well as its own weight, would make any such displacement an extremely difficult process while on course. Secondly, the load stowed upon the mast-step and inside the hold of a cargo ship would prohibit its intentional movement. Therefore, the only possibilities that remain, are before a voyage, when moored in the port, or during calm weather on the condition that the vessel was free of cargo.

Throughout the periods under examination, two cases of mast-step could be moved along the vessel's axis to change their position. The first mast-step comes from the Kyrenia shipwreck (S007, 310-275 BC), which Steffy (1985: 86, 95) refers to as movable and reversible. The shifting ability of the mast-step has been suggested due to the rabbets on the floor-timbers further to the fore of the ship. Steffy does not explain, however, why the mast-step could also be reversed. Most probably his suggestion was based on trials he made with the preserved timber and the additional rabbets found on the forward floor-timbers. *In situ*, the timber was found in the expected orientation, as the curvature of the main cavity indicates.

The second piece of evidence comes from the Grado shipwreck (S020, 117-150 AD). Wooden elements were found inside two of the five notches on the underside of the keelson/mast-step, for the purpose of preventing its longitudinal displacement. The presence of five notches and only two wooden elements, led scholars to suggest that this timber could also be shifted and placed in a different location along the ship's axis (Beltrame & Gaddi 2007: 139). Given that the Grado was a medium-sized vessel and is dated to the Roman period, the keelson/mast-step would be expected to be placed in the forward part of the hull instead of amidships. The possibility of a movable timber may indicate that at some point it was placed in the expected forward position, in correspondence to the proportion (the mast at 3/8 form the bow) suggested for the Roman vessels.

The long interval between the Kyrenia and Grado shipwrecks can lead one to suspect that the shifting ability of a mast-step or/and keelson perhaps was a known method, which was applied according to the choice of the shipwright and the need of each construction. This assumption, however, remains uncertain and opens to further discussion. Another hypothesis suggests that both the Kyrenia and Grado mast-steps may have been recovered and reused from another ship (Beltrame & Gaddi 2007: 139; Dell' Amico 2011: 59).

The possibility of a movable mast-step is also discussed by Tiboni and Tusa (2016: 12), regarding the form of the sister-keelsons discovered in the Marausa shipwreck (**Table 6, No. 8**) (the keelson/mast-step was not preserved). They argued that the keelson/mast-step would have been constructed in such a manner to specifically fit the individual shapes and dimensions of the frames and the sister-keelsons. Thus, the pre-determined form of the mast-step would not permit its movement. They also suggested that this mast-step was not found perhaps because it was recovered after the wrecking event, a statement which corroborates the aforementioned hypothesis for the reuse of the mast-step timbers.

5.6 The main and the adjacent cavities

The curvature of the cavity that was intended to receive the mast spur is an element that does not present any significant change during the period under examination. It has, in the vast majority of cases, a vertical plane towards the rear of the ship and an inclined one towards the front of the ship, which is an almost undisputed testimony about which side of the ship is the bow and which is the stern. The main cavity was deliberately chiseled in this way, serving to a dual function:

During navigation, the sail subjects to the mast strong thrusts of the wind from behind or from the sides. The vertical face towards the stern offers greater resistance for the mast, since the foot tends to translate into the main cavity in the direction opposite to the thrust of the wind. Thus, if it would not be right-angled but inclined, the force of the wind in the sails would provoke a displacement of the mast from its housing. In contrast, the inclined face towards the bow facilitates the process of removing the mast, while it allows its gradual pivoting and its lowering to the stern (Tchernia *et al.* 1978: 98; Nieto 1982: 165; Santamaria 1984: 110; 1995; 164, 168). The consistency in the form of the main cavity for centuries demonstrates that it was functionable and technologically satisfactory (Santamaria 1984: 113). There is only an exception throughout the examined period. In the Bon-Porté 1 (S003), the back face of the main cavity is not vertical, but it is inclined forward (Joncenray 1976: 33; Geannette 1983: 10). There isn't a sufficient explanation about this peculiar form of the mast cavity.

In most mast-steps, the pattern of the cavities adjacent to the main one, also shows a relative coherence (Liou 1975: 595). Through thorough examination of the arrangement of mast-steps' cavities presented in this thesis, it is inferred that the long and narrow mortises were intended to receive the mast boards (vertical planks), creating a frame for the mast foot. The rest of the cavities along the length of the upper surface of the mast-step or the keelson, usually of rectangular shape, were intended to receive stanchion poles that support the deck. Regarding the function of the mast-boards, Santamaria (1984: 110; 1995: 164, 168) points out that they prevent the mast at the level of the deck from moving laterally and transversally, but also guide the mast when it has to be removed.

The number and the arrangement of mortises around the main cavity is not always the same. In the cases where the main cavity does not have parallel mortises for the mast boards, the mast was not surrounded by a frame. This was the arrangement at the earliest shipwrecks, such as Mazarrón 2 (S001, 625-570 BC) and Golo (S002, 6th century BC), or in the Egyptian Ship 17 of Thonis-Herakleion (S005, mid-5th - early 4th century BC). Using the work of Santamaria (1984: 113; 1995: 170) regarding the arrangement of the main cavity with adjacent ones as a starting point, what follows is the evolution of mast-step's cavities arrangement, based on the shipwrecks of the catalogue (**Table 4**):

A. Two front and two side cavities (S003, S006).
B. Two side and two front cavities, the latter integrated into an elongated one (S007).
C. A front and two side cavities, all integrated into the main one (S008)
D. Two side cavities (S009).
E. A front and two side cavities (S011, S013, S015, S021, S017, S018, S019).

F. Two side cavities and two front cavities adjacent to each other, with no space between them (S010).

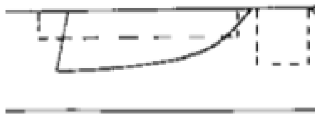
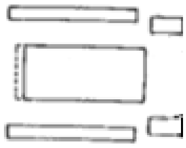
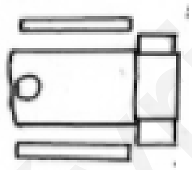
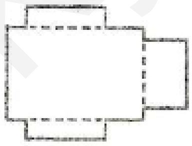
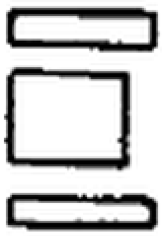
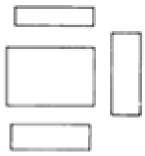
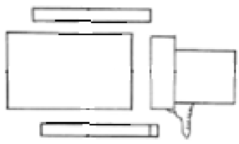
	Shipwreck	Profile/Side view	Top View
A	Bon-Porté 1 (S003)		
B	Kyrenia (S007)		
C	Chrétienne A (S008)		
D	Cavalière (S009)		
E	Cap de Vol (S013)		
F	Madrague de Giens (S010)		

Table 4: The chronological evolution of mast-step's cavities arrangement. Orientation: from left (towards the stern) to right (towards the bow). An example of each case has been chosen.

Regarding the Hellenistic shipwrecks, Charlin *et al.* (1978: 74, 77) mention that the shape and the size of the Cavalière's cavity is very common when compared to other discovered mast-steps. On the other hand, Geannette (1983: 22) refers that the Chrétienne A's cavity area is six times that of Cavalière, leading to the assumption that the mast of the former may be in significantly larger proportion due to the size (24-32m long) and the capacity (200 tons) of the former (S008). He also observes (1983: 18) that the depth of the Cavalière's two parallel mortises almost doubles in comparison to those of Kyrenia mast-step.

What is inferred when someone compares the Hellenistic mast-steps with the earlier examples, is that the number of the cavities on the upper side of the mast-step decreases (Chrétienne A, Cavalière) (**Table 4, C and D**) and the form becomes more simplified. This is not equivalent to a weak supporting system for the mast. In the case of Cavalière, it seems that the greater depth of the main and the adjacent cavities was enough to secure the mast in its place, rather than additional supporting elements that should require more cavities around it. In addition, at the beginning of this period, the front perpendicular cavity has an inverse orientation from the main cavity and this feature is first seen in Kyrenia and then in Chrétienne A shipwrecks.

The inverse orientation of the perpendicular cavity reappears also to the Roman period (see S010, S011, S013) (Geannette 1983: 12, 22, 27). Moreover, from this period onwards, the main cavity is flanked on its three sides by long mortises (**Table 4, E and F**), in a percentage of more than 50% of the Roman shipwrecks under consideration (9 out of 15). It is possible that this cavity was intended to receive a mast-board to provide additional stability to the mast which would be bigger and heavier, in ships of big size and robust construction.

5.7 The Mast, the Mast-Step & the Mast Partners

Having established the distinguishing characteristics of the mast-step, the attention turns to the mast itself, an extremely scarce discovery amongst shipwrecks. The few examples that have hitherto been discovered provide new information or confirm evidence derived from the mast-step remains. The surviving examples have been already briefly mentioned (see Chapter 1) but they will be analyzed thoroughly and in relation to the mast-step, from a structural and functional point of view.

The possible mast found in Olbia (**Table 6, No. 6**) was *c.*7.87m in length, 42cm in diameter from the base of the mast and includes the foot, which ended in a semi-circular, 18cm long tenon. The preserved wooden element was broken at one end, but its longitudinal section (octagonal for the first 1. 34m and circular above) and the tenon at its base led scholars to interpret it as a mast (Gavini *et al.* 2014). Riccardi (2002: 268-269) states that this break is roughly at mid-length of the mast; thus, the preserved timber demonstrates that the mast's total length would have been 12-15m. Based on modern mast constructions, he concludes that this mast was intended for a ship, about 30-35m long. Casson (1971: 231-232) supports that the masts of the ancient ships were likely comprised of different wooden parts. It remains uncertain, however, whether the mast of Olbia was made of a single piece or two sections of wood.

A portion of a mast was also found at the Dramont E shipwreck (425-455 AD, **Table 6, No. 10**), in its original position, i.e. the main cavity. It is an exceptional example that shows the form of a mast's base, the shape of the mast's foot, as well as the way it was inserted into the main cavity. It was preserved to a height of 55cm, ending with a tenon, which was rounded at its front side and vertical at the back, in full correspondence with the curvature of the main cavity. The technological relationship between the main cavity and the particular shape of the tenon serves to the gradual pivoting of the mast and its lowering to the stern (Tchernia *et al.* 1978: 98; Nieto 1982: 165; Santamaria 1984: 107, 110; 1995: 164). The mast itself was not perfectly round and measured 27.5cm fore-and-aft and 23.5cm from side to side (**Fig. 55**). This mast would have been smaller than that of Olbia and intended for a vessel with an estimated length of 16m (Santamaria 1995: 176).

Figure 55: The mast base and the main cavity of the Dramont E mast-step (Santamaria 1984: 109, fig. 3).

Contemporaneous to the Dramont E, the Shipwreck D (5th century AD, **Table 6, No. 9**) (Ward & Ballard 2004) preserves a single-pieced mast in place, with the associated spars and deck structures. The length of the vessel has been estimated to 12-14m (Ward & Ballard 2004: 6-11). The length of the mast can only be only hypothesized, based on evidence provided through experimental archaeology on a similar-sized ship: For the *Kyrenia II* replica (14m long), a single-pieced mast was used, which was 10.5m in length, tapering upwards from 25cm to 10cm (Katzev & Katzev 1989: 164, 173). Thus, it stands to reason that the original length of the Shipwreck D mast would have been approximately the same.

The aforementioned evidence indicates that the ratio between the length of the hull and the height of the mast must be close to 2:3 (**Table 5**). Belov (2019: 94; 2020; 103) confirms this ratio for Ship 17 (S005, mid-5th – early 4th century BC); the height of the mast is estimated to 17-18m, based on the original vessel's length, of about 27-28m.

Shipwreck	Ratio	Mast Length (m)	Estimated Ship Length (m)
Ship 17 (S005)	2:3	17-18	27-28
Kyrenia (S007)	2:3	10.5	14
Shipwreck D (**Table 6, No. 9**)	2:3	(8-10)	12-14

Table 5: The ratio between the mast and the reconstructed length of a vessel.

The reconstructed length of a vessel, taking into account the ratio, allows the reconstruction of the mast height. In addition, the preserved mast-steps reflect another way to gather information about the masts. The footprint of the mast on the timber, as seen in Saint-Gervais 3 (S021, mid- 2nd century AD), the interpretation of possible preserved mast partners, as seen in Ma'aghan Mikhael (S006, *c.* 400 BC) and Kyrenia (S007, 310 – 275 BC) and mainly, the measured distance between the elongated mortises, provide an indication of the form, the diameter and the thickness of the mast.

Future research on ancient masts, in conjunction with experimental archaeology, is expected to shed more light on this aspect.

Mast Partners

The mast remained in place through the use of timbers arranged in such a manner that created a supporting system around it. The study of the mast partners contributes to the understanding of the complicated arrangement of the mast-step timber (Geannette 1983: 67) and, *vice versa*, the form of the latter is indicative of these structural elements that rarely survive. In this respect, Steffy (1994: 5-6) underlined the significance of reconstructing ancient hulls and their experimental usage, adding that *"an example of how modern models can be combined to solve problems may be seen in the mast-support studies"* (Steffy 1989: 253).

The Kyrenia's mast-step was discovered in a good state of preservation, along with two stanchion steps, port and starboard ceiling strakes and transverse-beams (Steffy 1985: 72, 87). By extending these beams, scholars noticed that they are reminiscent of those found in a Cypriot clay model, dated to the Archaic period (*c.*750 -500 BC) (Westerberg 1983: 28-31, Catalogue no. 32) (**Fig. 56**). The model depicts a complex mast-step arrangement in considerable detail: the transverse beams, the side supports, as well as the main cavity for housing the foot of the mast (Casson 1971: 65-66). It was these features of the clay model that were used for the reconstruction of the mast-support structure of *Kyrenia II*. The mast of the clay model, however, would be reclined in a forward direction, which is unusual; therefore the mast partner complex for the replica was constructed in such way that the mast could be reclined towards the stern (Geannette 1983: 14, 64-65; Steffy 1989: 253). Furthermore, the mast in the clay model would be stepped amidships, whereas in the replica is stepped forward, in correspondence with the archaeological evidence.

Figure 56: Teracotta merchant galley (c. 750-500 BC) (© British Museum).

The mast-step and the two stanchion steps preserved in the Kyrenia shipwreck, were precisely replicated in pine wood and used for *Kyrenia II* (Katzev & Katzev 1986: 10; 1989: 172) in the following manner: The transverse-beams that were discovered at the port side, were interpreted as partner beams and were used for supporting the mast. The aft partner beam ran across the hull, whilst the forward partner beam was penetrated exactly above the mast-step, in order to leave space for the retractable mast to be lowered aft. Both mast partner beams were secured in place by nails to a shelf clamp that runs on their underside (Katzev & Katzev 1989: 172; 1974: 622 - 623). Above them, partner shelves have been placed parallel to each side of the mast-step (**Fig**. **57**) (Katzev & Katzev 1989: 172).

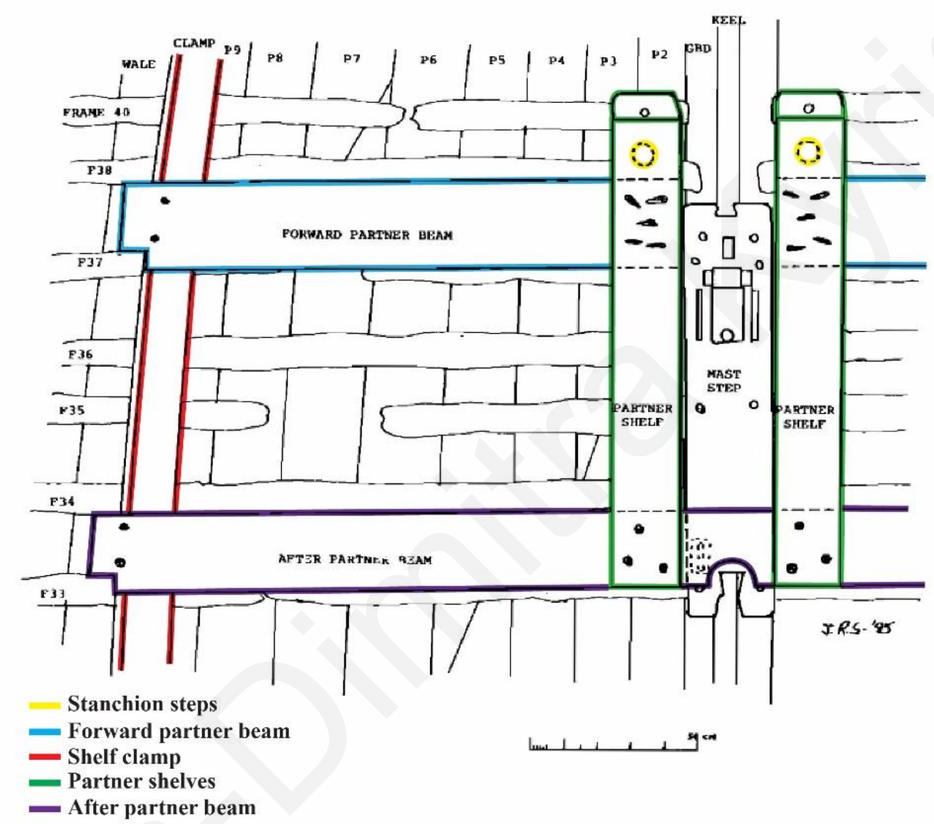


Figure 57: Top view of the reconstructed mast supporting system as used in the replica (based on Steffy 1989: 259, fig. 7).

Moreover, the aft partner beam was centrally supported by rectangular stanchions fitted into the cavities onto the mast-step. Partner shelves at their aft ends were nailed to and supported by the aft partner beam; at their forward part, they were supported by round stanchions placed into the stanchion steps. The forward partner beam was not supported by a stanchion pole but was instead nailed to the partner shelves on their underside (**Fig. 58**).

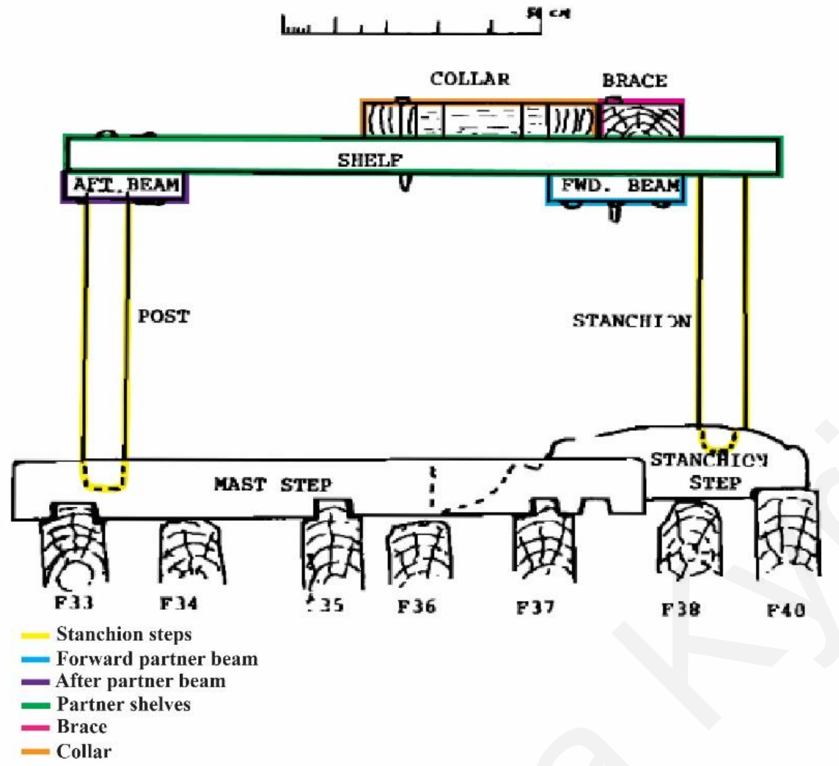


Figure 58: Side view of the reconstructed mast supporting system as used in the replica (based on Steffy 1989: 259, fig. 7).

On the top of the partner shelves, a collar consisting of two pieces, supported the mast; when the mast was to be lowered, these pieces could be removed. The brace in the forward part of the collar, which stabilized the entire mast complex, was also removable (Katzev & Katzev 1989: 172) (**Fig**. **59**).

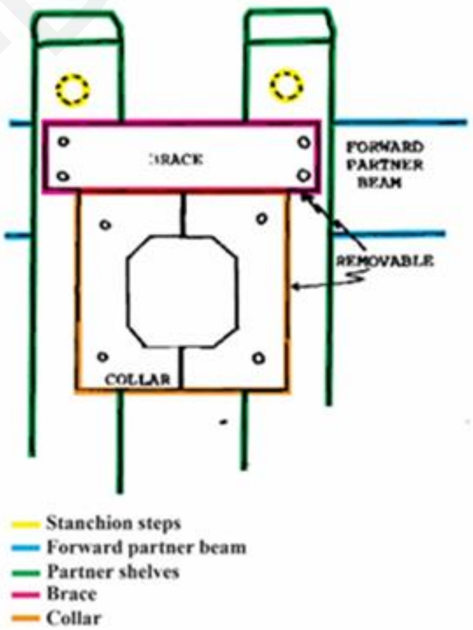


Figure 59: Top structures of the reconstructed mast supporting system as used in the replica (based on Steffy 1989: 259, fig. 7).

Foremasts

Merchant ships with a mainmast carrying a large rectangular sail and a second mast placed near the bow (foremast), carrying a sail called *artemon* or *spritsail*, are documented iconographically from at least 100 BC. This second mast must have been used mostly to balance and steer the vessel when sailing upwind and crosswind or when sailing on close-hauled courses, such as straits or harbours (Whitewright 2011: 8; 2016: 881; Davey 2015). The existence of a third mast at the stern (*mizzenmast*) is also documented iconographically, but it is not discussed here as there are no archaeological evidence for it throughout the period under examination. In contrast, archaeological evidence (even limited) for the existence of foremasts during the Roman period, do exist.

The present thesis includes two shipwrecks, of which the archaeological remains demonstrate the existence of a foremast: the Madrague de Giens (S010) and the Saint-Gervais 3 (S021) shipwrecks. In the case of the former, the cavity on the front extremity of the mast-step timber has been interpreted as the step on which a slanted foremast would be placed. The inclined form of the foremast has been proposed only on the basis of iconographic evidence (see above, **Fig. 54**) (Pomey 1982: 146-148; 1997: 180; Pomey & Rieth 2005: 68). The mainmast and the foremast must not have been placed far away from each other, taking into account that the total length of the Madrague de Giens mast-step is not more than 4 metres.

Saint-Gervais 3 preserves a second cavity to the front extremity of the keelson, intended to receive a straight foremast (Liou & Gassend 1990: 223; Davey 2016: 41). Beltrame (1996: 135) aptly notes that 'these steps differ from the slots in the mainmasts because of their very advanced position in the bows and because of the absence of elements supporting the mast'. The closest iconographic parallel can be seen in a graffito (1^{st}-4^{th} c. AD) form the Roman Villa at Cucuron (Vaucluse, France), showing a foremast-stepped into the keel, angled forward (**Fig. 60**) (Gassend *et al.* 1986: 24-25). In addition, possible excavated parallels can be deduced from four Roman shipwrecks, although evidence is fragmentary or inadequately reported, thus any further comparison should be done with caution. All four wrecks were discovered in Italy - at Punta Ala (Livorno), Torre Santa Sabina (Brindisi), Procchio (Elba) and Torre Sgarrata (Puglia) (Geannette 1983: 27; Beltrame 1996: 135-136).

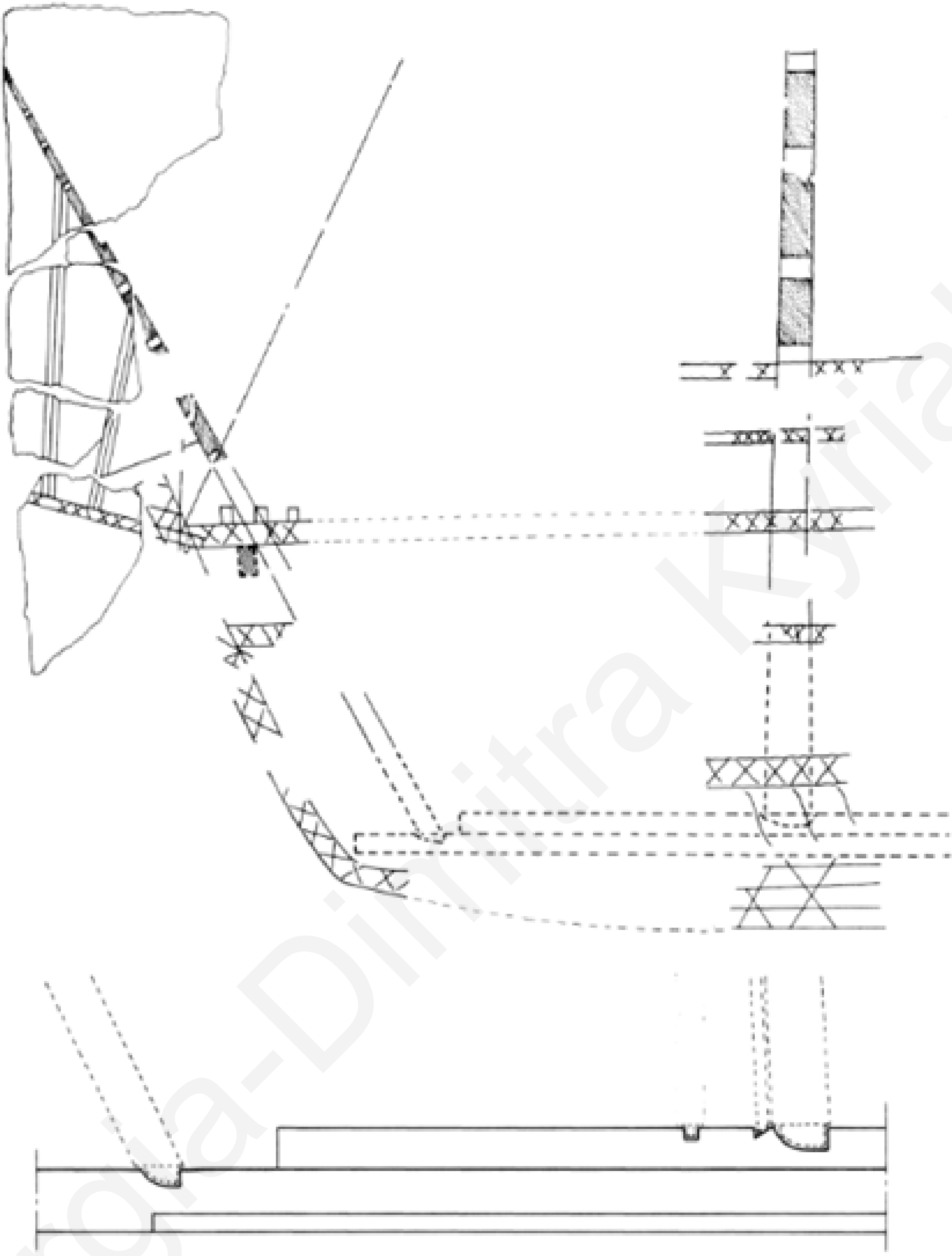


Figure 60: A graffito (1st-4th c. AD) from the Roman Villa at Cucuron (Vaucluse); the mast-steps of Saint-Gervais 3. Note the similarity for the stepping of the masts (Gassend et al. 1986: 25).

No.	Shipwrecks	Place/Date	Feature	Bibliography
1	Mazarrón 1	Spain, 650 - 600 BC	Mortises on the keel	De Juan 2014; Tejedor 2018
2	Jules-Verne 9	France, end of the 6th century BC	Reconstruction of the mast-step timber (based on the Bon-Porté 1mast-step)	Pomey 2003; Pomey & Poveda 2018
3	Jules-Verne 7	France, end of the 6th century BC	Reconstruction of the mast-step timber (based on the Gela 1 mast-step)	Pomey 2003
4	Albenga	Italy, 100-80 BC	Portion of mast	Lamboglia 1952
5	Titan wreck	France, mid-1st century BC	First evidence of a keelson fastened to the keel	Basch 1972
6	Olbia	Sardinia, 1st century AD	Possible mast	Riccardi 2002; Gavini *et al.* 2014
7	La Bourse (Lacydon)	France, 190–220 AD	Bolts	Gassend & Cuomo 1982
8	Marausa	Sicily, late 3rd–early 4th century AD	Sister-keelsons	Tiboni & Tusa 2016
9	Shipwreck D	Black Sea, 5th century AD	Portion of mast	Ward & Ballard 2004
10	Dramont E	France, 425-455 AD	Portion of mast	Santamaria 1984; 1985

Table 6: Shipwrecks (in chronological order) which are not part of the corpus but are used as supplementary evidence in the analysis and interpretation.

Chapter 6: Conclusions

The purpose of this thesis was to examine and interpret the available archaeological data regarding a specific structure of ancient sailing ships, the mast-step. The mast-step is a very rare discovery amongst shipwrecks that preserve hull remains, a fact which makes the tracing of its structural evolution difficult. The information provided by the excavated evidence, especially before the Roman period, appears to be limited. Nevertheless, the examination and interpretation of the archaeologically attested mast-steps, can significantly contribute to our knowledge regarding the development of ancient shipbuilding.

From the structural and typological analysis, it became obvious that shipbuilding technology is neither linear nor limited within certain norms. Many shipwrecks which belong to the same era could present a similar mast-step, despite the fact that their general hull construction varies significantly. Moreover, some mast-steps of the same shipbuilding tradition may present totally different designs.

The transition from mast-step to keelson/mast-step also appeared to be a long and complex evolutionary phenomenon. Taking into account the different forms and the diverse development of the mast-step, the formulation of a structural typology seemed to be the only way to detect the changes occurred in the principles of its construction. By dividing the mast-step into its individual features and through their close inspection, it was possible to understand this structure and interpret its function through the passage of time.

Three systems of mast-step placement into the hull were detected throughout the period under examination. These types, when are combined with the comparative data between vessels of the same type and shipbuilding tradition, have been proven extremely useful to the reconstruction of the mast-step, in the cases when the timber does not survive in the archaeological record or is badly eroded.

Another important aspect under consideration is the position of the mast-step into the hull. During the Archaic period the mast-step is placed in the central part of the vessel, but by the end of the Hellenistic period, the location of the mast can be precisely calculated to 3/8 of the length of the vessel from the bow (or 5/8 from the stern). The ability of a movable mast-step is also discussed. It echoes the pioneering character and novelty in the structural design, as well as the technological knowledge of ancient shipbuilders.

The upper surface of the mast-step can also provide information regarding the function of the mast and the mast partners. Furthermore, the curvature of the main cavity can serve to distinguish which end of the ship corresponds to the bow and which to the stern and, consequently, which side corresponds to the starboard and which to the port side of the vessel. This information is of vital importance for the study and interpretation of ancient shipwrecks. Moreover, the arrangement of the adjacent cavities can reveal information concerning the chronological evolution, providing valuable insights for the structural development.

The aforementioned information is of particular significance for the interpretation of the element for which the mast-step was constructed, i.e. the mast, which is rarely preserved. Even though the archaeological remains of Mediterranean masts are extremely limited, the evidence provided by the mast-steps, iconography and experimental archaeology, can offer important insights. The reconstructed length of a vessel (taking into account the suggested ratio of 2:3), permits the reconstruction of a mast's height. The footprint of the mast on the mast-step timber itself, the interpretation of possible preserved mast partners but, mainly, the measured distance between the adjacent cavities, can provide indications of the form, diameter and thickness of a mast. Through experimental archaeology such information can be evaluated and used to hypothetically reconstruct an ancient ship's mast, which can be subsequently tested and revised according to trials.

Throughout the period under examination, only two shipwrecks provide information about two-masted ancient sailing ships. The iconographic evidence is proved as the most useful tool for their study and interpretation, revealing remarkably precise information. This important element requires further study.

Further research is necessary to determine the relationship between the mast-step and the mast and, consequently, the sails and the rigging. The iconographic evidence can contribute significantly to the analysis and interpretation of this system. This examination can also benefit from experimental archaeology, by replicating ancient sailing vessels (physical and digital replicas). In this manner, other issues, for instance, the hydrodynamic properties, stability and seaworthiness of the sailing ship can be tested, according to these elements.

In conclusion, it becomes clear that the mast-step has become a telltale structural component in the history of ancient shipbuilding and sheds light on different aspects of ancient seafaring. Shipwrights over the centuries, through trial and error, intellectual and manual labor, achieved to build of seaworthy vessels, which were able to sail throughout the Mediterranean.

Glossary

This glossary is essentially concerned with the terms used in this dissertation. It is based on previous glossaries (Steffy 1985; 1994; Kahanov 2003; Hocker 2004).

Amidships: A contraction of midships, i.e. the middle of a vessel, either longitudinally or transversely.

Bilge sump: The cavity or compartment in the bottom of a hull, usually near amidships, where bilge water is collected and from which it was pumped out or bailed.

Bow: Forward part of a hull, specifically, from the point where the sides curve inwards to the stem.

Ceiling: The internal planking of a vessel (i.e. attached to the top of the internal frames and onto which the cargo, etc. was stored).

Cross-beams: A substantial timber placed across a pair of bitts.

False Keel: A plank, timber, or timbers attached to the bottom of the keel to protect it in the event of grounding or hauling; on large ships, false keels were sometimes made quite thick in order to increase the size and strength of the keel.

Floor-Timber: A framing member which was centered over the keel and whose arms spanned both sides of the bottom of the hull.

Frame: A transverse timber, or line or assembly of timbers, that describe the body shape of a vessel and to which the planking and ceiling were fastened.

Futtock: A frame timber other than a floor-timber, half-frame, or top timber; one of the middle pieces of a frame.

Half-frame: A timber which commenced near the keel and spanned the bottom and part of the side of a hull. Half-frames were used in pairs, one on each side of the keel.

Mast: Principle length of wood from which rigging and sails are suspended.

Mast Boards: Vertical planks fitted on mortises around the main cavity of the mast-step, for supporting the mast.

Mast partners: Fore-and-aft beams that helped support a mast where it pierced a deck; also called **mast carlings**.

Mortise-and-tenon joint: A union of planks or timbers by which a projecting piece (tenon) was fitted into one or more cavities (mortises) of corresponding size.

Keel: The main longitudinal timber(s) of most hulls upon which the frames, deadwoods, and ends of the hull were mounted: the backbone of the hull.

Keelson: an internal keel, mounted on top of the floor-timbers and directly above the keel, which provided additional longitudinal strength to the hull.

Limber holes: Channels cut into the bottom surfaces of frames to permit the passage of bilge water.

Planking: The outer lining, or shell, of a hull.

Port: The left side of a vessel when facing forward.

Rabbet: A groove or channel cut into the edge or surface of a timber, usually to receive the edge of a plank.

Retractable (Mast): The mast that is able to be removed by tilting backwards.

Shell-first construction [Shell-built]: A modern (sometimes misleading) term used to describe the process by which all or part of the outer hull planking was erected before frames were attached to it. In pure shell-built hulls, outer planking was self-supporting and formed the primary structure; the framework fastened to it formed the secondary, or stiffening, structure.

Sister-Keelsons: Auxiliary (short) keelsons attached alongside the main keelson

Skeletal construction [Frame-first construction]: A modern (sometimes misleading) term used to describe the procedure in which hulls were constructed by first erecting frames and then attaching the outer skin of planking to them.

Stanchion: An upright supporting post, including undecorated supports for deck beams and bulkheads.

Starboard: The right side of a vessel when facing forward.

Stempost: A vertical or upward-curving backbone timber or assembly of timbers, scarfed to the keel or central plank at its lower end, into which the two sides of the bow were joined.

Stringer: A heavy, longitudinal timber, such as a clamp, on the interior of the vessel.

Stern: The aft end of a vessel.

Sternpost: A vertical or upward-curving timber or assembly of timbers stepped into, or scarfed to, the after end of the keel or heel.

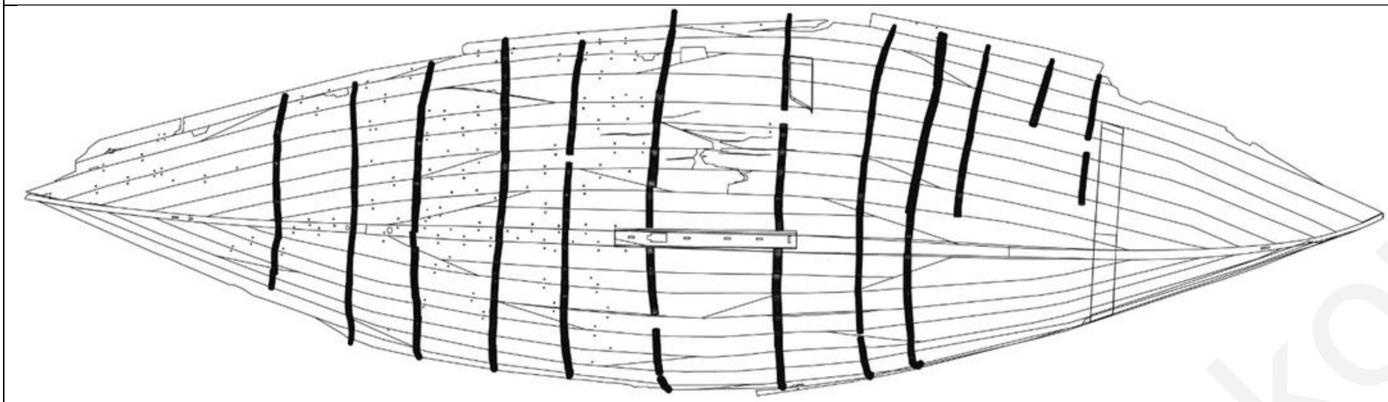
Wale: A thick strake of planking or a belt of thick planking strakes located along the sides of a vessel for the purpose of girding and stiffening the outer hull.

Appendix – The Shipwrecks

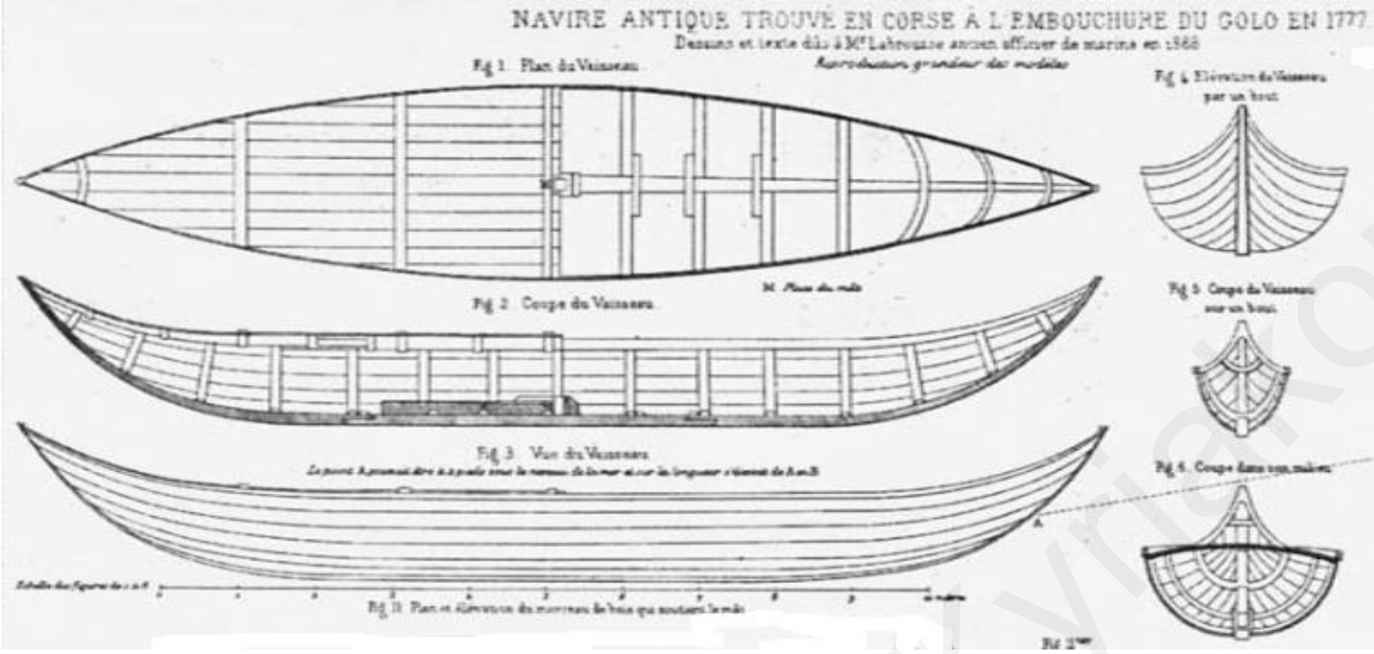
The Shipwrecks discussed in this thesis are listed here in chronological order, accompanied with an ID number prefixed by the letter ‘S’. In the main text, each shipwreck is followed by its ID number: e.g. S001 stands for Shipwreck 001 – Mazarrón 2.

References to Parker’s catalogue correspond to wreck numbers rather than the pages.

Hull schematics are provided for a better understanding and general view of the vessels’ construction.

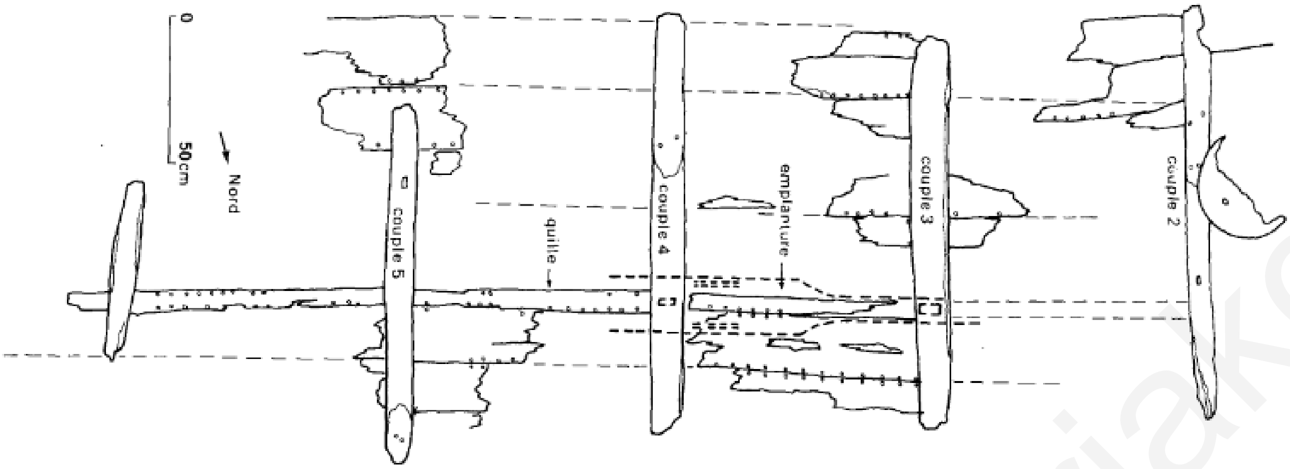
Mazarrón 2 (S001)	
 Miñano 2014: 4, fig. 2	
Location	Murcia, Cartagena, Spain
Date	625-570 BC
Research	Discovered in 1988 and excavated in 1999-2001
Preserved (Length x Beam) (m)	8 x 3
Reconstructed (Length x Beam) (m)	8.15 x 2.25
Construction Principle	Shell-First
Lateral Section	Round Bottom
Planking Assembly	M&T, sewn on few strakes
Description	coaster
Shipbuilding Tradition	Iberian Tradition with Punic Influence
Bibliography	Negueruela 2004; Miñano 2014; De Juan 2014; Tejedor 2018; Pomey & Boetto 2019

Golo (S002)

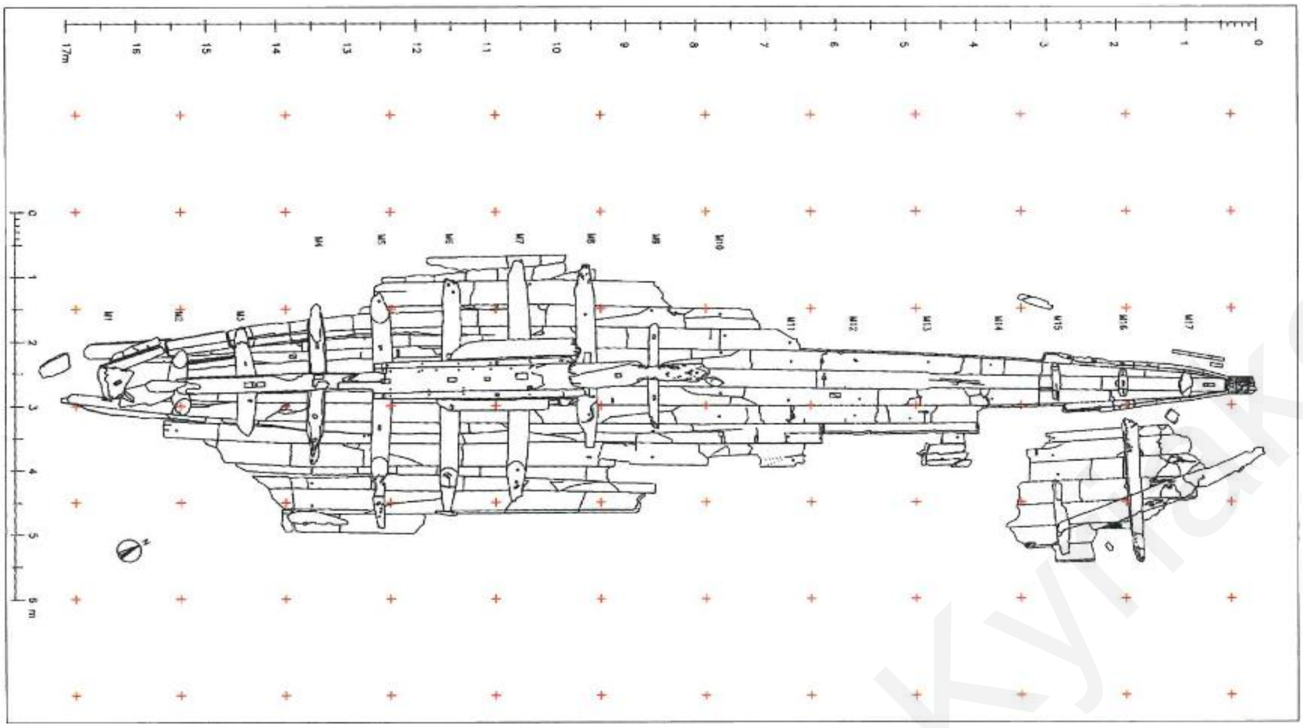


Dell' Amico 2008: 14, fig. 2

Location	Near the mouth of Golo, Corsica, France
Date	6th c. BC
Research	1777
Preserved (Length x Beam) (m)	14 x 2.6
Reconstructed (Length x Beam) (m)	N/A
Construction Principle	Shell-First
Lateral Section	Round Bottom
Planking Assembly	M&T
Description	Coastal or lagoon boat
Shipbuilding Tradition	Iberian Tradition with Punic Influence
Bibliography	Parker 1992: No. 460; Pomey 2012; Pomey & Boetto 2019

Bon-Porté 1 (S003)	
 Joncheray 1976: 24	
Location	Bay of Bon-Porté, Saint-Tropez, France
Date	540-510 BC
Research	Discovered and excavated in 1974
Preserved (Length x Beam) (m)	4 x 2
Reconstructed (Length x Beam) (m)	10 x c. 6
Displacement (tons)	20
Construction Principle	Shell-First
Lateral Section	Round Bottom
Planking Assembly	Sewn
Description	Small boat
Shipbuilding Tradition	Greek (Original Phase)
Bibliography	Joncheray, J.-P., 1976; Pomey 1981; Geannette 1983; Parker 1992: No. 106; Kahanov & Pomey 2004; Pomey & Boetto 2019

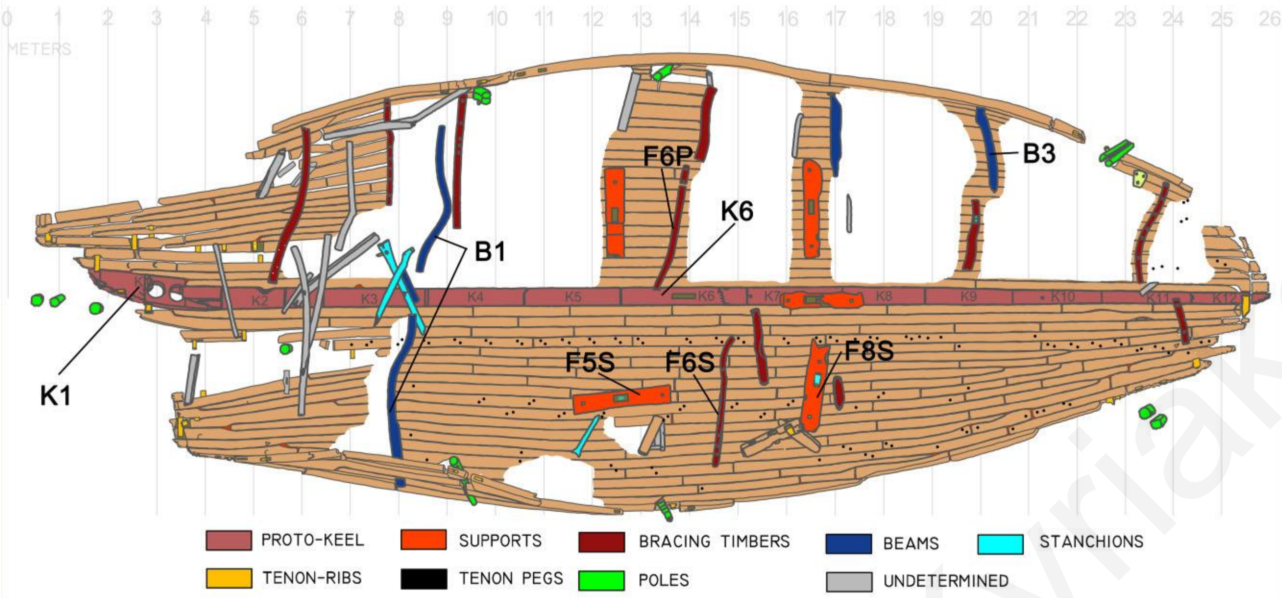
Gela 1 (S004)



Benini 2017: 409, fig. 1

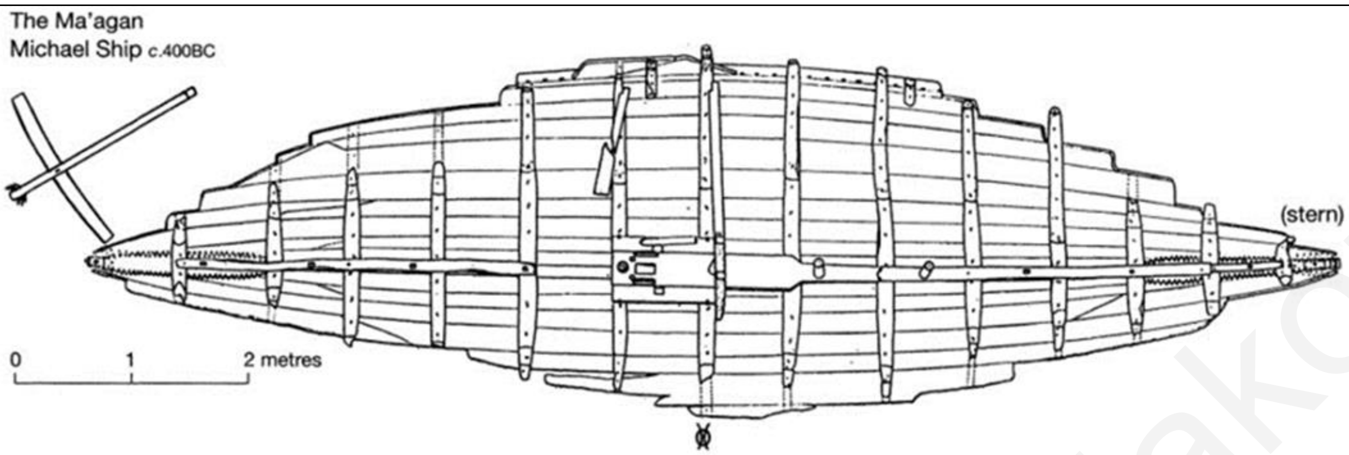
Location	Southern shore of Gela, Sicily, Italy
Date	500-480 BC
Research	Discovered and excavated in 1988
Preserved (Length x Beam) (m)	18 x 6.8
Reconstructed (Length x Beam) (m)	22/25 - ?
Construction Principle	Shell-First
Lateral Section	Round Bottom
Planking Assembly	Sewn, M&T on the extremities
Description	Large cargo ship
Shipbuilding Tradition	Greek (Transition phase)
Bibliography	Parker 1992: No. 441; Panvini 2001; Kahanov & Pomey 2004; Pomey & Boetto 2019; Benini 2017

Ship 17 – Thonis Herakleion (S005)

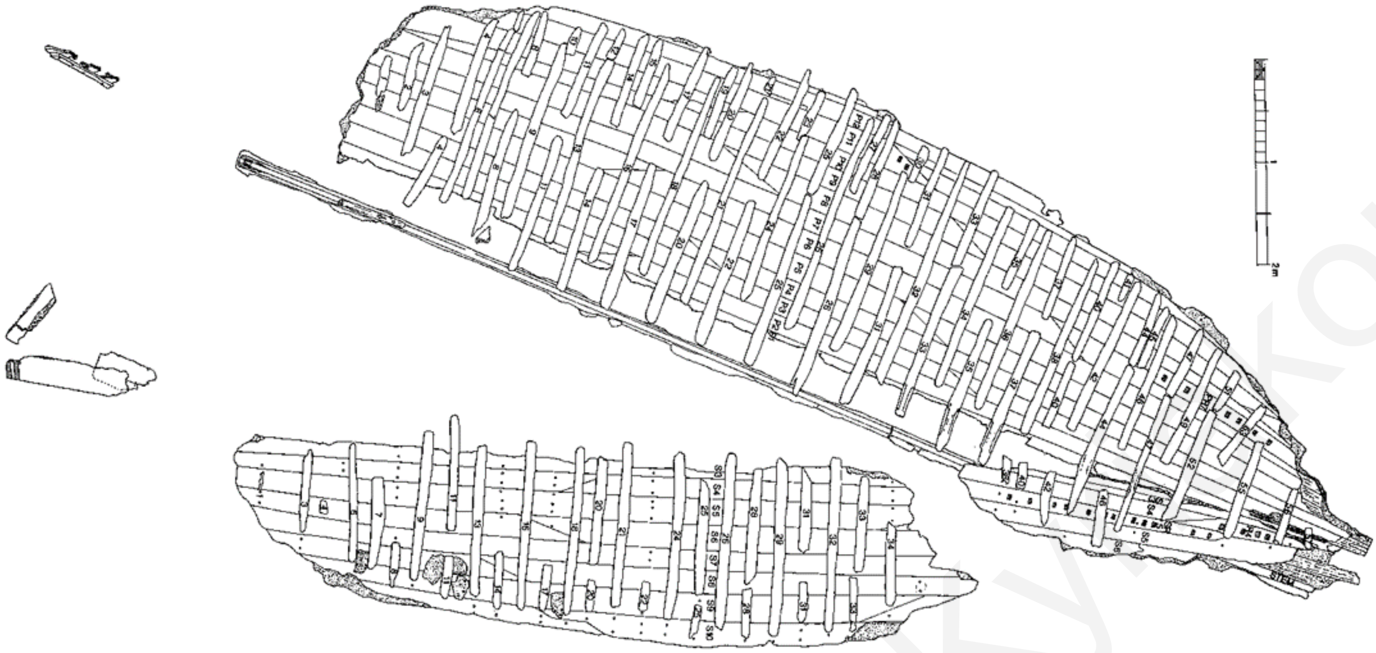


Belov 2014: 2, fig. 2

Location	Thonis - Herakleion, Egypt
Date	Mid-5th - early 4th c. BC
Research	Discovered in 2003 and excavated in 2009-2011
Preserved (Length x Beam) (m)	24.2 x 9.4
Reconstructed (Length x Beam) (m)	27-28 x 8
Construction Principle	Shell-First
Lateral Section	crescent-shaped, flat-bottomed
Planking Assembly	M&T
Description	Nilotic freighter, named by Herodotus (History, 2.96) *as baris*
Shipbuilding Tradition	New Type?
Bibliography	Belov 2104; 2015; 2019; 2020

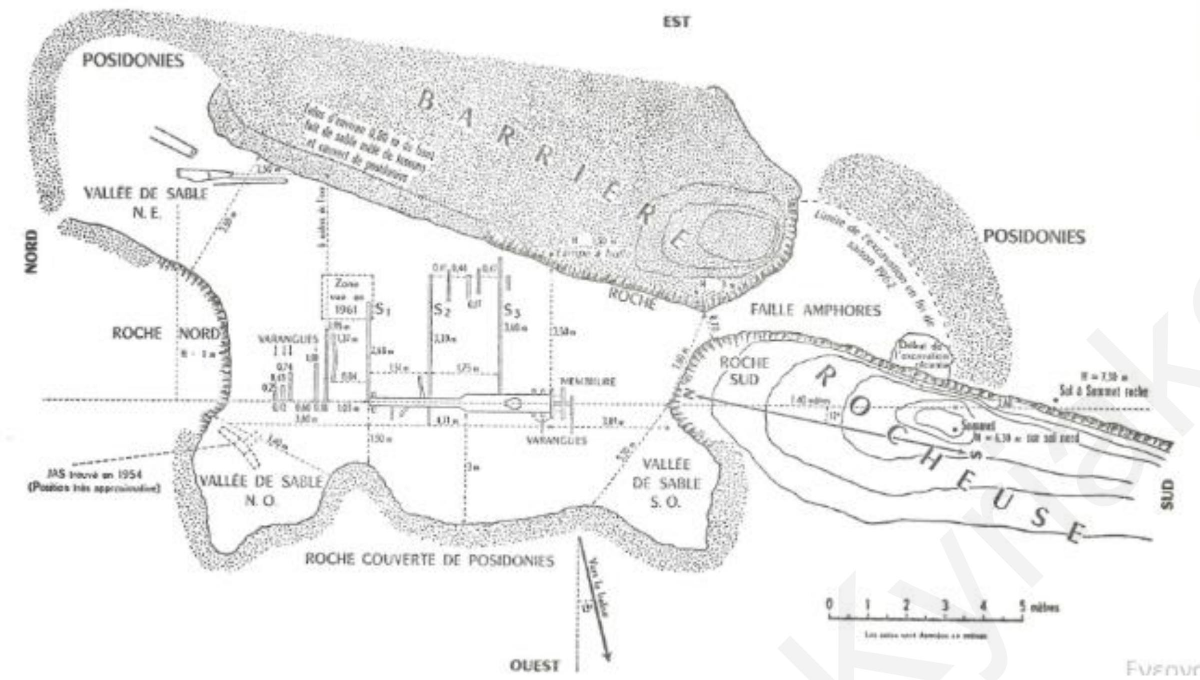
Ma‘agan Mikhael (S006)	
 McGrail 2001: 136, fig. 4.33	
Location	Off shore of Kibbutz Ma‘agan Mikhael, Israel
Date	*c.* 400 BC
Research	Discovered in 1985 and excavated in 1988 - 1989
Preserved (Length x Beam) (m)	11.15 x 3.11
Reconstructed (Length x Beam) (m)	13.5 x 4
Displacement (tons)	22.9
Construction Principle	Shell-First
Lateral Section	Wine - glass
Planking Assembly	M&T, sewn at bow and stern
Description	Small cargo ship
Shipbuilding Tradition	Greek (Development phase)
Bibliography	Parker 1992: No. 612; Kahanov 1998; 2003; 2011; Kahanov & Pomey 2004; Pomey *et al.* 2012

Kyrenia (S007)

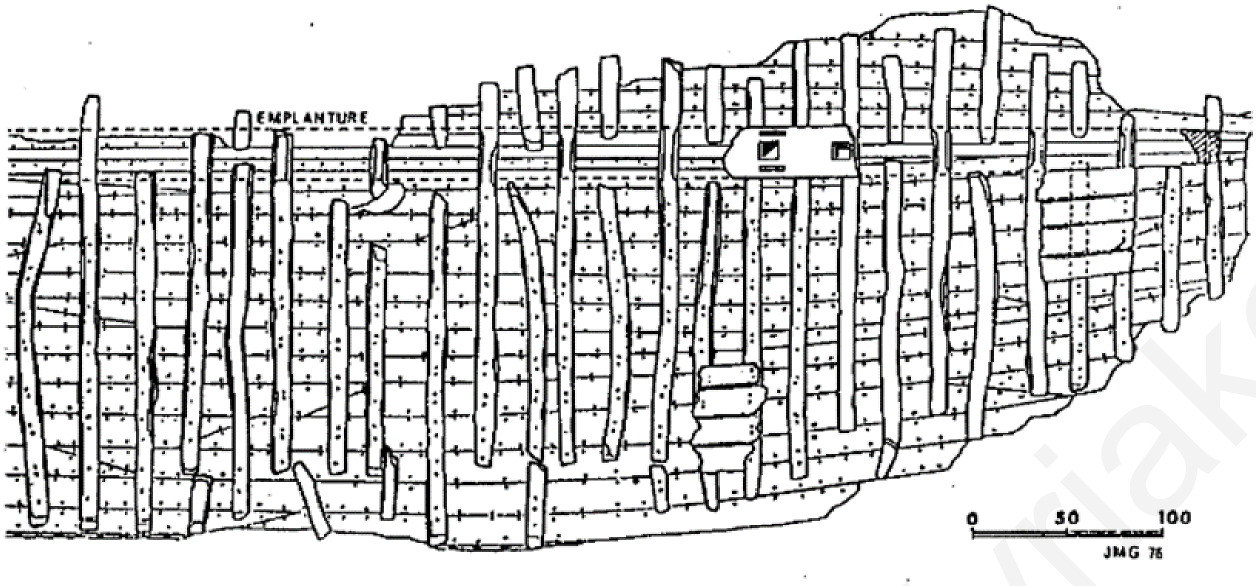


Steffy 1985: 76, ill. 2

Location	Kyrenia, northern coast of Cyprus
Date	310 – 275 BC
Research	Discovered in 1965 and excavated in 1968-1969
Preserved (Length x Beam) (m)	12 x 6
Reconstructed (Length x Beam) (m)	14 x 4.2
Displacement (tons)	20+
Construction Principle	Shell-First
Lateral Section	Wine - glass
Planking Assembly	M&T, reuse of a sewn plank as ceiling
Description	Cargo ship
Shipbuilding Tradition	Greek (Final Developments)
Bibliography	Parker 1992: No. 563; Geannette 1983; Steffy 1985, 1994; Kahanov & Pomey 2004; Pomey & Boetto 2019

Chrétienne A (S008)	
 Dumas 1974: 120, fig. 72	
Location	Off Anthéor, France
Date	150-100 BC
Research	Discovered in 1948
Preserved (Length x Beam) (m)	5 x 3.5
Reconstructed (Length x Beam) (m)	(24-32) x ?
Displacement (tons)	200
Construction Principle	Shell-First
Lateral Section	Wine-glass
Planking Assembly	M&T
Description	Cargo ship
Shipbuilding Tradition	N/A
Bibliography	Dumas 1964; Geannette 1983; Parker 1992: No. 302

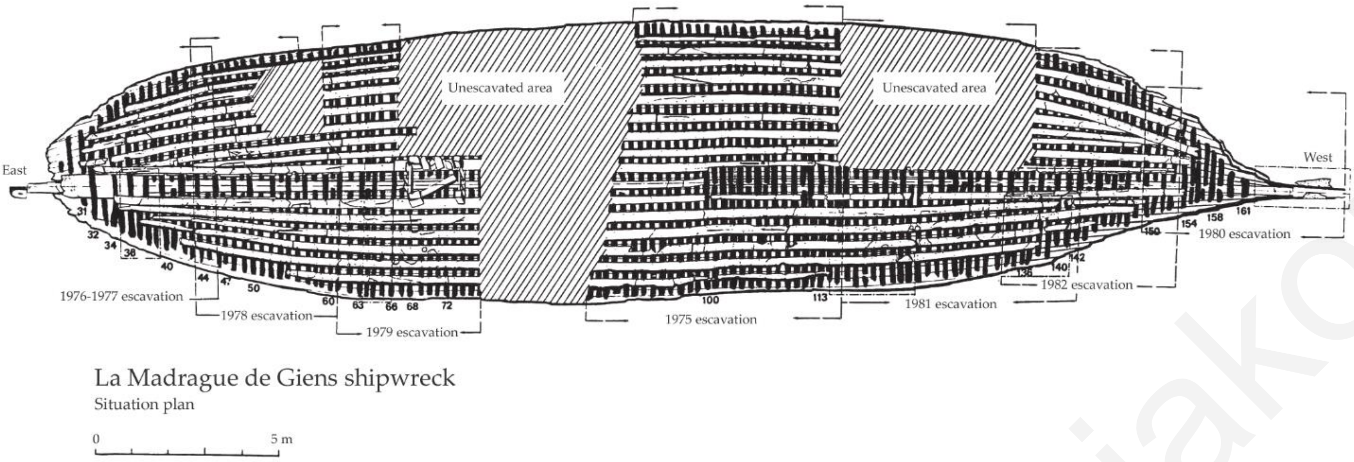
Cavalière (S009)



Charlin et al. 1978, fold-out

Location	Cove of Cavalière, Le Lavandou, France
Date	110-90 BC
Research	Excavated in 1972-1975
Preserved (Length x Beam) (m)	13 x 3
Reconstructed (Length x Beam) (m)	12.98 x 5
Displacement (tons)	27
Construction Principle	Shell-First
Lateral Section	Flat bottom; sharp bottom; Round turn of the *bilge*
Planking Assembly	M&T, sewn as part of the superstructure and as repair in the stern / internal lashings
Description	small coaster
Shipbuilding Tradition	North-western Mediterranean Tradition (group 1)
Bibliography	Liou 1975; Charlin *et al*. 1978; Geannette 1983; Parker, 1992: No. 282; McGrail 2001; Pomey & Boetto 2019

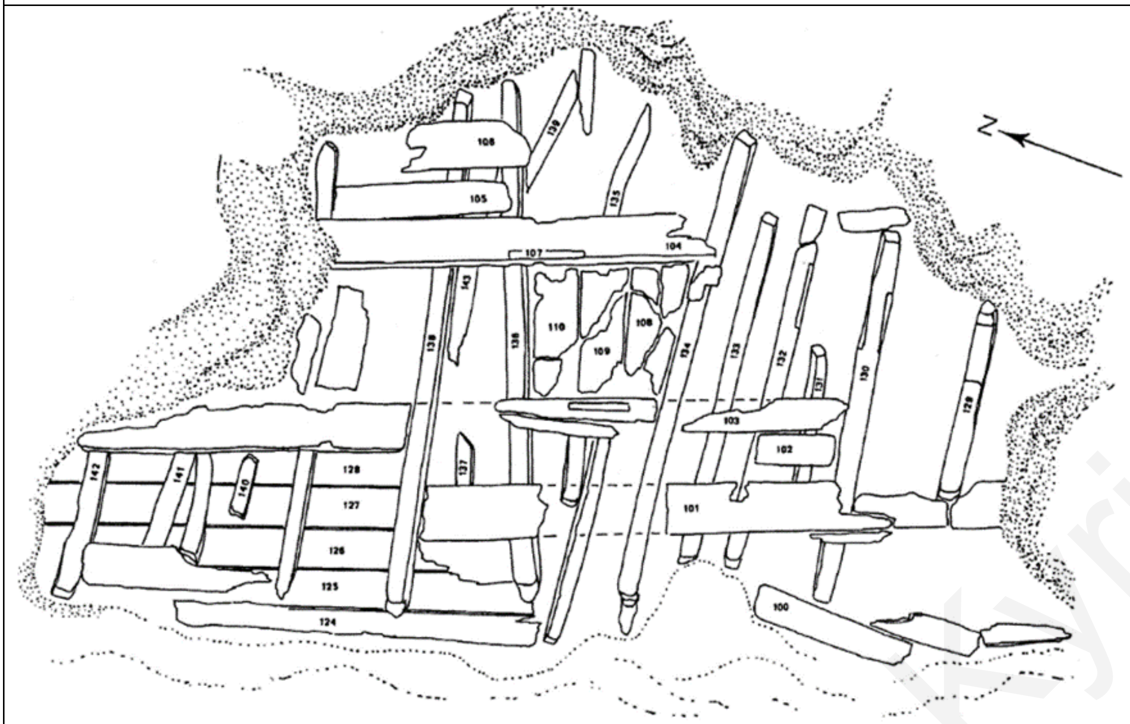
Madrague de Giens (S010)



Pomey 2020: 33, fig. 3.5

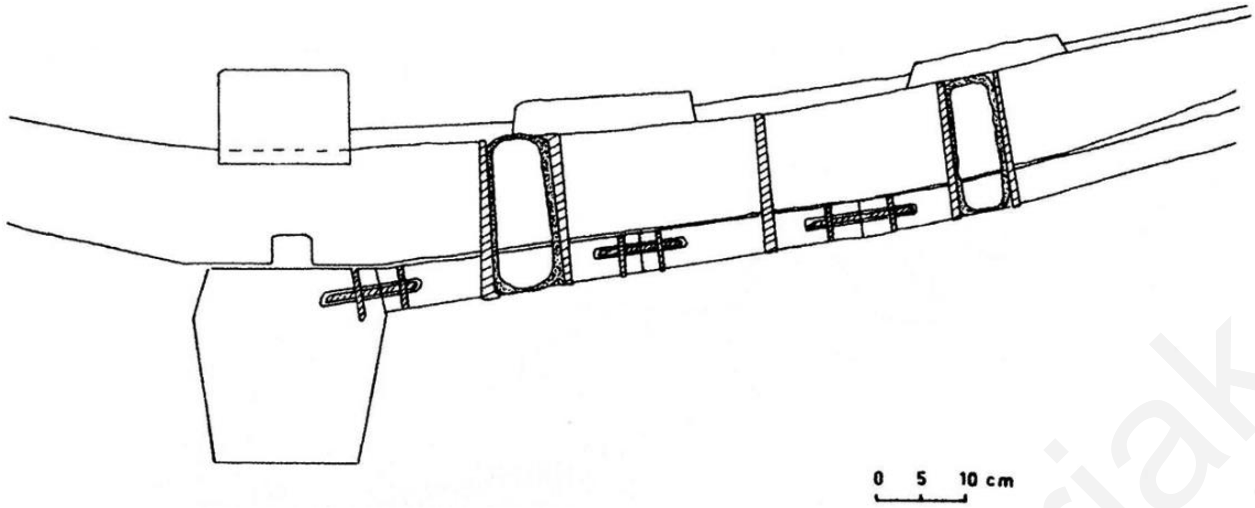
Location	Port of La Madrague, Giens peninsula, France
Date	75-60 BC
Research	Excavated in 1972-1982
Preserved (Length x beam) (m)	35.10 x 12
Reconstructed (Length x beam) (m)	40 x 9
Displacement (tons)	400
Construction Principle	Shell-First
Lateral Section	Wine Glass
Planking Assembly	M&T
Description	seagoing large merchantman, *myriophoros* (a ship capable of carrying 10,000 amphorae, or 500 tons of deadweight)
Shipbuilding Tradition	N/A
Bibliography	Tchernia *et al.* 1978; Pomey 1982; 2011; 2020; Gennette 1983; Pomey & Tchernia 1978; Parker 1992: No. 616

Plane 1 (S011)

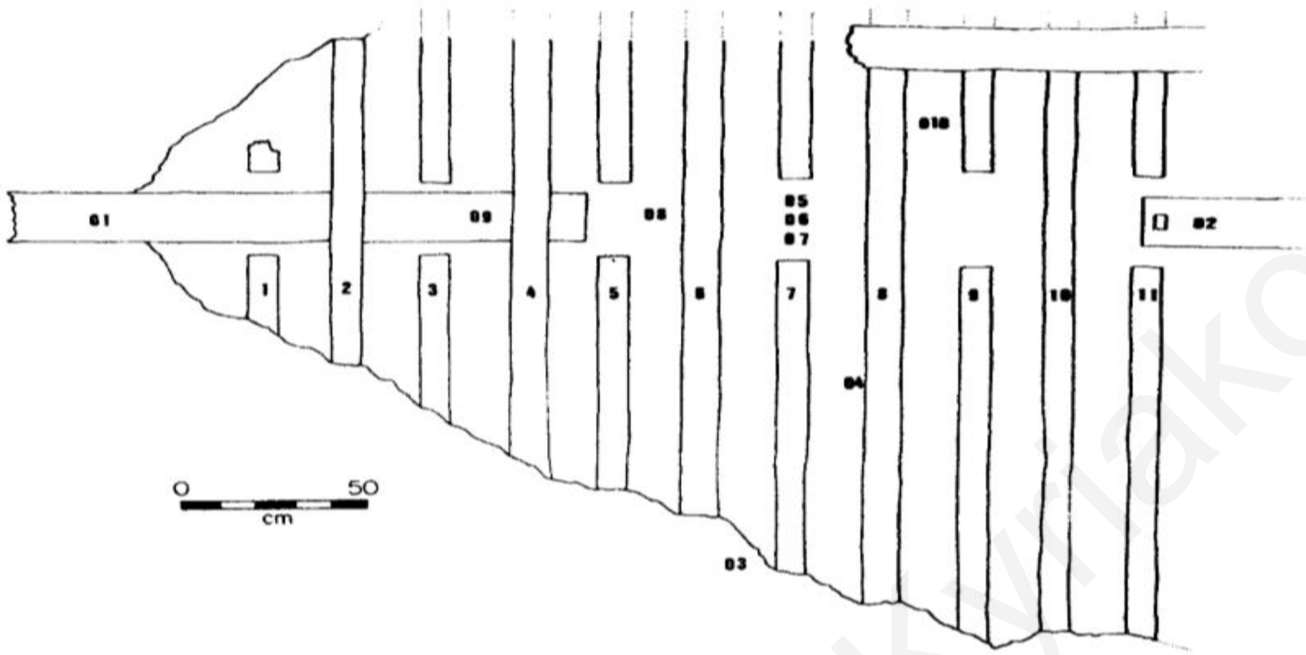


Pomey & Boetto 2019: 39, fig. 38

Location	Marseilleveyre archipelago, Bay of Marseilles, France
Date	Mid-1st century BC
Research	Discovered in 1975. The hull was partially recorded in 1992.
Preserved (Length x Beam) (m)	4.50 X 3
Reconstructed (Length x Beam) (m)	N/A
Construction Principle	Shell-First
Lateral Section	sharp bottom
Planking Assembly	M&T / internal lashings
Description	small coaster
Shipbuilding Tradition	North-western Mediterranean Tradition (group 1)
Bibliography	Liou & Pomey 1985; Parker 1992: No. 819; Pomey & Boetto 2019

Cap Béar 3 (S012)	
 Pomey & Boetto 2019: 37, fig. 35a	
Location	off the French coast, between Port-Vendres and the Spanish border
Date	50-25 BC
Research	1982-1986
Preserved (Length x Beam) (m)	8.2 x 8.7 m
Reconstructed (Length x Beam) (m)	15
Construction Principle	Shell-First
Lateral Section	Sharp bottom
Planking Assembly	M&T
Description	small coaster
Shipbuilding Tradition	North-western Mediterranean Tradition (group 1)
Bibliography	Parker 1992: No. 171; Marlier 2005; McGrail 2001; Pomey & Boetto 2019

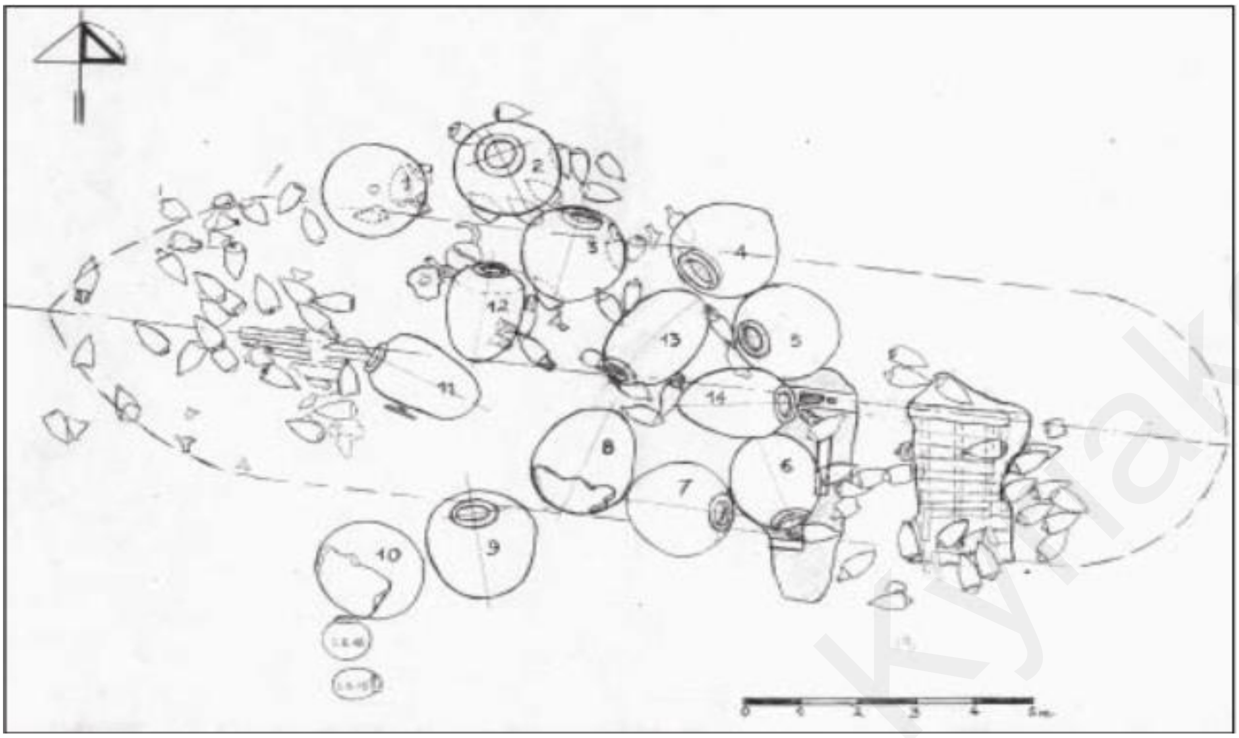
Cap de Vol (S013)



Foerster 1980: 245, fig. 1

Location	Cap Creus, Catalonia, Spain
Date	10-5 BC /beginning of the 1st century AD
Research	Excavated in 1978
Preserved (Length x Beam) (m)	N/A
Reconstructed (Length x Beam) (m)	18-20 x ?
Displacement (tons)	50
Construction Principle	Shell-First
Lateral Section	Flat bottom
Planking Assembly	M&T, internal lashings
Description	Fuvio-maritime vessel adapted to navigating the coasts of Catalonia and the Narbonne region
Shipbuilding Tradition	North-western Mediterranean Tradition (group 2)
Bibliography	Foerster 1980; Geannette 1983; Parker 1992: No. 186; Pomey & Boetto 2019

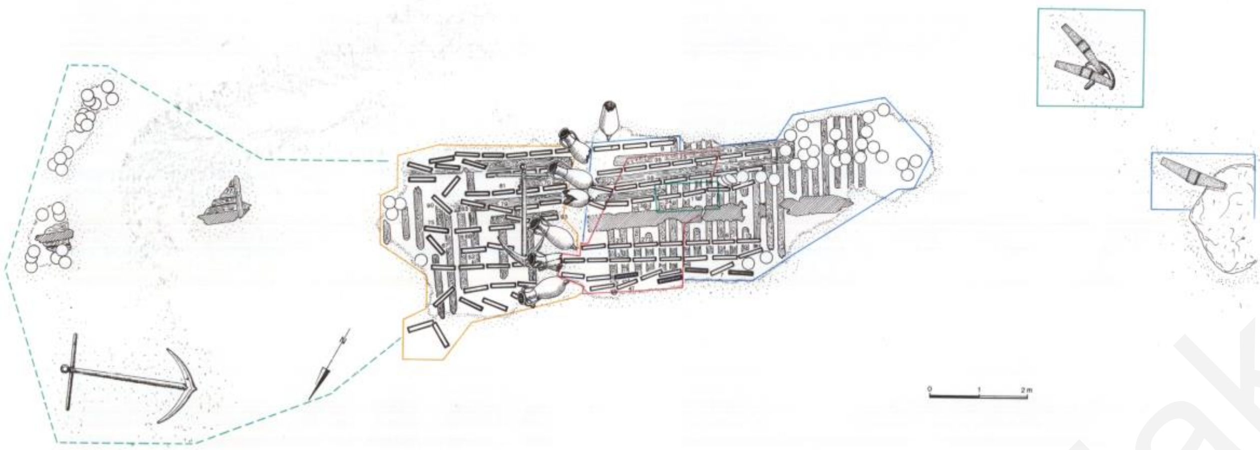
Diano Marina (S014)



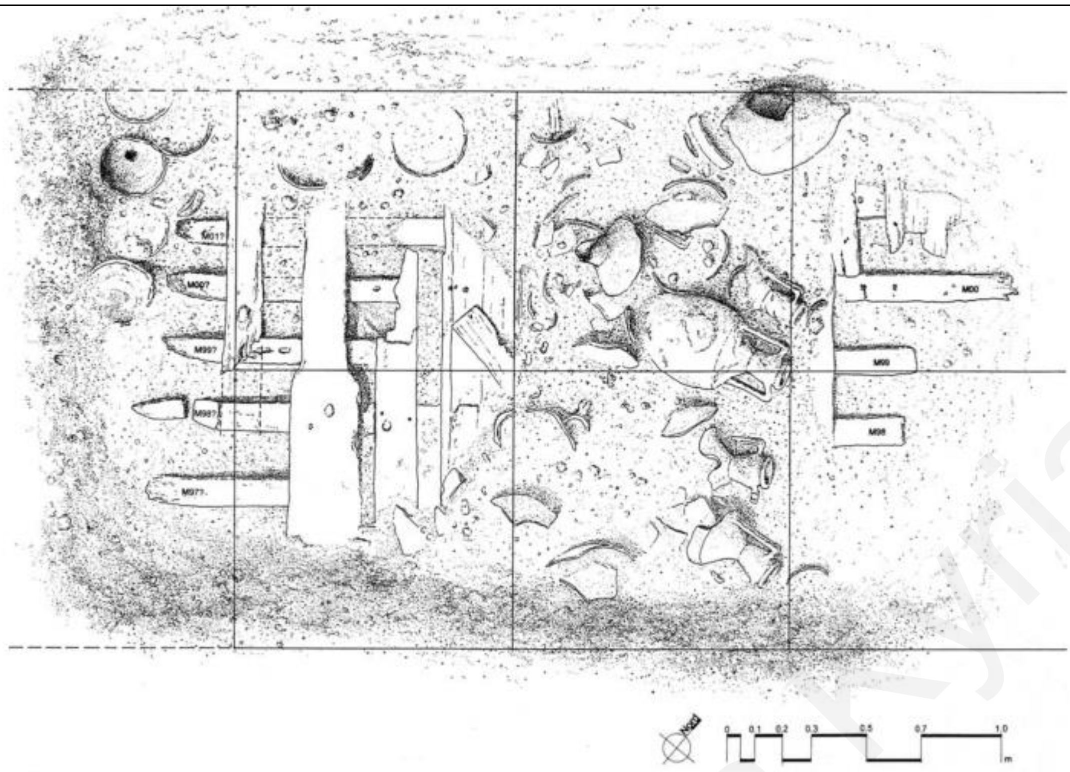
Dell' Amico & Pallarés 2005: 69, fig. 2

Location	Diano Marina, Liguria, Italy
Date	25 – 75 AD (mid-1st century AD)
Research	Excavated in 1976-1981
Preserved (Length x Beam) (m)	4.5 x
Reconstructed (Length x Beam) (m)	20-22 x 6
Construction Principle	Shell-First
Lateral Section	-
Planking Assembly	?
Description	Dolia ship, i.e. a merchantman, that carried *dolia* (large earthenware vessel used in Roman times for storage or transportation of goods)
Shipbuilding Tradition	N/A
Bibliography	Parker 1992: No. 364; Dell'Amico & Pallarés 2005

Caska 2 (S015)	
 Boetto & Rossi 2015: 284, fig. 9	
Location	bay of Caska, Pag island, Croatia
Date	1^{st} c. BC – 1^{st} c. AD
Research	2013-2015
Preserved (Length x Beam) (m)	13 x 4
Reconstructed (Length x Beam) (m)	-
Construction Principle	Shell-First
Lateral Section	Flat bottom
Planking Assembly	M&T
Description	scuttled ship, as part of a large breakwater
Shipbuilding Tradition	N/A
Bibliography	Boetto & Rossi 2015; Rossi & Boetto 2020

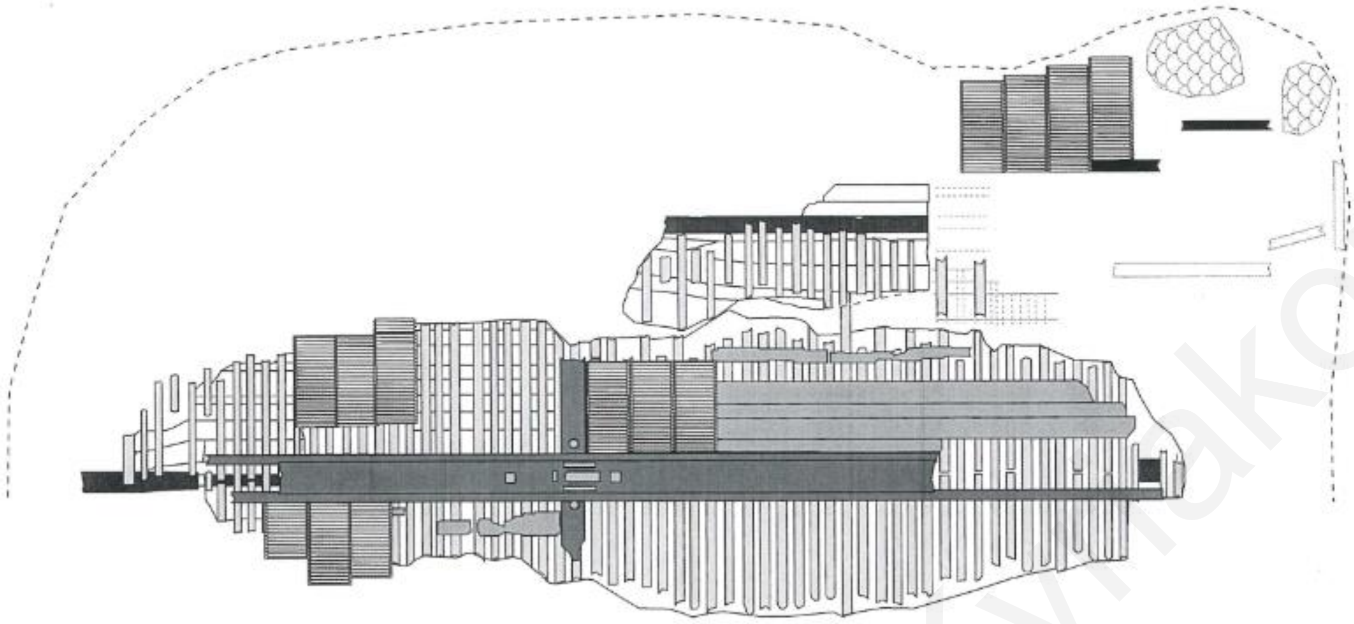
Sud-Lavezzi 2 (S016)	
 Liou & Domergue 1990: 16, fig. 6	
Location	Strait of Bonifacio, Lavezzi reef, France
Date	Mid-1st c. AD
Research	Excavated in 1972-1975
Preserved (Length x Beam) (m)	23.8m
Reconstructed (Length x Beam) (m)	-
Construction Principle	Shell-First
Lateral Section	-
Planking Assembly	-
Description	Cargo Ship
Shipbuilding Tradition	N/A
Bibliography	Liou & Domergue 1990; Parker 1992: No. 1118

Rabiou (S017)

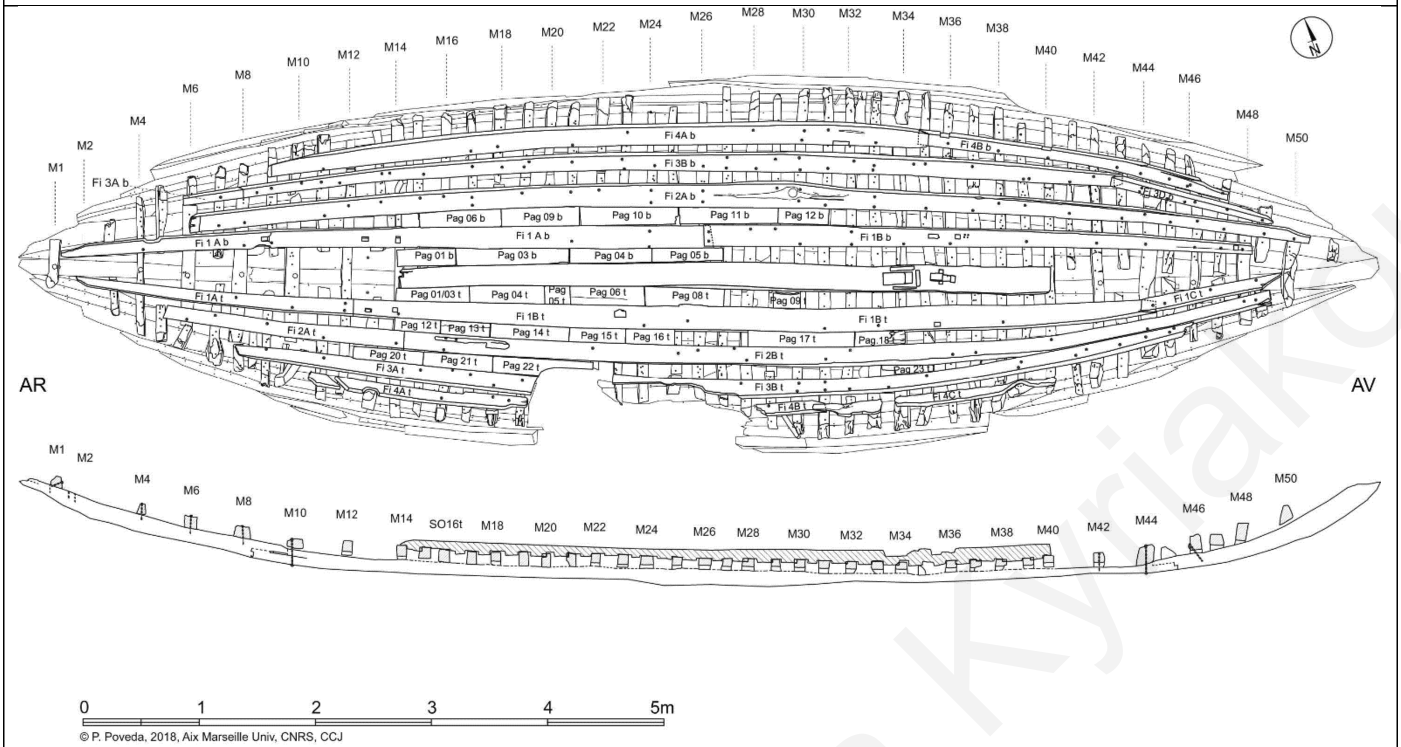


Joncheray & Joncheray 2001: 79, fig. 54

Location	Rabiou beacon, bay of Saint-Tropez, France
Date	50 AD
Research	Excavated in 2005-2006
Preserved (Length x Beam) (m)	11.3 x ?
Reconstructed (Length x Beam) (m)	-
Construction Principle	Shell-first
Lateral Section	-
Planking Assembly	M&T
Description	Small cargo ship
Shipbuilding Tradition	N/A
Bibliography	Parker 1992: No. 1009; Joncheray & Joncheray 2001; 2005

Calanque de l'Âne (S018)	
 Ximénès & Moerman 1998: 301, fig. 2	
Location	Frioul archipelago, bay of Marseilles, France
Date	End of the 1st century AD
Research	Discovered in 1956 and excavated in 1988
Preserved (Length x Beam) (m)	13, 40 x 6
Reconstructed (Length x Beam) (m)	25 x ?
Construction Principle	Shell-First
Lateral Section	-
Planking Assembly	M&T
Description	Large cargo ship
Shipbuilding Tradition	N/A
Bibliography	Parker 1992: No. 158; Ximénès & Moerman 1998

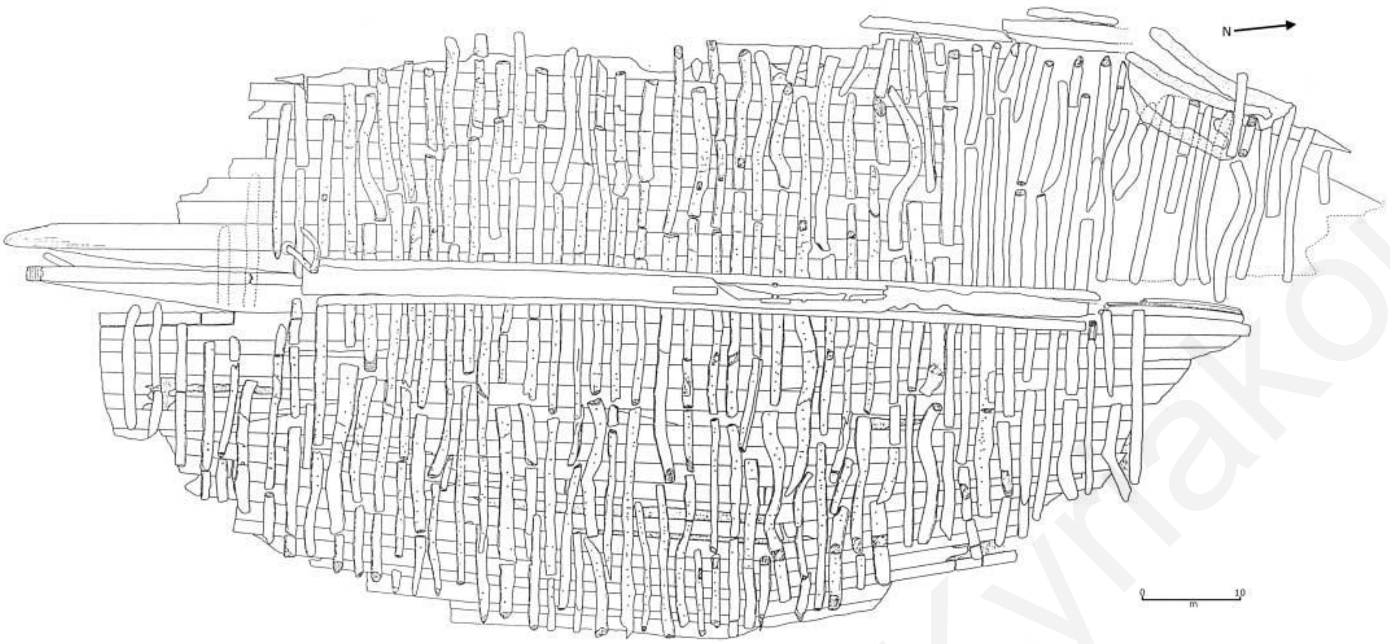
Napoli A (S019)



Boetto & Poveda 2018: 24, fig. 7

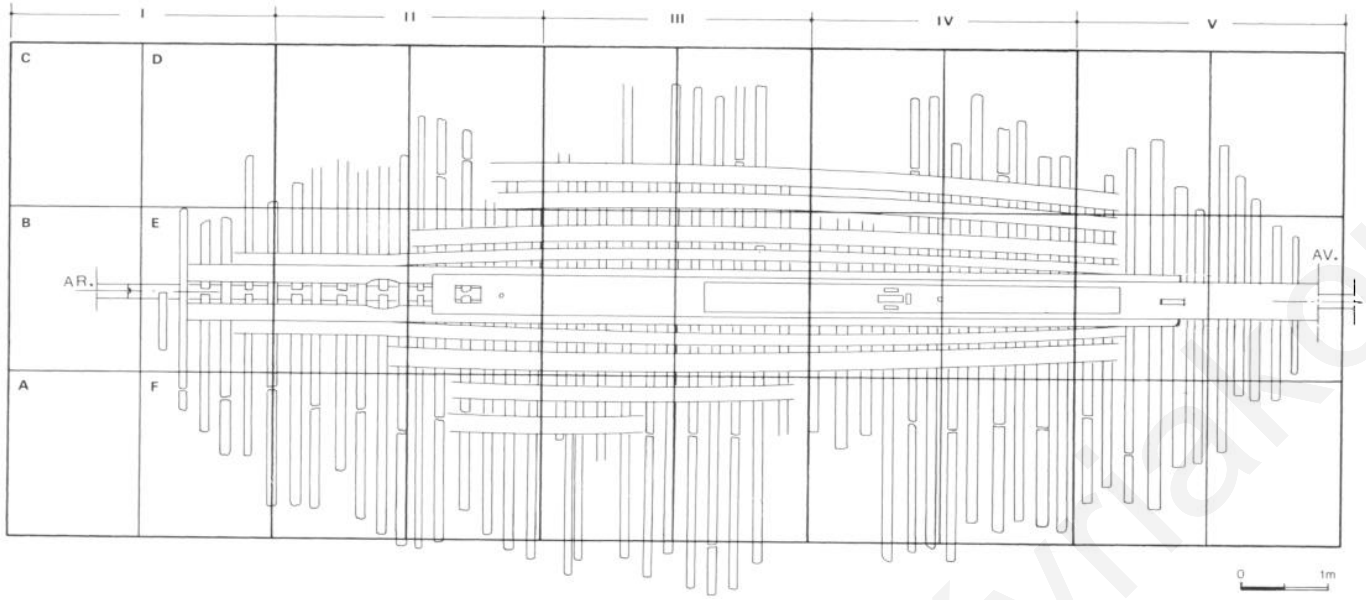
Location	Ancient port of Neapolis, Naples, Italy
Date	End of the 1st century AD
Research	Discovered and recovered in 2004
Preserved (Length x Beam) (m)	11.7 x 3.2
Reconstructed (Length x Beam) (m)	-
Construction Principle	Shell-First
Lateral Section	Flat Bottom **?**
Planking Assembly	M&T
Description	Small trading vessel, *oneraria* (ship used primarily for maritime trade in both small- and medium-scale coastal navigation)
Shipbuilding Tradition	N/A
Bibliography	Giampaola *et al.* 2005; Boetto & Poveda 2018

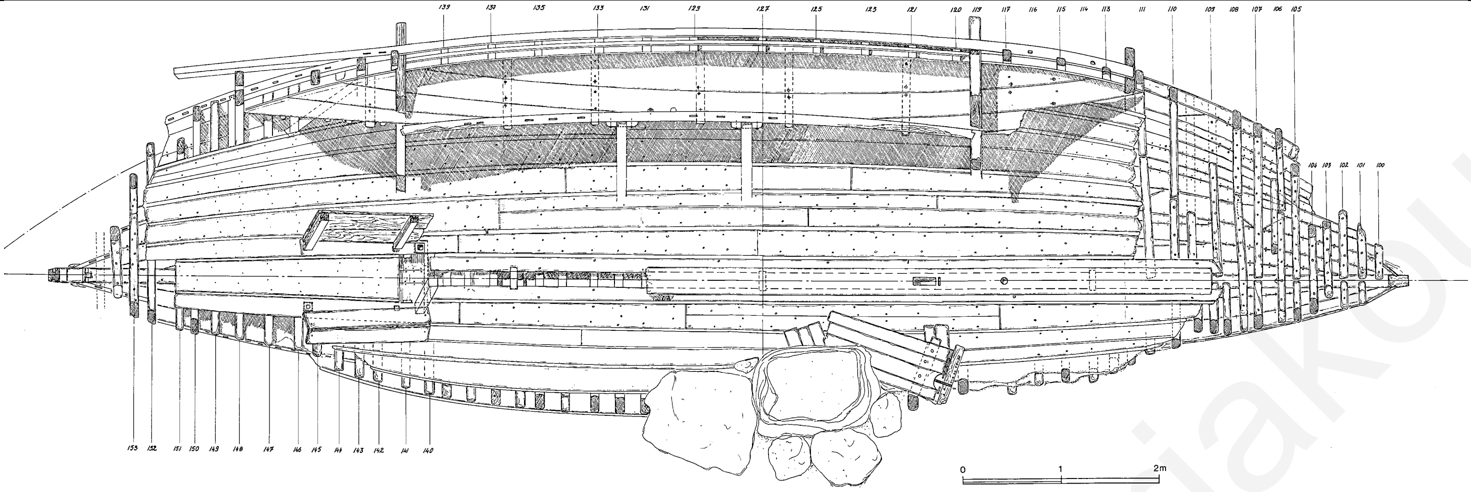
Grado (S020)



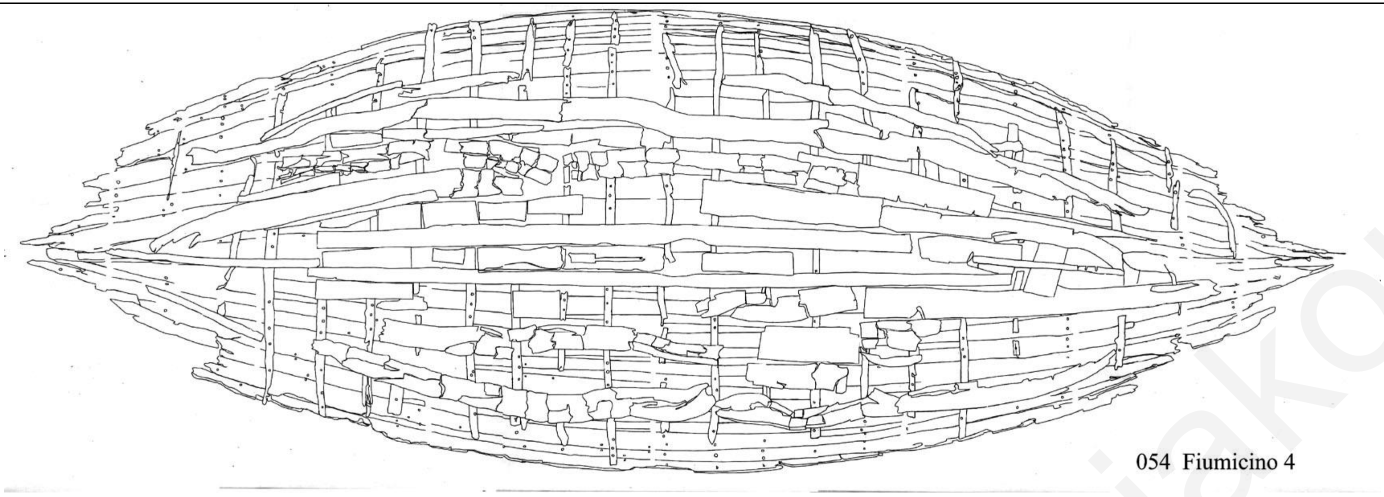
Beltrame & Gaddi 2007: 140, fig. 5

Location	off the island of Grado, Adriatic
Date	117 - 150 AD
Research	Discovered in 1986 and excavated in 1987-1999
Preserved (Length x Beam) (m)	13.1 x 6.1
Reconstructed (Length x Beam) (m)	18 x 5.6
Construction Principle	Shell-First
Lateral Section	Round Bottom
Planking Assembly	M&T
Description	Cargo ship
Shipbuilding Tradition	N/A
Bibliography	Parker 1992: No. 464; Dell'Amico 2001; Beltrame & Gaddi 2007

Saint-Gervais 3 (S021)	
 Liou *et al.* 1990: 164, fig. 9	
Location	near Saint-Gervais in the Golfe de Fos, France
Date	mid-2nd century AD
Research	Excavated in 1978
Preserved (Length x Beam) (m)	14.7 x 6.8
Reconstructed (Length x Beam) (m)	17 x 7.5
Construction Principle	Shell-First
Lateral Section	Flat-bottom
Planking Assembly	M&T
Description	Cargo ship
Shipbuilding Tradition	Western Roman Imperial
Bibliography	Liou *et al* 1990; Parker 1992: No. 1002; Pomey *et al.* 2012

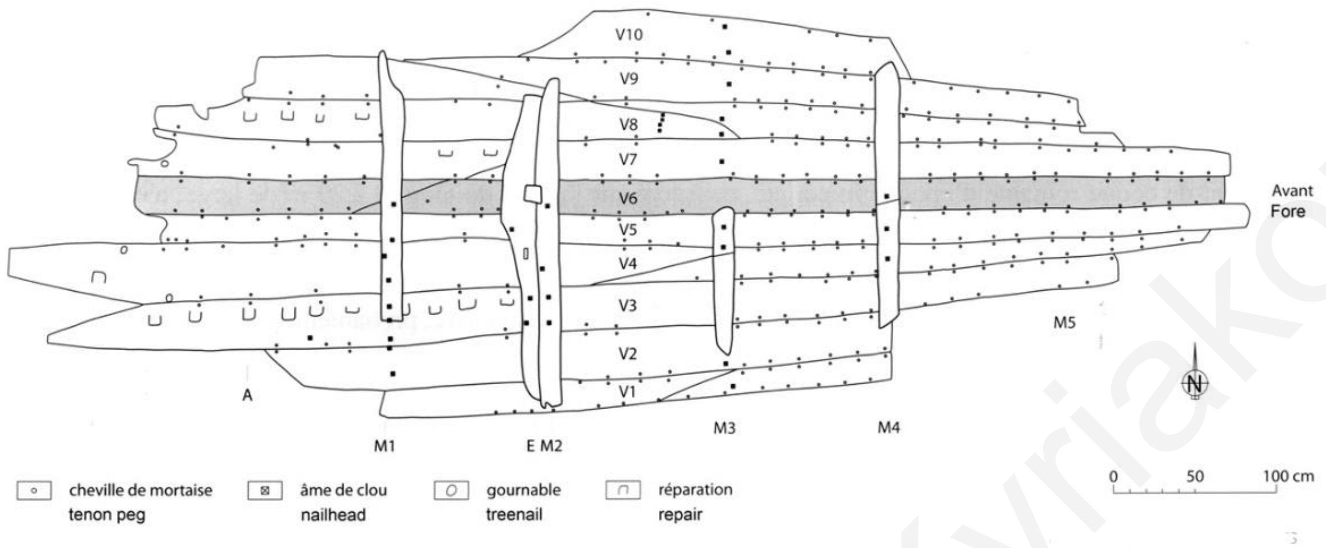
Laurons 2 (S022)	
 Gassend *et al.* 1984, fig. 21	
Location	Southern France
Date	end of the 2nd / 3rd century AD
Research	discovered in late 1970's and excavated in 1978-1983.
Preserved (Length x Beam) (m)	13.3 x 6
Reconstructed (Length x Beam) (m)	15 x 5
Construction Principle	Shell-First
Lateral Section	Flat Bottom
Planking Assembly	M&T
Description	Cargo ship
Shipbuilding Tradition	Western Roman Imperial
Bibliography	Parker 1992: No. 578; Gassend *et al*. 1984; Steffy 1994

Fiumicino 4 (S023)



Boetto (website)

Location	Fiumicino, Rome, Italy
Date	2nd-3rd century AD
Research	Discovered in 1965 and salvaged in 1968
Preserved (Length x Beam) (m)	7.96 x 2.79
Reconstructed (Length x Beam) (m)	10 x ?
Construction Principle	Shell-First
Lateral Section	concave-convex
Planking Assembly	M&T
Description	cargo ship used in coastal trade or a fishing ship
Shipbuilding Tradition	Western Roman Imperial
Bibliography	Parker 1992: No. 405; Boetto 2001; https://www2.rgzm.de/navis/ships/ship054/fiumicino4engl.htm

Conque des Salins (S024)	
 Jézégou 2011: 168, fig. 1	
Location	Étang de Thau, Hérault, France
Date	15-236 AD
Research	Discovered in 1998
Preserved (Length x Beam) (m)	7.7 x 2.2
Reconstructed (Length x Beam) (m)	N/A
Construction Principle	Shell-First
Lateral Section	flat-bottomed
Planking Assembly	M&T
Description	Boat used for transporting cargo on the lagoon or/and a lighter
Shipbuilding Tradition	Romano-Celtic with Mediterranean influence
Bibliography	Jézégou 2011; Jézégou *et al.* 2009; Pomey *et al.* 2013

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