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Master Frame and Flat Floor-Timber: An 'Architectural Signature' of the Mediterranean Shipyards?

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Abstract: This article is an attempt to analyse the master frame form characterised by a flat floor-timber, a sharp or shaped turn of the bilge, and more or less straight sides. This form of master frame is associated with the Mediterranean architecture of the 'frame-based' principle, as attested from the end of the 5th century to the beginning of the 6th century AD Dor 2001/1 shipwreck (Israel), which is considered as one of the five origins (Root 4: Nilotic-riverine) of the 'frame-based' architecture. A series of medieval and modern wrecks of coastal ships and galleys bear witness to this form of master frame linked more generally to the Mediterranean whole moulding. In view of the consistency of these archaeological as well as ethnographic evidence on traditional Mediterranean shipbuilding, this form of master frame with a flat floor-timber appears to be one of the most revealing 'architectural signatures' of the practices of Mediterranean shipyards.

Keywords: architectural signature; flat floor-timber; frame-first shipbuilding; master frame; Mediterranean whole moulding

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1. Introduction

This article is a direct continuation of a long-term research program devoted to the Mediterranean moulding method, on the one hand, and to a type of master frame geometry characterised by a flat floor-timber and a chine or a round bilge particular to the 'frame-first' Mediterranean architectural tradition on the other hand. The first aspect of the research has given rise, in a general perspective of history of techniques, to various articles [1–5] and a synthesis book [6]. The second aspect has been the subject of several articles in relation to the specific archaeological problem of the origins and developments of the 'frame-first' carvel shipbuilding in the Mediterranean during the early Middle Ages [7,8]. The subject of the present article is an essay to make the link between the two aspects and to establish a relationship between a design method of Mediterranean origin, that of the Mediterranean moulding method, and a form of master frame, interpretable as one of the 'architectural signatures' [9] or 'fingerprints' of Mediterranean tradition, characterised geometrically by a flat floor timber, a chine or a rounded bilge, which is attested in the Mediterranean until the end of the traditional wooden shipbuilding.

2. The Origins of the Mediterranean Master Frame with Flat Floor Timber

At the origin of this study is the transverse section of the master frame from the Dor 2001/1 (Israel) shipwreck dated from the end of the 5th to the early 6th century AD [10]. It should be remembered that in the current state of archaeological documentation, this shipwreck is the oldest evidence of a Mediterranean ship built on keel according to the transverse 'frame-first' principle of shipbuilding. Moreover, it has been interpreted as one of the five possible roots of Mediterranean 'frame-first' architecture and qualified as 'Root 4: riverine-Nilotic-construction tradition' [8] (pp. 302–304). In contrast to the other four possible origins of 'frame-first' architecture, it is linked to the southern shore of the Mediterranean and to a nautical space of fluvio-deltaic origin.

Inspired in all probability by the "bottom-based" fluvial architecture, the master frame of the Dor 2001/1 shipwreck is characterised by shapes that can be fully developed and projected on the same plane: a flat bottom, without any upturns, an angular chine, and straight open sides (Figures 1 and 2). This is undoubtedly the simplest geometric figure of a master frame in terms of architectural design. It is also the simplest cross-sectional shape to reproduce in a building process. The 'thinking' and the 'making' are in this case identical in every respect. Thus, the finished structure of the master frame is completely superimposed on its geometric figure.

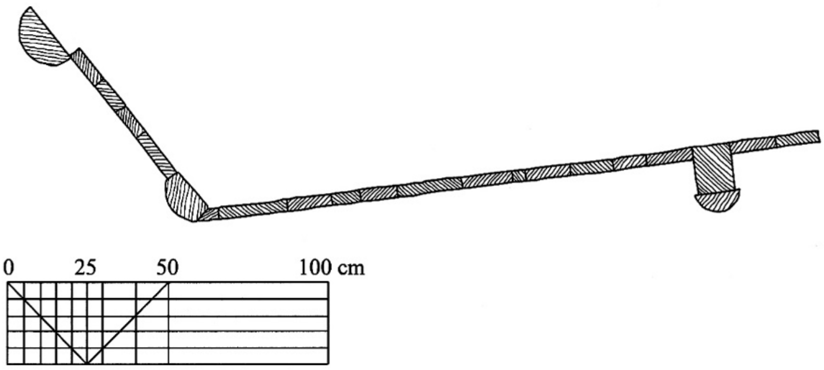

Figure 1. Cross-section of the Dor 2001/1 shipwreck [10].

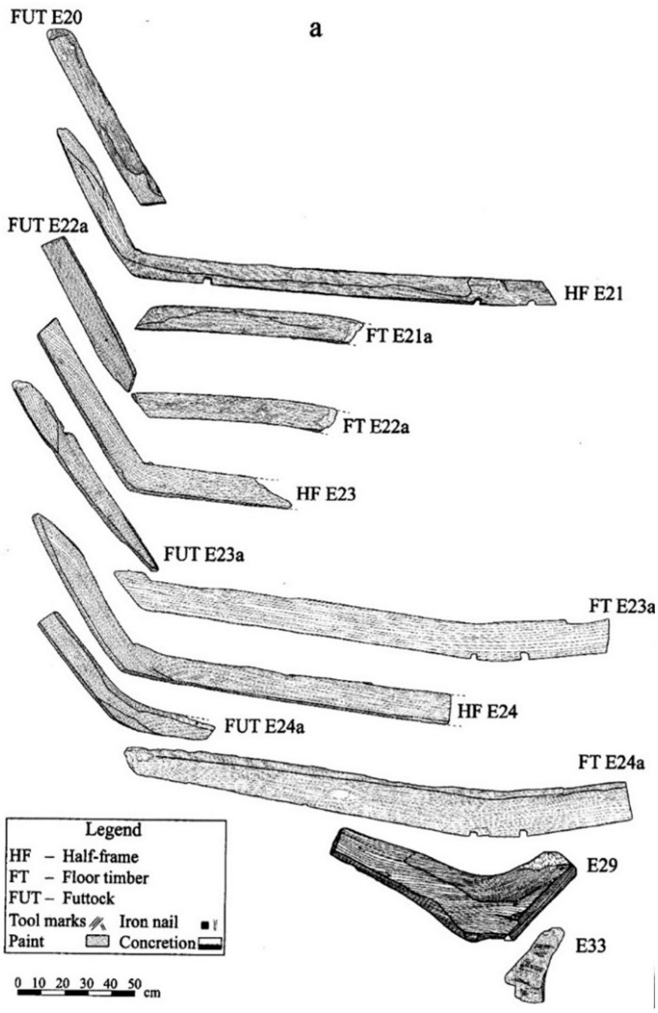

Figure 2. Floor timbers (FT), half-frames (HF), and futtocks (FUT) of the Dor 2001/1 shipwreck [10].

This same relationship between the conception of the midship cross-section and its materialisation in the building process can be found in the Bataiguier shipwreck (France), which is dated to the beginning of the 10th century [11] (Figure 3). It is an historically important milestone in so far as this shipwreck, whose ceramics testify of similarities with productions from the southeast Spain caliphal, or even with those from North Africa or Sicily, could also correspond to a ship of the same origin. In this hypothesis, the architecture of the Bataiguier shipwreck could be interpreted as the result of a technical transfer from the "riverine-nilotic architectural root" to the Arab–Muslim West territories. It should also be noted that the Bataiguier shipwreck is the most recent archaeological evidence of a keeled hull with a flat bottom and a sharp bilge.

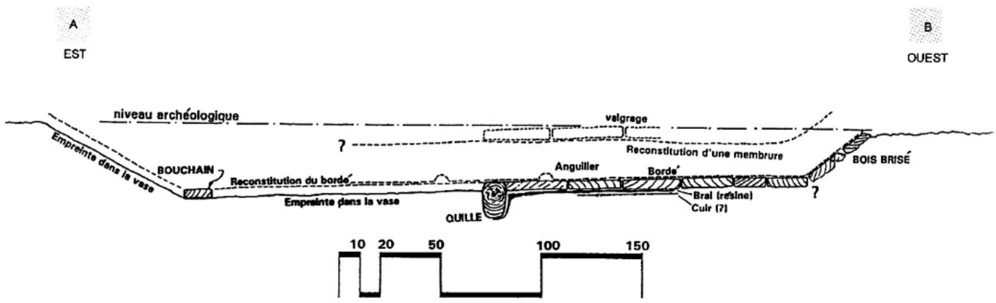

Figure 3. Cross-section near the master frame of the Bataiguier shipwreck (Alpes-Maritimes) [11].

This geometry of the master frame, with a strictly flat bottom and sharp chine, which is still very close to that of a 'bottom-based' river boat, could be considered as the first or the primitive geometric form of this 'frame-first' architecture in relation with a hull built on keel. According to the archaeological sources, a morphological evolution quickly appeared and resulted in a connection between the flat bottom and the side by means of a rounded bilge with a more or less wide radius of curvature. One of the earliest attestations is that of the Tantura F shipwreck, (Israel), which is dated to the mid-7th–8th centuries AD, where some of the ceramics archaeologically associated with the shipwreck were produced in the Nile Delta region [12,13]. The origin of the ship is unknown, although a Nilotic origin would seem possible.

In terms of structure and mechanical resistance to the stresses of a maritime environment, a rounded bilge combined with a flat bottom contributes to greater strength, greater rigidity, and less deformability of the hull than an angular chine. On the other hand, the rounded bilge makes the hull geometry non-developable and therefore more complex to design and to build than a fully developable hull. One of the questions posed by this presumably more geometrically elaborate stage of rounded bilge is how to design it. An answer has been proposed by Richard J. Steffy in his study of the early 11th century shipwreck from Serçe Limanı (Turkey) [14]. The master frame of this probably Byzantine coaster built on a 'frame-first' principle [15] is characterised by a flat bottom, a rounded bilge with a small curvature, and slightly open straight sides (Figure 4). This is the transverse section of a hull using L-shaped ribs cut from naturally curved pieces of wood (trunk and large branch) in relation with the later phase of 'making' the ship of Serçe Limanı. In contrast, the design of the midship section, corresponding to the earlier phase of 'thinking', is based on a geometric figure with straight lines for the bottom and the sides, resulting in a cross-section with an angular chine (Figure 5). This is clearly noted by Richard J. Steffy: "*these frame shapes were predetermined by a very simple form of logic […] The bottom had no lateral curvature within the limits of the hold, and the lowest meter or so of the sides was also straight so that both bottom and lower sides could be represented by straight lines*" [16]. Thus, this predefined geometrical figure, as conceived during the design phase, is translated during the construction phase into a rounded bilge, with the sharp angle of the original geometrical figure rounded off in correspondence with the piece of wood naturally curved used to carve the floor timber.

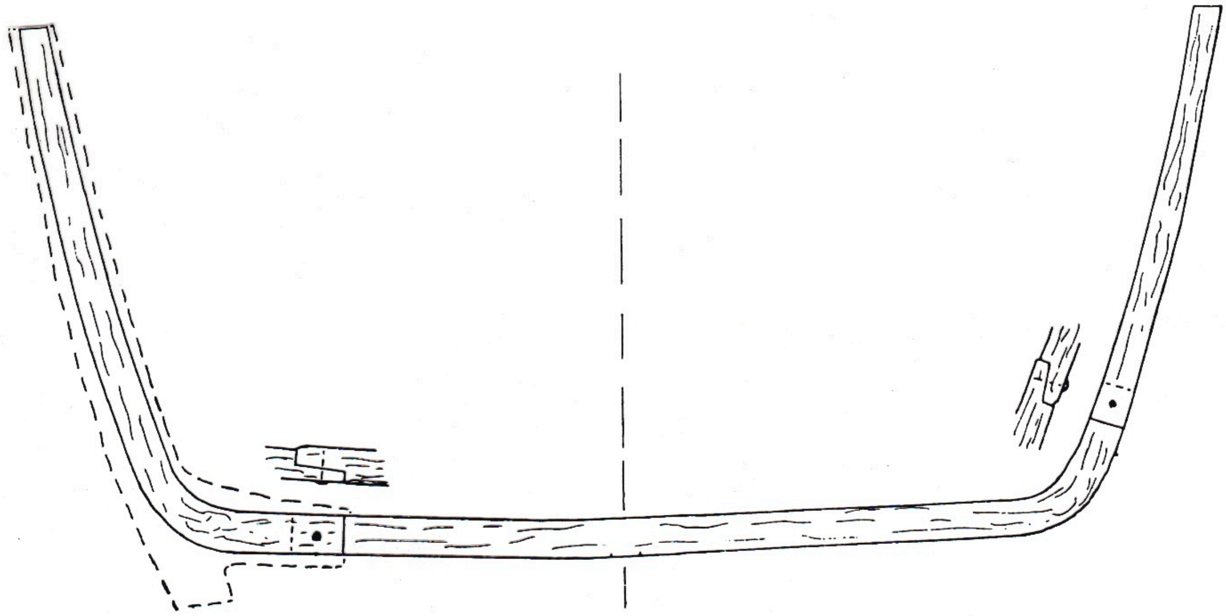

Figure 4. Reconstruction of the midship section of the Byzantine Serçe Limanı shipwreck (Turkey) [14].

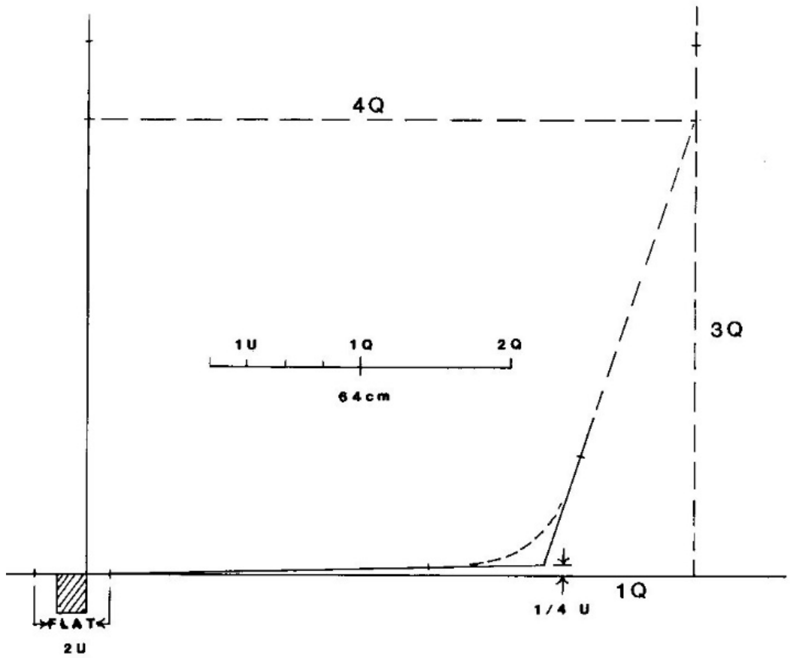

Figure 5. Reconstruction of the geometric construction of the midship section of the Serçe Limanı shipwreck [14].

In view of the similarity of the geometric construction of the master frame based on straight segments of line, there would seem to be an architectural relationship between the Dor 2001/1 shipwreck and that of Serçe Limanı on the one hand, and between the Dor 2001/1 shipwreck and that of the Bataiguier on the other. However, this architectural and technical relationship must not be confused with a historical relation of diffusionist nature, even if the hypothesis of a transfer of technique from the riverine nilotic aera to the Eastern Mediterranean by going up the Syro-Palestinian coastline to the territory of Byzantium does not seem totally implausible.

3. From the Flat Midship Transverse Section of the 11th-Century Coaster of Serçe Limanı to the Flat Midship Transverse Section of Traditional Mediterranean Boats and Ships of the Contemporary Period

The shape of the Serçe Limanı coaster with its flat bottom, slightly raised at both ends, rounded bilge, and open straight sides is part of a centuries-old lineage of shipwrecks of eastern and western Mediterranean origin, of which one of the earliest archaeological testimonies is the Tantura F shipwreck dated to the mid-7th–8th centuries AD. It would be beyond the scope of this article to establish a complete list of shipwrecks of Mediterranean origin built on keel according to a 'frame-first'principle with a main transverse section of the Serçe Limanı type. Some of the most representative archaeological evidence will suffice to illustrate the maintenance of this type of master frame over the centuries:

- Boccalama B (Italy), dated 1275–1325 [17]; this is the shipwreck of a galley of Venetian origin, the remains of which are preserved over 38 m long and 5 m wide. Among the many unknown questions raised by this exceptionally shipwreck is the one relating to the architectural type: military galley or "*galea di mercato*" and, in the latter case, the question is to know if this merchant galley was destined for trade towards the Black Sea, Romania, or Flanders, which were the three main trade routes of Venice.
- Culip VI (Spain), dated from the late 13th to early 14th century [18]; this is the remains of a coastal vessel probably built in Catalonia, whose restored dimensions are 16.35 m in overall length, 4.11 m in width at the main beam, and 1.94 m in depth. The load capacity of the vessel has been estimated at around 40 tonnes (Figure 6). This is the earliest archaeological evidence for the use of the Mediterranean moulding method of design.

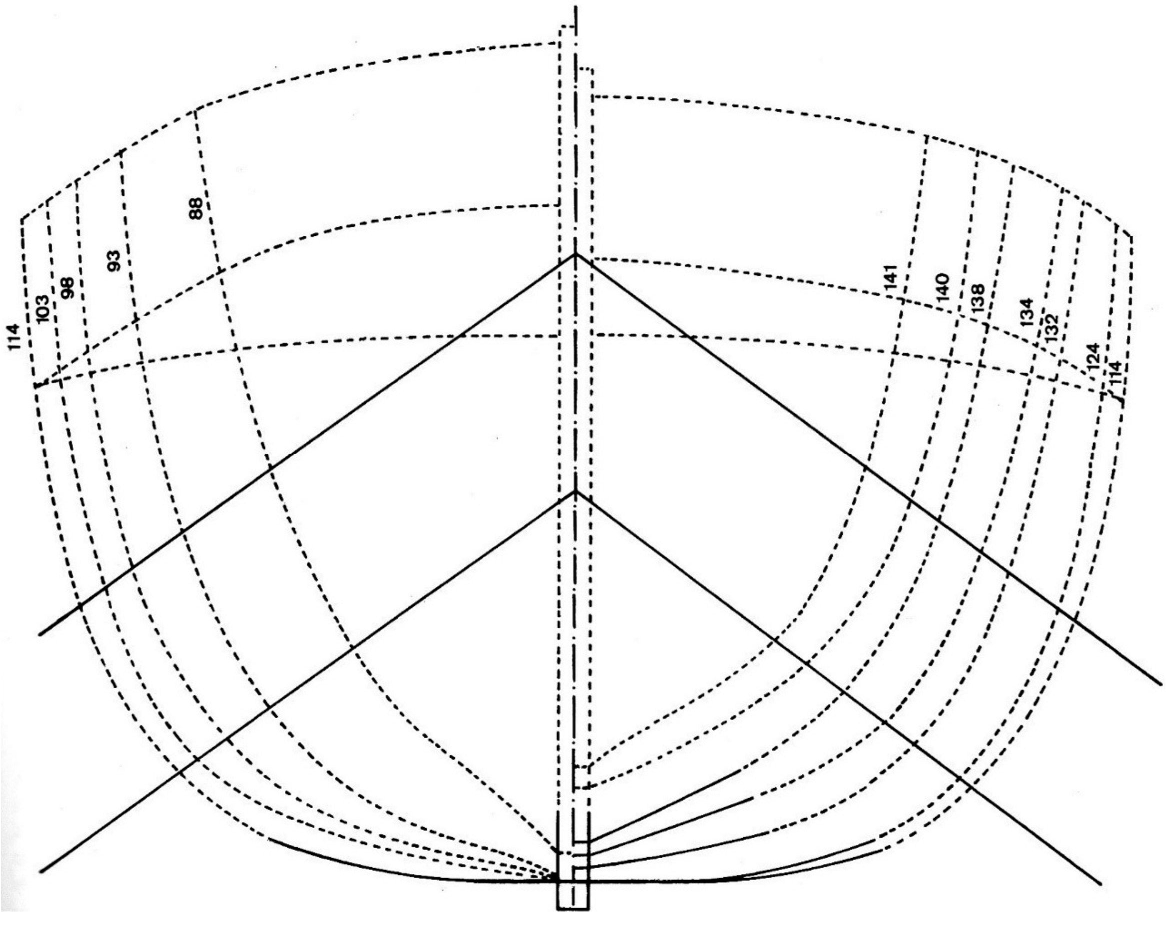

Figure 6. Restitution (René Burlet) of the body plan of the Culip VI shipwreck (Spain) [18].

- Contarina 1 (Italy), dated 1425–1475 [19]; this is the remains of an Adriatic coaster whose restored dimensions are 20.90 m long overall, 5.10 m wide at the main beam, and 2.46 m depth (Figure 7).

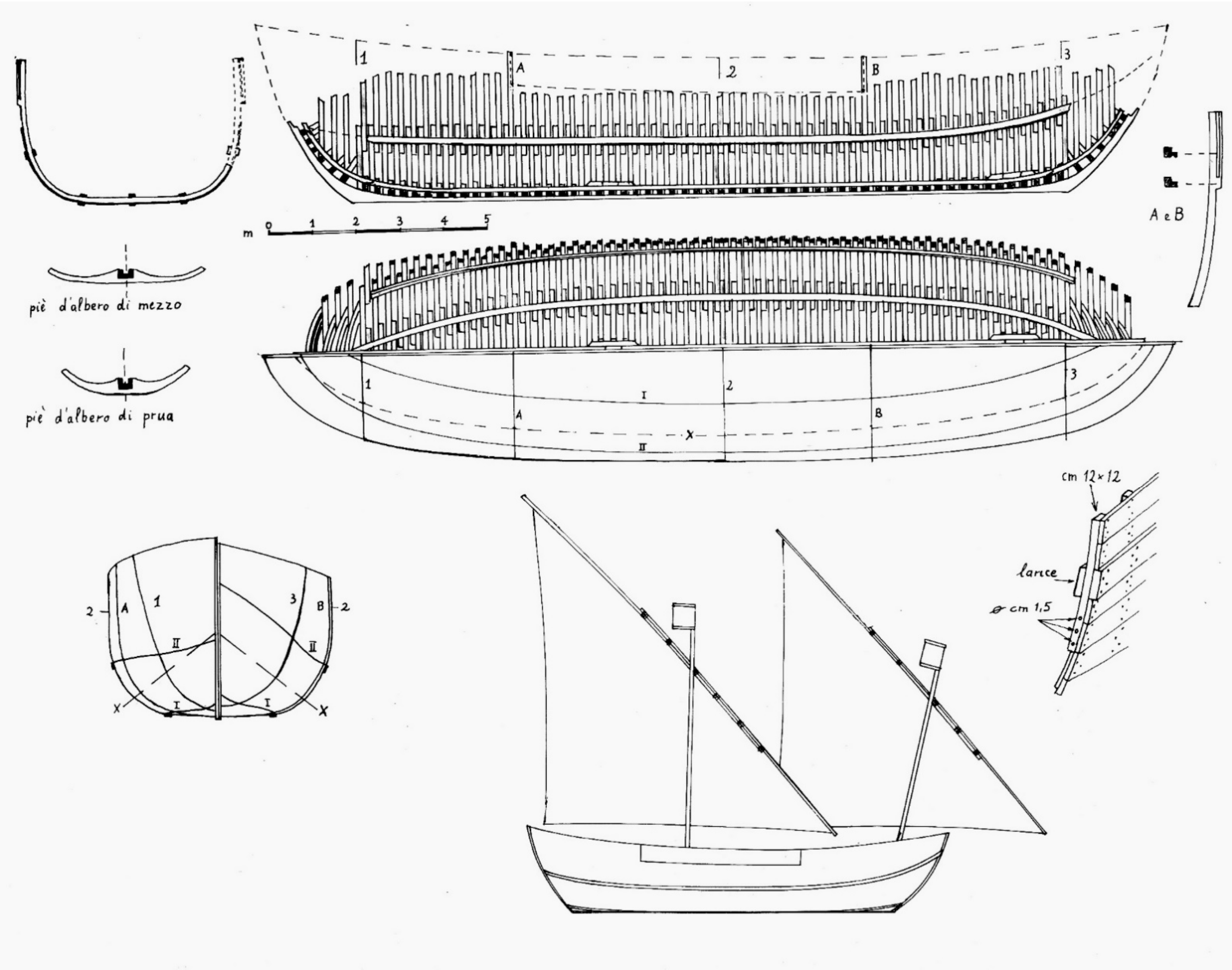

Figure 7. The Contarina 1 shipwreck [19].

- Lazise, Lake Garda (Italy) [20]; this shipwreck of Venetian origin is that of a vessel of the galley family built in the 15th century, transported by land in Lake Garda, and sunk in the early 16th century (Figure 8).
- Yassiada 3 (Turkey), dated 1575–1600 [21]; this is the remains of a merchant sailing ship of Ottoman origin, whose restored dimensions are 21.20 m long overall, 6 m wide at the main beam, and 1.20 m deep. Its displacement has been estimated at nearly 63 tonnes (Figure 9).
- Les Sardinaux (France), dated to the end of the 17th century [22]; this is the poorly preserved shipwreck, only 7.65 m long and 1.62 m wide, of a small coaster whose original length could be between 10 and 12 m.

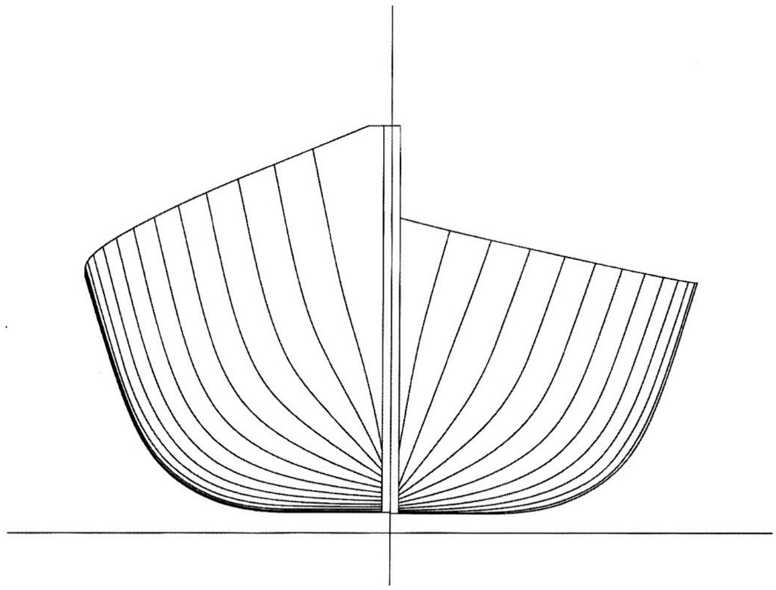

Figure 8. Preliminary restitution (Mauro Bondioli) of the body plan of the Lazise shipwreck [20].

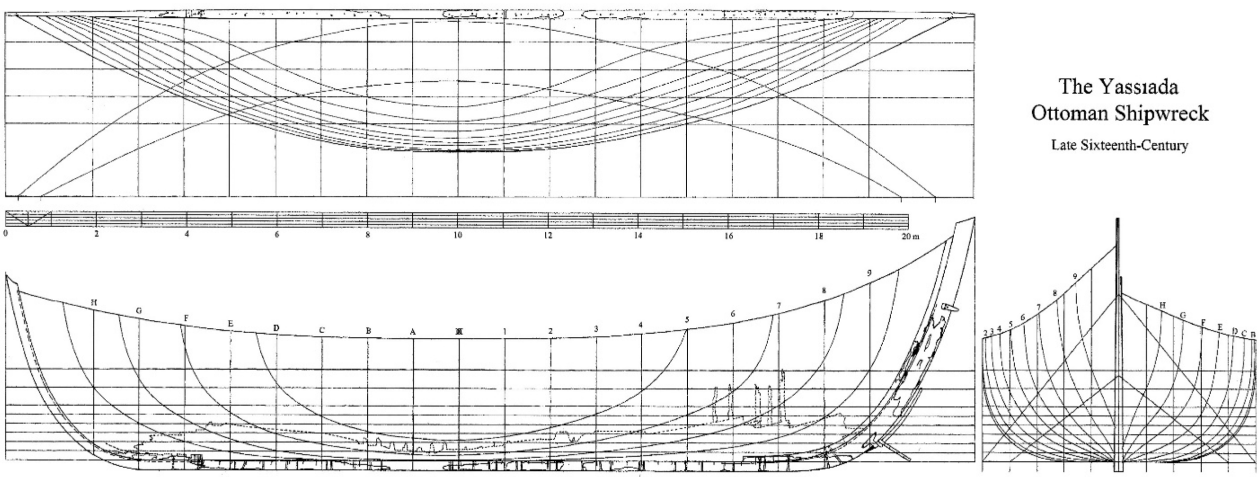

Figure 9. Restitution of hull lines of the Yassiada 3 Ottoman shipwreck [21].

- Paragan 1, Corsica (France), dated from the end of the 17th to the early 18th century [23,24]; this is the remains of a coastal vessel from western Mediterranean whose restored dimensions are 19 m long, 5.30 m wide, and 2.50 m depth for a load capacity estimated between 73.50 and 78.25 tonnes according to the French tonnage calculation formulae of 1681 (Figure 10).

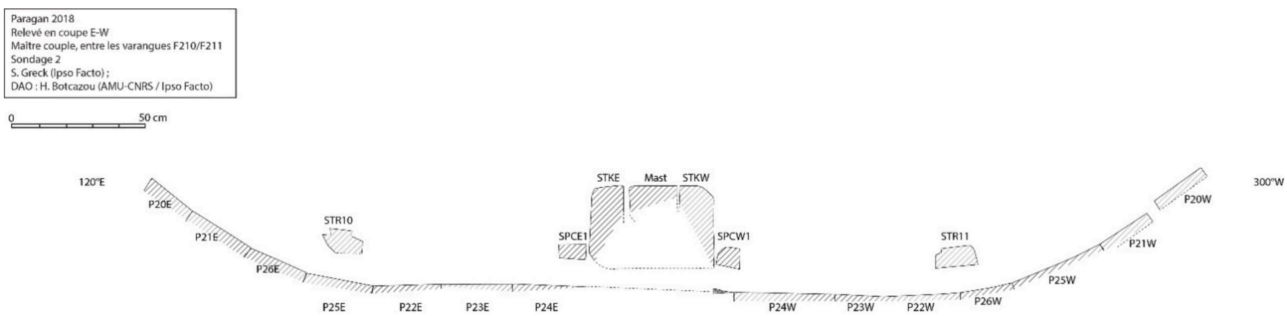

Figure 10. Cross-section of the Paragan shipwreck at the level of the master frame (DAO Hélène Botcazou).

- Kitten (Bulgaria), dated c. 1800 [25]; this is a large coastal vessel probably built in the Black Sea, nearly 23 m long overall, 7.46 m wide at the main beam, and 3.56 m depth (Figure 11). Its load capacity has been estimated as between 120 and 130 tonnes.

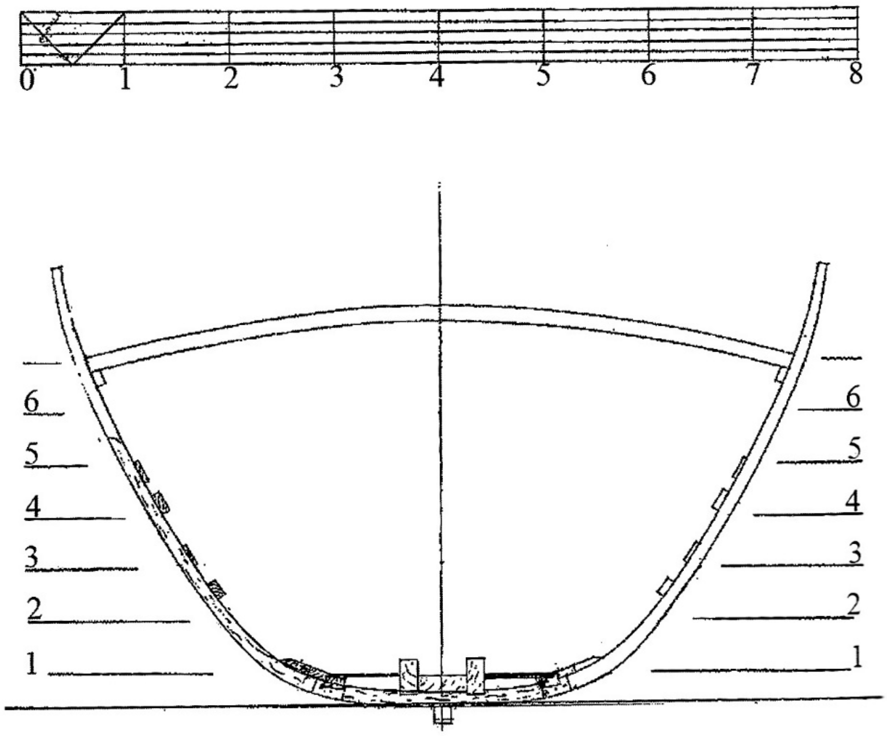

Figure 11. Reconstruction of the midship section of the Kitten shipwreck [25].

A group of shipwrecks from the early Middle Ages should be considered separately. These are the 37 wrecks found at Yenikapı, Istanbul (Turkey), in the former port of Theodosius [26,27]. Six of these wrecks (YK 10, YK 17, YK 19, YK 27, YK 29, YK 31) dated from the 7th to 9th centuries AD have their carvel planking arranged without any connection between them and " . . . *have at least some frames placed before the planking*" [26] (p. 34). In other words, these shipwrecks would appear to be of the 'frame-first' or more probably of the 'pre/proto frame-first' principle of design (shape and structure) and 'mixed' construction methods/procedures. Three of these shipwrecks have a flat-bottomed master section of the Serçe Limanı type, and the other three have a 'wine glass' master section [28]. The interpretation of these six shipwrecks in terms of history of Mediterranean naval architecture is in fact complex due to their minority position within the 37 shipwrecks of Yenikapı, the vast majority of which would seem to be related to a 'mixed' architecture (principle and methods) [27] (p. 69) and belong to a regional tradition whose techno-historical perimeter has yet to be defined.

In the context of traditional shipbuilding, an excellent observatory of the practices in use in Provence at the end of the 19th century is provided by the shipbuilder Jules Vence [29]. The shape of the Marseille pilot boat, the *barquette*, and the *gourse* show a flat master frame with a more or less significant rise at the so-called *escoue* points, but these are always small (Figure 12). The only exception is the shape of the Toulon boat known as a *rafiau* or *pointu*, which is characterised by a rising and a practically non-existent flat floor timber of the master frame.

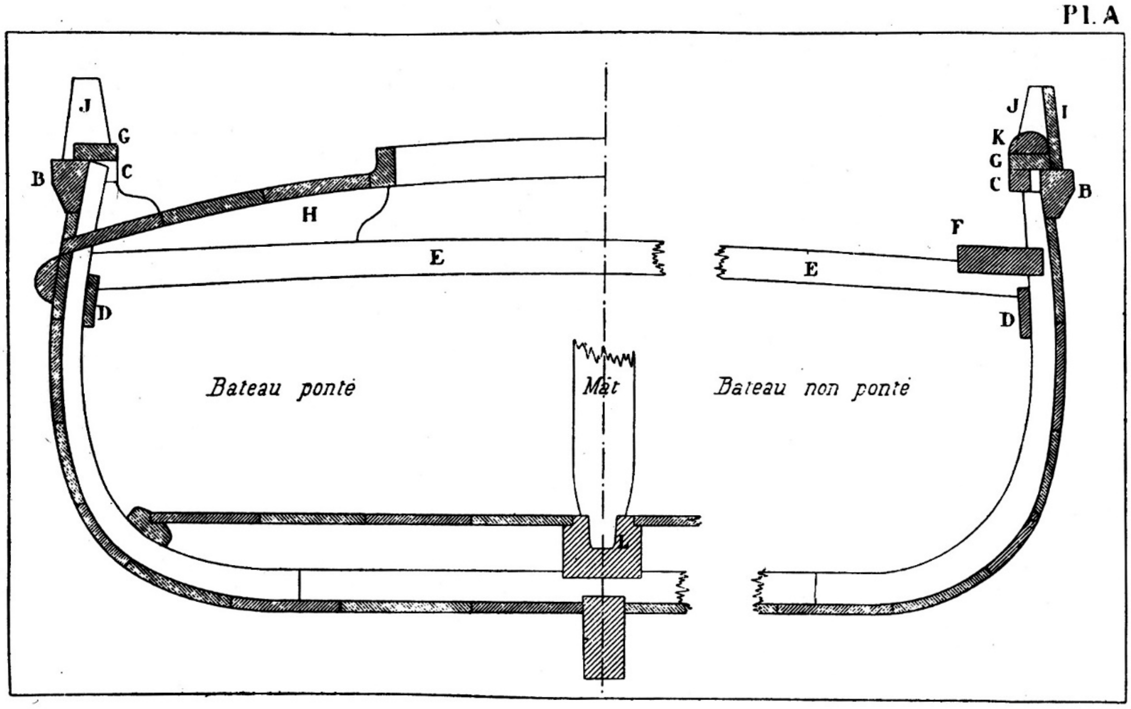

Figure 12. Midship section of a *bateau à éperon* or *Mourré dé pouar* [29].

This quick examination of the shape of the master frame calls for three main comments. Firstly, it is certain that although the general shape of these master frames has similar characteristics and is based on the same overall geometric design, it also varies in detail in terms of the length of the line of the flat and height of the rising depending on the examples considered, in particular according to a number of chronological and functional parameters. Secondly, all but one of the cases considered relate to fishing or coastal vessels with a maximum length (Kitten shipwreck) of 23 m. Therefore, they are either small vessels intended for local coastal navigation or regional or even extra-regional coastal navigation, but in all cases with a tonnage of no more than around 100 tonnes (120 to 130 tonnes in the case of the Kitten shipwreck). One of the exceptions, along with the Lazise "galley/fuste", is the Boccalama galley, which is probably close to 40 m long. However, this is a very specific Mediterranean architectural family. Thirdly and finally, the ethnographic documentation shows that hauling on the beach, either on a daily time in the case of small coastal fishing boats or on more time for careening operations, particularly for coasters, was a common practice along the Mediterranean shoreline until the 20th century. In this functional context, it is obvious that a hull with a flat master frame facilitates hauling and beaching straight without the need of side supports to prevent the boat from tipping sideways. It is important to emphasise that coastal vessels with a flat master frame form the basis of maritime trade from the Middle Ages until the disappearance of side commercial shipping under sail. Therefore, they are very representative vessels historically.

This same type of main section, which appears to be the most frequently attested in the archaeological and ethnographic documentation, does not mean, of course, that Mediterranean naval architecture has known only one and the same model of flat-bottomed main section without rising, from the early Middle Ages until the 20th century. Two examples will suffice to show the contrary. These are two 16th century wrecks. The first is the presumed *Lomellina*, which was a large Genoese *nave* sunk in the bay of Villefranche-sur-Mer (France) in 1516 [30]. The restored dimensions are between 40 and 45 m overall length and 10 m width at the main beam, with a load capacity between 700 and 800 tons. The midship section of this very large ship belongs to the "wine glass" type with a garboard return (Figure 13). The second wreck is that of Calvi 1, Corsica, dated 1550–1600 [31,32]. The reconstructed dimensions of this ship are as follows: overall length 24.90 m, width at the main beam 7.80 m, depth in hold 3.80 m, load capacity between 220 and 330 tons [31] (p. 112). The restitution of the master frame shows a "glass wine" section with a garboard return [33] (p. 147) (Figure 14). These two examples seem to show a different geometry of the master frame than the one with a flat bottom without rising. Even if the hypothesis can be formulated, it would be risky to systematically associate, as a sort of "architectural signature", the master frame with a "wine glass" section to the category of large tonnage ships only, which, it should be remembered, represent a minority proportion of the shipping industry in terms of economy of maritime transport in the Middle Ages and the modern period. The documentary sample remains far too small to be able to make such a claim. In any case, it is certain that this model of master frame appears to be very much in the minority with regard to the archaeological documentation and therefore would not seem to be representative of a Mediterranean tradition, even if limited to its western basin. It could be only considered as a "shipyard signature" of regional/local boarder. However, this is not the case for the flat-bottomed type whose geographical distribution and chronological extent would seem to allow this model of master frame to be considered representative of an authentic Mediterranean tradition.

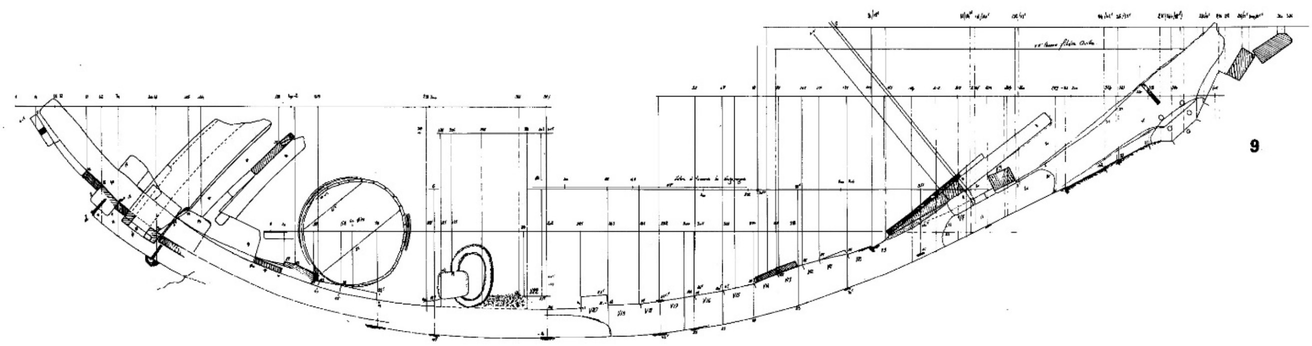

Figure 13. Cross-section at the level of the floor timber W 54 close to the presumed midship floor timber W 59 [30].

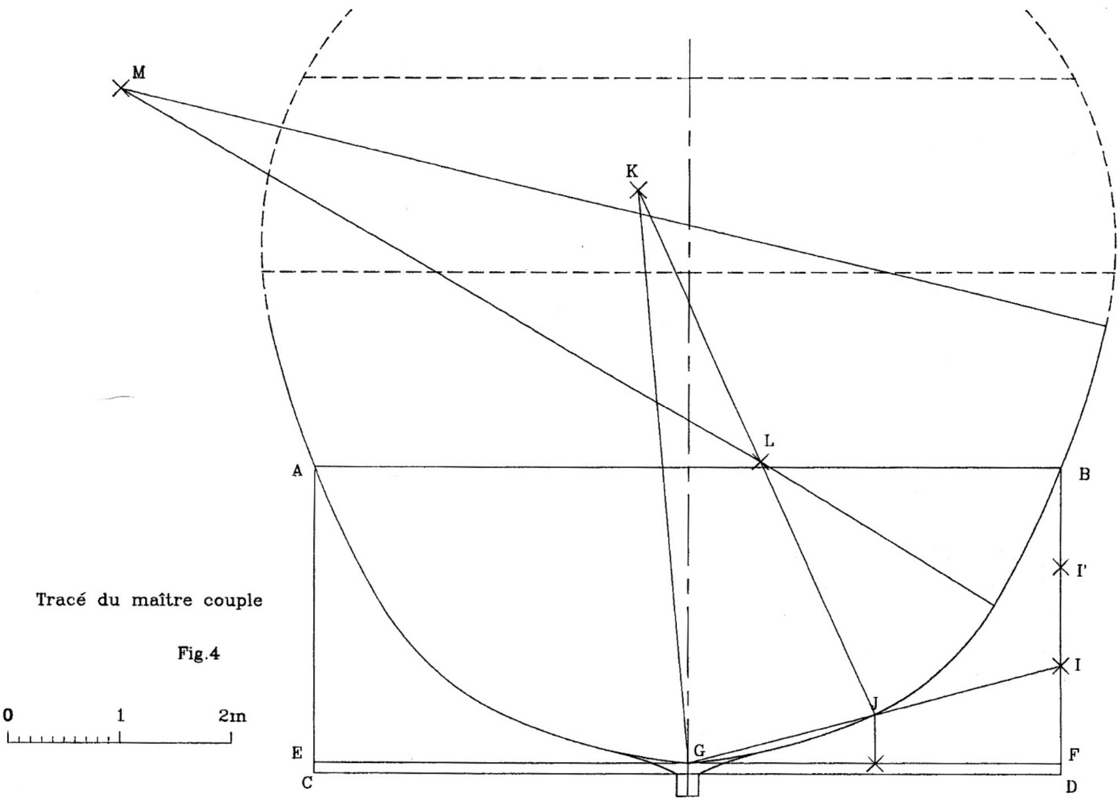

Figure 14. Hypothetical reconstruction of the midship section of the Calvi 1 shipwreck based on three arcs of circle [33].

There is one last remark that is important to underline. If, indeed, the flat-bottomed master frame and the so call "glass wine" master frame with a rising floor timber appear to constitute two different geometrical families of design, there must have been variables within each of the families corresponding to the particular "architectural signature" of one shipbuilder. This was recalled by a naval officer at the beginning of the 18th century, La Madeleine, author of a treatise on naval architecture, when he wrote [34]: "*Whatever rule one uses in naval architecture, one must begin by forming the master frame . . . the outline of this frame is always arbitrary to the shipbuilder who must be careful to give it a shape that determines the bottom of the vessel according to the use to which it is to be put*". This "arbitrariness" refers to the technical freedom that allows the shipbuilder to personalise the shape of his master frame.

4. On the Possible Origin of a Proto/Pre-Moulding Method

Richard J. Steffy is responsible for a particularly innovative study of the process of designing the frames of the 11th century shipwreck of Serçe Limanı [14–16] considered, before the discovery of the Tantura Lagoon/Dor wrecks, to be one of the earliest archaeological attestations in the eastern Mediterranean [of a ship 'frame-first' built. Two main aspects of his study should be noted. Firstly, the midship section is subject to a double modification of its design (Figure 15). The first one is located at the level of the length of the floor timber, which progressively decreases towards the ends of the hull. The second is located at the level of the rise which increases progressively towards the bow and the stern. This double modification does not change the angle of the chine. The sides remain parallel, thus preserving the developable nature of the hull shapes. Secondly, this double modification concerns a set of eight floor timbers, four of which are arranged on either side of the midship section. These would appear to be the only predefined/moulded elements of the transverse framework before any stringers or planking were put in place to support these frame elements. In this hypothesis, they could be considered as "active" frames, in the sense defined by Lucien Basch [35]. Furthermore, Richard J. Steffy adds: "*I suspect our builder determined at least one more pair of hull shapes before or during the planking process*" [16] (p. 5). The position towards the ends of the hull of these presumed frames could be more or less similar to that of the tail frames.

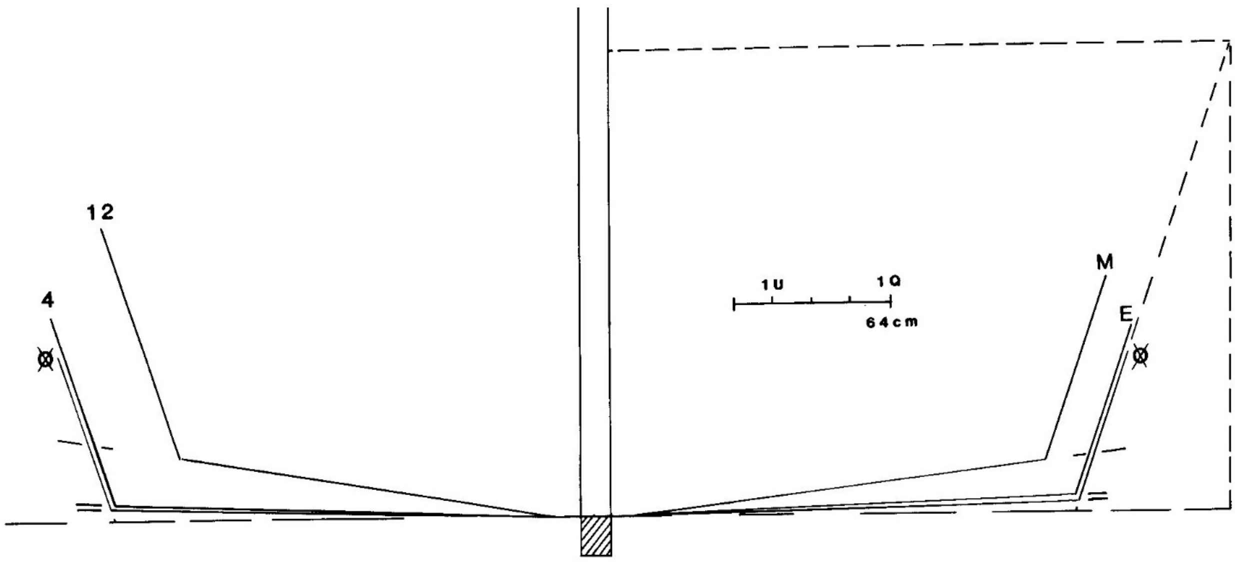

Figure 15. Hypothetical modification of the geometric figure of the predefined frames of the Serçe Limanı shipwreck [14].

In any case, this double modification of the master frame, by decreasing the length of its floor timber and by increasing the height of its rise, would seem to be indicative of a proto/pre-moulding method, as these two modifications are present in the classical Mediterranean moulding method.

Two questions arise in relation to this presumed proto/pre-Mediterranean moulding method. How is the gradual decrease in the length of the floor timber and the gradual increase in the rising carried out? Was this proto/pre-moulding method preceded before the 11th century by another method of modifying the two dimensions of the master frame floor timber? This is the meaning of Richard J. Steffy's observation when he writes that "*this method did not begin in the eleventh century; it was too sophisticated for that*" [36] (p. 91). To the first question, there are no data in the current state of archaeological documentation to suggest an answer. To the second question, an answer seems to be possible. Examination of the reconstructed hull lines of the Dor 2001/1 shipwreck reveals a double progressive modification of the midship section by a decrease in the length of the floor timber and an increase in the rising, which appears similar to that reconstructed for the Serçe Limanı shipwreck (Figure 16). Among the unknown aspects related to the restitution of the hull lines of the Dor 2001/1 shipwreck, the two most important ones concern the limits between the presumed predefined frames and the frames directly defined during the process of building, on the one hand, and the process of modification of the length and of the rising of the floor timber on the other hand. With all due reservations, the Dor 2001/1 shipwreck could perhaps date the proto/pre-moulding method, or more precisely one of the methods, to the late 5th or early 6th century AD and thus confirm Richard J. Steffy's observation at a time when the Dor 2001/1 shipwreck had not been studied. It should be added that in the context of a transverse 'frame-first' design principle such as that of the Dor 2001/1 shipwreck, it seems logical that a controlled method of modifying at least part of the frame should be implemented.

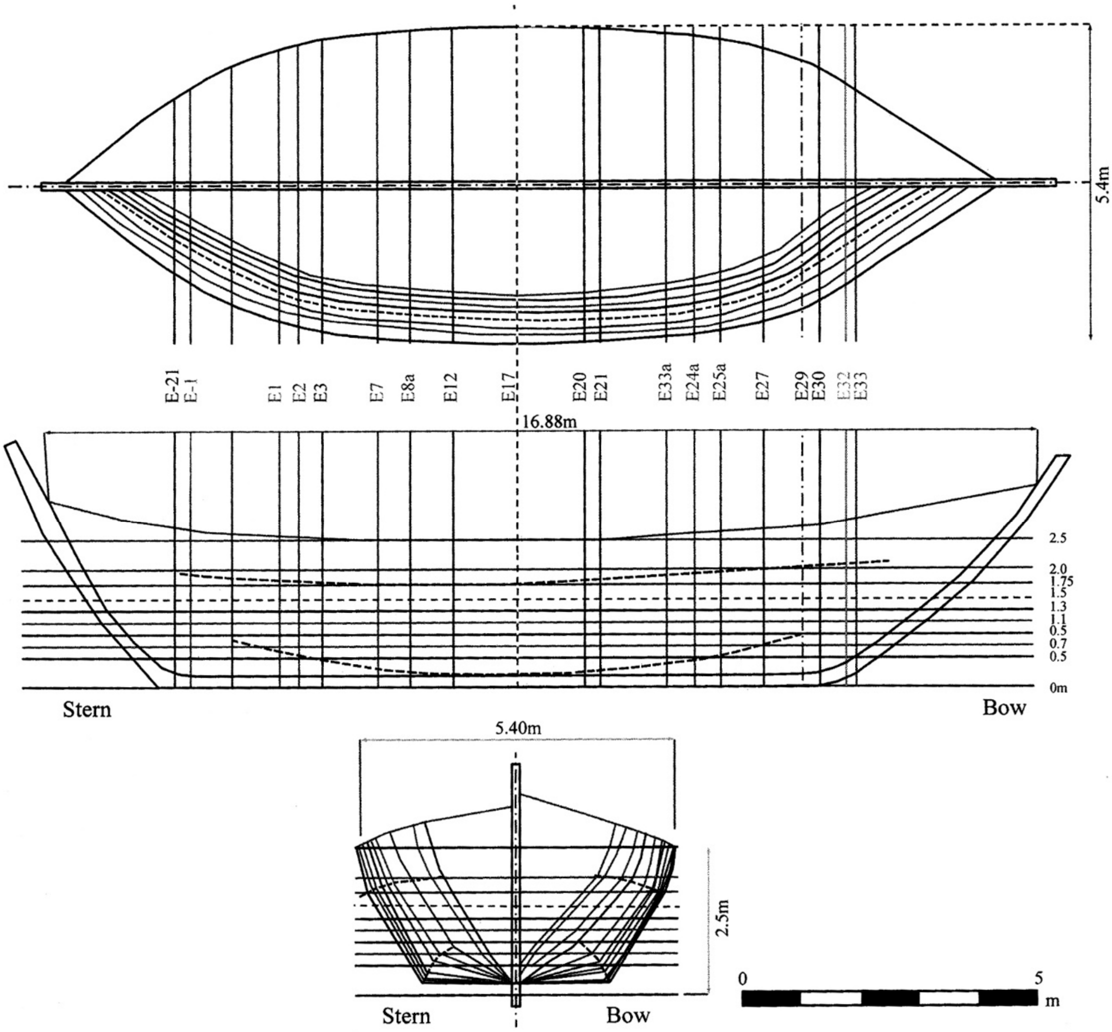

Figure 16. Reconstruction of the Dor 2001/1 shipwreck hull lines (A. Ben Zeev) [10].

5. Mediterranean Moulding Method

This method of designing the transverse shapes of the hull is based on the geometric figure of the master frame, which is the keystone of the whole process of predefining the figure of the frames, or at least of a number of 'active' frames, as limited towards the bow by the fore tail frame and towards the stern by the aft tail frame. This predefined or moulded part of the hull may be more or less important. In some cases, it may extend over most of the length of the keel.

As mentioned previously, the two basic modifications of the midship section figure, which, let us underline again, do not affect the geometrical construction of its overall layout, which remains stable up to the level of the two tail frames sections, concern the reduction of the length of the floor timber (a theoretical line of geometrical construction of the lower part of the floor timber), the increase in the rising (elevation of the length of the floor timber above the keel) and possibly one other main correction: the *trebuchement* (widening) (Figure 17). The two first basic modifications are based on purely graphic procedures using elementary geometric constructions (the half-moon and the isosceles triangle for the oldest examples) carried out at full size and based on the principle of progressive divisions (arithmetic progression). These procedures were called 'geometric operators' [37] (p. 157).

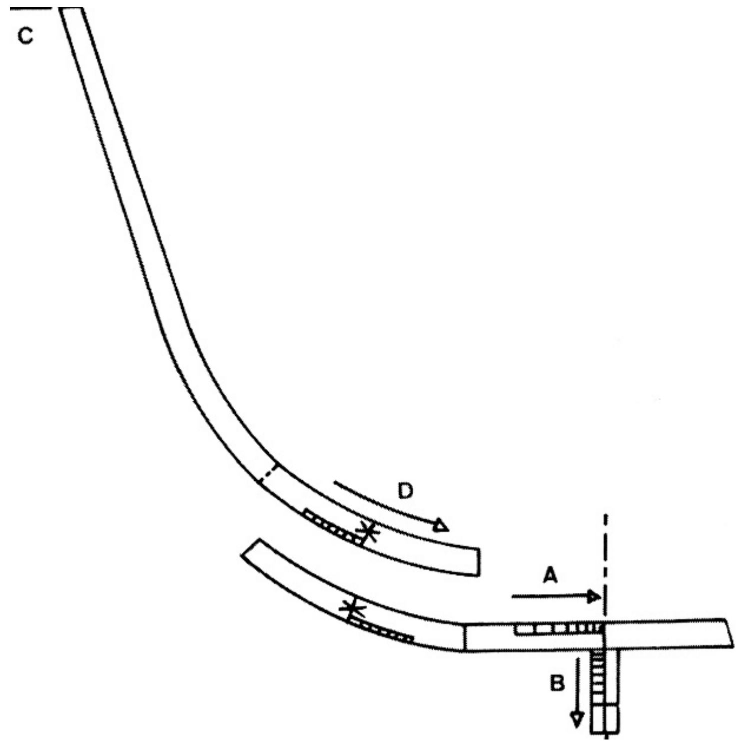

Figure 17. The various 'mechanic' modifications of the Mediterranean midship mould [38].

In practice, in the Middle Ages as in modern times, the layout of the midship section was drawn on the ground at full size. Then, based on this drawing, three wooden 'instruments' were made: a mould reproducing the figure of the master frame, a rising board, and a *trebuchet* (widening tablet). On each of these 'instruments' were directly plotted, also in full size, the values of the different series of progressive divisions obtained with the help of the 'geometric operators' and relating to the reduction of the length of the floor timber, the increase in the rising and, possibly, the *trebuchement*.

The mechanic combination in horizontal (for the reduction of the length of the floor timber), vertical (for the increase in the rising), and transverse (for the *trébuchement*) of these different 'instruments', which are by definition mobile, led to the tracing of the entire contour of the frames arranged between the two tail-frames. At this stage, the design 'instruments' had become 'construction' instruments, underlining how closely the design and the building phases are associated in this method. In a sense, there was no break in the chain of operation between the upstream phase of design and 'thinking' and the downstream phase of building and 'making'.

This Mediterranean moulding method is attested in written sources from the end of the 13th century and, in archaeological sources, from the end of the 13th to the beginning of the 14th century with the Culip VI shipwreck (Spain) [39]. It remained in use in France, along the Provençal and Languedoc coastline, until the 20th century in the form of the Saint-Joseph's mould [30] (pp. 25–31) which, according to a fine definition by François Beaudouin, "*serves as a lofting room and hull lines for Provençal carpenters*" [40] (p. 73); (Figure 18).

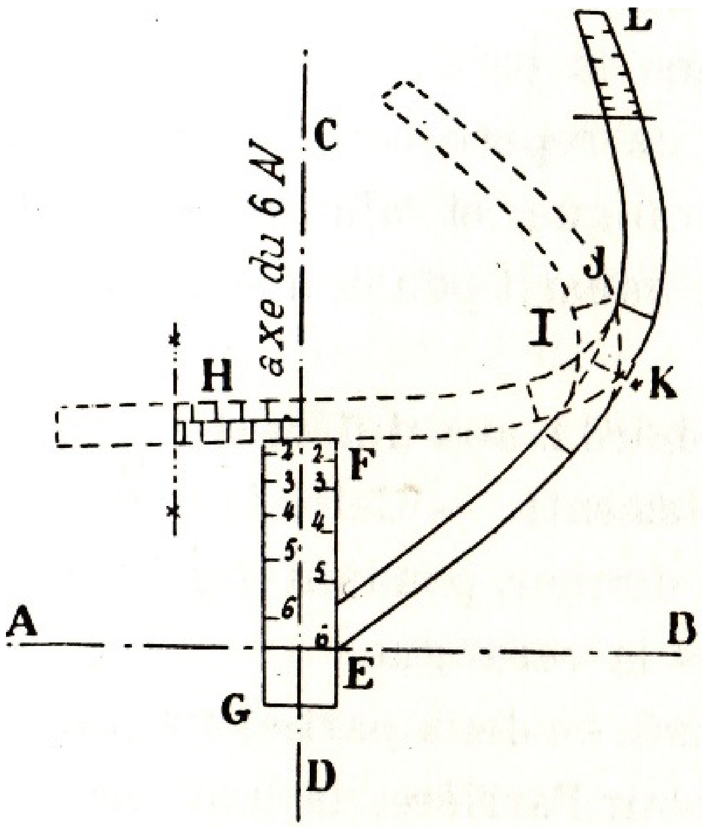

Figure 18. Use of the Saint Joseph's mould and the rising square for shaping the predesigned frame 6 [29].

An important characteristic linked to the use of the midship mould and the rising square method was formulated by Walter Gaspard. When asked by a shipwright about the use of the Saint-Joseph's mould, the carpenter told him that the midship section had to be a floor timber absolutely flat "*pour bien porter sur le talon*", i.e., "*to rest well on the heel of the floor timber*" [40].

This characteristic of the Saint-Joseph's mould of the Provençal and Languedoc ship carpenters refers to the oldest representation [41] of the midship mould of a *galley* and *nave* in the Venetian "treatises on technical recipes for naval architecture" from the 14th century [42–48], including the mythical anonymous manuscript of the *Fabrica di galere*, which was edited in part as early as 1840 by the French historian Augustin Jal in his *Archéologie navale*. It is obvious that there is a continuity of technical culture between the medieval method of the Mediterranean moulding method and the traditional method of the Saint Joseph's mould. This continuity of architectural design associated with a transverse principle 'frame-first' is indeed reflected in the geometric figure of the master frame resting on a flat floor-timber, only the end of which has a more or less significant rising at the *escoue* points. Therefore, this geometrical figure of the midship section would seem to be the most significant and representative of the 'architectural signatures' of the Mediterranean architectural tradition.

However, as we have noted, archaeology also testifies to the existence, albeit in a very small minority, of another model of the midship section with a different geometric figure marked by a 'wine glass' section with the return of garboard. One of the questions that arises is whether this 'wine glass' midship section model can be designed using the Mediterranean moulding method.

One possible answer to this question is provided by the treatise on naval architecture (1686) by the Venetian shipbuilder Steffano de Zuanne [49]. Although Zuanne's manuscript does not explicitly mention the use of the Mediterranean moulding method, the title page makes an implicit reference to it. S. de Zuanne notes that his text "*descritte le raggioni e regole p. fabricare ogni Sorte di Navi, Galere, Galeazo, Galeote, Caichy, Feluche, et ogni altro bastimenti*". He adds that his manuscript also contains "*li dissegni [. . .] per formare li Sesti e Partizioni per fabricare*". These terms refer both to the design phase—the proportions and rules—[*le raggioni e regole*], and to the building phase—the tracings for making the Mediterranean master mould [*sesti*] and using the geometric operators [*partizioni*]. This is also implicit in the figures accompanying each numerical specification for a particular type of ship. Indeed, the figures systematically include the three sections or half-sections of the master frame (*Corba Maistra*), the fore tail frame (*Cao di Sesto da Proua*) and the aft tail frame (*Cao di Sesto di Pupa*). On the figure of the midship frame, almost systematically, and on that of the tail frames, more irregularly, the position of the middle of the line of the floor timber (*fondi*) and that of the rising at the *escoue* point are graphically indicated. Furthermore, the *stella* is systematically represented under the line of the floor timber, which corresponds to a geometrical construction line and not to the real shape of the floor timber. All these indications are indicative of the use of the Mediterranean moulding method without or with rising. In this second case, the principle remains the same; only the application changes and involves an additional operation to connect the line of the flat of the floor timber to the rising square by a straight or a curve line either by turning the mould over or by using an additional 'instrument', the 'hollow mould'.

Two important aspects should be highlighted. Of the 25 midship sections designed by S. de Zuanne, which correspond to as many different architectural models of ships, 19 midship sections have a flat floor timber and only six midship sections have a raised floor timber, the height of which remains reduced in all cases. For example, the *stella* of the *corba maistra* of a "*navi di piedi di 90 in colomba*", i.e., a ship with 90 Venetian feet (about 31.25 m) of keel length, is about 5.5 cm (Figure 19).

It is obvious that the manuscript of S. de Zuanne is not an official statistical collection of the different Mediterranean master frame models of the late 17th century. It reflects the technical thinking of a Venetian shipbuilder, which can nevertheless be considered as probably representative of the architectural trends of his time. It can be seen that within the limits of this treatise on Mediterranean naval architecture, the midship sections with flat floor-timber are in the vast majority and seem to correspond to the 'architectural signature' shared by the Mediterranean shipyards. In addition, S. de Zuanne refers in his treatise to some types of ships from other traditions than Venetian. This is the case for the shape of ships in the *maniera Genovese* [49] (f° 43). The Genoese midship section designed by S. de Zuanne ("*corba maistra che usano li Genovesi nelle loro navi*") [48] (f° 62 v°) has a strictly flat floor-timber which is totally in keeping with this Mediterranean architectural tradition whose origins would seem to lie, along with the Dor 2001/1 shipwreck, in the very early Middle Ages (Figure 20).

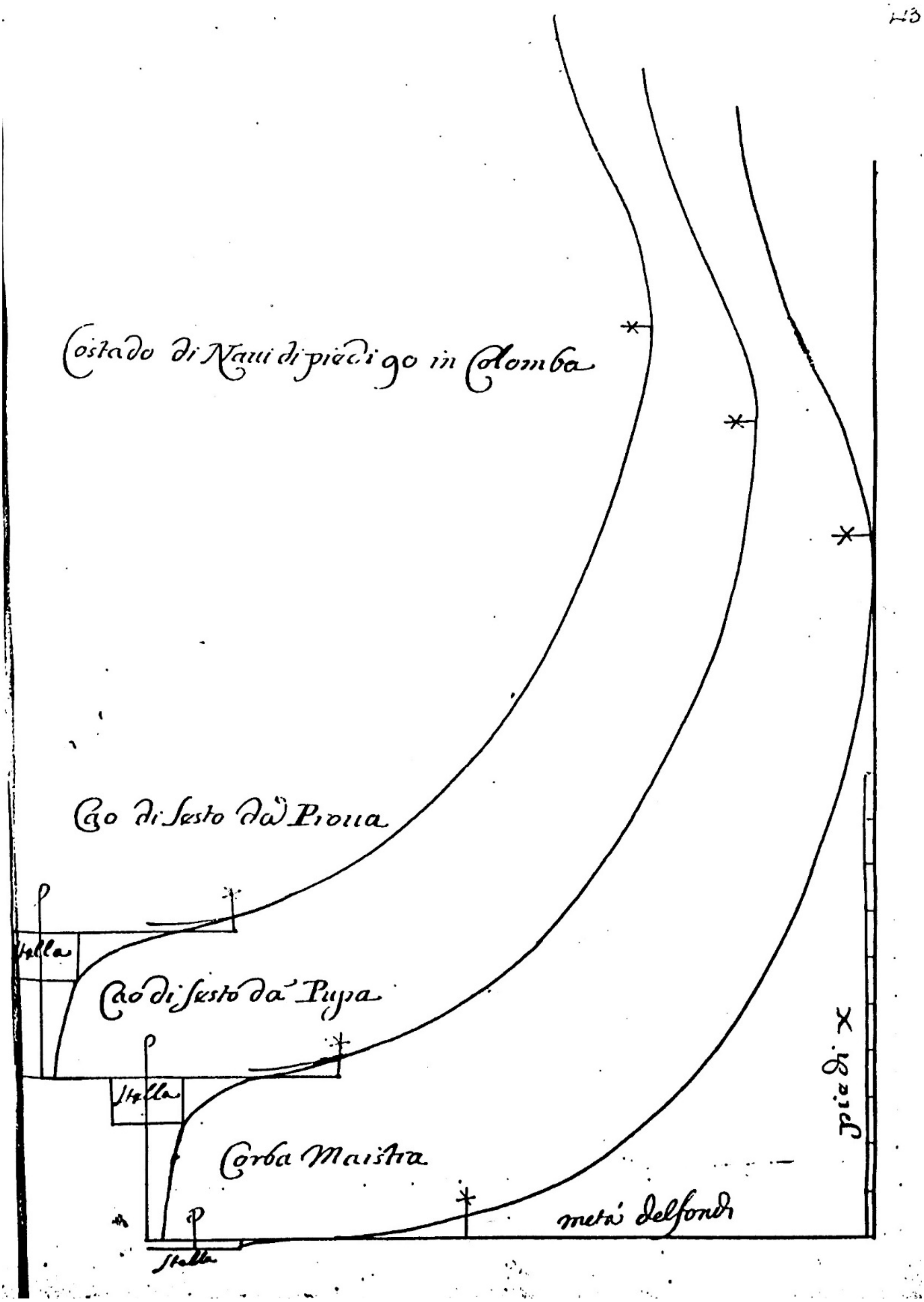

Figure 19. Midship section and tail sections of a *nave* of 90 feet keel length [48].

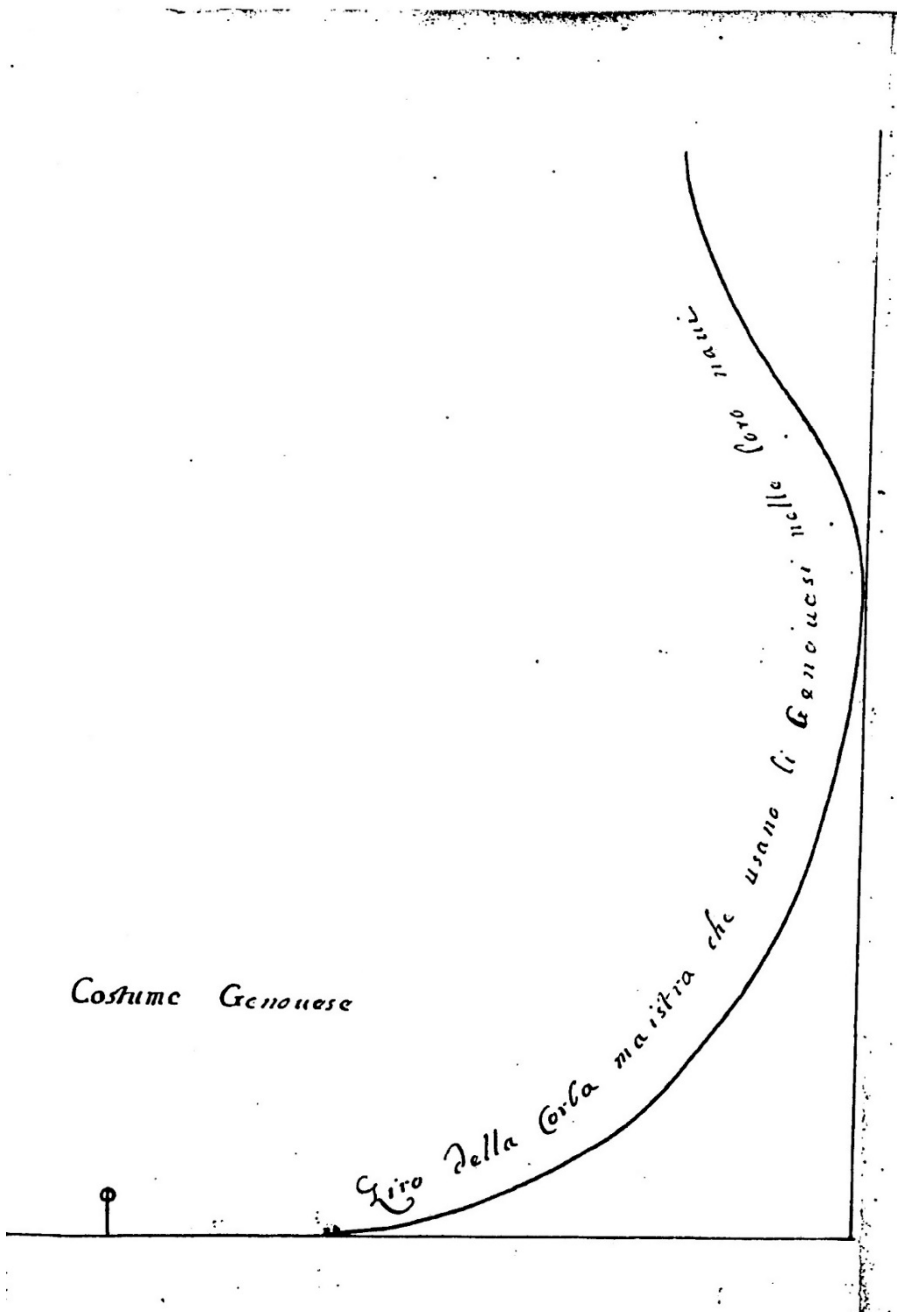

Figure 20. Midship section *in the Genoese manner* [48].

6. Conclusions

From the origins to the present day, this geometric 'architectural signature' of the technical culture of Mediterranean shipbuilders and shipwrights, characterised by a flat master frame in relation to the Mediterranean moulding method of design, was still very much in evidence until a few years ago in some of the small traditional shipyards on the southern shores of the Mediterranean. It is a part of this living medieval memory that we had the chance to observe with our dear Tunisian friend and fellow historian, the late Abdelhamid Barkaoui, in the Kerkenna Islands, an archipelago located off the port of Sfax in Tunisia [50]. The master mould used in the small shipyard of El Ataïa situated on the beach allowed the ship builder to design a *"flûka arbi"* master frame: an extraordinary living lesson in naval architecture referring to a technical culture inscribed in the historical *longue durée* and shared by the southern and northern, eastern, and western shores of the Mediterranean (Figures 21 and 22).

Figure 21. Shipbuilder from the El Ataïa shipyard (Kerkenna Islands, Tunisia) drawing a floor timber with the help of the Mediterranean midship mould (Ph. E. Rieth).

Figure 22. Detail of the Mediterranean midship mould and the rising square from the El Ataïa shipyard showing the marks for reducing the length of the floor timber and those for increasing the rising (Ph. E. Rieth).

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References

1. Rieth, E. From Words to Technical Practices: Moulds and Naval Architecture in the Middle Ages. In *Creating Ships in Civil and Naval Architecture. A Cross-Disciplinary Comparison*; Nowacki, H., Lefèvre, W., Eds.; Brill: Boston, MA, USA, 2009; pp. 349–366.
2. Nowacki, H.; Valleriani, M. A similar Atlantic and Mediterranean ships design method: The case of the French royal dockyards at the end of the XVIIth c. In *Shipbuilding Practice and Ship Design Methods from the Renaissance to the 18th Century: A Workshop Report*; Preprint; Max Planck Institut für Wissenschaftgeschichte: Berlin, Germany, 2003; Volume 245, pp. 79–89.
3. Rieth, E. Une tradition médiévale et méditerranéenne de conception des navires construits à franc-bord « membrure première. In *Concevoir et Construire les Navires. De la Trière au Picoteux*; Rieth, E., Ed.; Technologies, Idéologies, Pratiques, XIII, 1; Editions Erès: Ramonville Saint-Agne, France, 1998; pp. 91–108.
4. Villain-Gandossi, C.; Durteste, L.; Busuttil, S. La méthode méditerranéenne du trébuchet dans la conception des navires: Quelques repères chronologiques. In *Proceedings of the Méditerranée, Mer Ouverte: Actes du Colloque de Marseille*; International Foundation: Paola, Malta, 1997; pp. 307–321.
5. Rieth, E. A propos du terme espalhamento chez Manoel Fernandes (1616). *Neptunia* **1996**, *203*, 33–40.
6. Rieth, E. *Le Maître-Gabarit, la Tablette et le Trébuchet. Essai Sur la Conception Non Graphique des Carènes du Moyen Age au XX^e^ Siècle*; CTHS: Paris, France, 1996.
7. Pomey, P. Pour une approche nilotique des origines (Ve-VIIe siècle) de la construction navale «sur membrure première» en Méditerranée. In *La Batellerie Égyptienne. Archéologie, Histoire, Ethnologie*; Etudes Alexandrines: Alexandria Governorate, Egypt, 2015; Volume 34, pp. 201–225.
8. Pomey, P.; Kahanov, Y.; Rieth, E. Transition from Shell to Skeleton in Ancient Mediterranean Ship Construction: Analyses, problems and future research. *Int. J. Naut. Archaeol.* **2012**, *41*, 235–314. [CrossRef]
9. Rieth, E. Construction navale à franc-bord en Méditerranée et Atlantique (XIV^{e}–XVII^{e} siècle) et "signatures architecturales": Une première approche archéologique. In *Méditerranée Antique. Pêche, Navigation, Commerce*; CTHS: Paris, France, 1998; pp. 177–188.
10. Kahanov, Y.; Mor, H. The Dor 2001/1 Byzantine Shipwreck, Israel: Final report. *Int. J. Naut. Archaeol.* **2014**, *43*, 41–65. [CrossRef]
11. Joncheray, J.-P.; Jézégou, M.-P.; Lopez, A.; Toulet, J.; Ximénes, S. L'épave sarrasine (X^{e} siècle ap. J.-C.) de Bataiguier. Rapport d'évaluation de 1993. *Cahiers d'Archéologie Subaquatique* **2007**, *16*, 213–222.
12. Barkai, O.; Kahanov, Y. The Tantura F shipwreck, Israel. *Int. J. Naut. Archaeol.* **2007**, *36*, 21–31. [CrossRef]
13. Barkai, O. The Tantura F shipwreck. In *Between the Seas. Transfer and Exchange in Nautical Technology, Proceedings of the Eleventh International Symposium on Boat and Ship Archaeolpogy*; Bockius, R., Ed.; Römisch-Germanischen Zentralmuseums: Mainz, Germany, 2009; pp. 25–31.
14. Steffy, R.J. Construction and Analysis of the Vessel. In *Serçe Limanı: An Eleventh-Century Shipwreck*; Bass, G.F., Matthews, S.D., Steffy, R.J., van Doorninck, F.H., Eds.; Texas A&M University Press: College Station, TX, USA, 2004; Volume 1, pp. 153–169.
15. Beltrame, C.; Bondioli, M. A hypothesis on the development of Mediterranean ship construction from Antiquity to Late Middle Ages. In *Connected by the Sea, Proceedings of the Tenth ISBSA, Roskilde, Denmark 21–25 September 2003*; Blue, L., Hocker, F.M., Englert, A., Eds.; Oxbow Books: Oxford, UK, 2006; pp. 89–94.
16. Steffy, R.J. The Mediterranean shell to skeleton transition: A Northwest European parallel? In *Carvel Construction Technique, Proceedings of the Fifth International Symposium on Boat and Ship Archaeology, Amsterdam, The Netherlands, 1988*; Reinders, R., Kees, P., Eds.; Oxbow Books: Oxford, UK, 1991; pp. 1–9.
17. Fozzati, L. (Ed.) *La Galea Ritrovata*; Consorzio Venezia Nuova: Venice, Italy, 2002–2003.
18. Rieth, E. L'arquitectura naval. In *Excavacions Arqueologiques Subaquatiques a Cala Culip. 2. Culip VI*; Nieto, X., Raurich, X., Eds.; Monografies del CASC: Girona, Spain, 1999; pp. 115–117, 137–201.
19. Bonino, M. Lateeen-rigged medieval ships. New evidence from wrecks in the Po Delta (Italy) and notes on pictorial and other documents. *Int. J. Naut. Archaeol.* **1978**, *7*, 9–28. [CrossRef]
20. Capulli, M. *Le Navi Della Serenissima: La "Galea" di Lazise*; Marsilio Editori: Venice, Italy, 2004.
21. Labbe, M.A. A Preliminary Reconstruction of the Yassiada Sixteenth-Century Ottoman Shipwreck. Master's Thesis, Texas A&M University, College Station, TX, USA, 2010.
22. Joncheray, J.-P. Un navire de commerce de la fin du XVIIe siècle, l'épave des Sardinaux. Première partie: Le navire et son mode de chargement. *Cahiers d'Archéologie Subaquatique* **1988**, *7*, 21–67.
23. Rieth, E. L'épave de Paragan, fin du XVII^{e}-début du XVIII^{e} siècle. Un témoin remarquable des pratiques des chantiers navals méditerranéens. In *Commerce de Cabotage Dans les Bouches de Bonifacio et en Corse aux XVII^{e} et XVIII^{e} Siècles, Catalogue de L'exposition*; Espace Saint Jacques, Édition Ville de Bonifacio: Bonifacio, France, 2019; pp. 73–83.

24. Cibecchini, F.; Rieth, E. L'épave de Paragan 1, Bonifacio, Corse: Un voilier de cabotage de la fin du XVII^{e}-début du XVIII^{e} siècle. *Archeol. Marit. Mediterr.* **2020**, *17*, 125–159.
25. Batchvarov, K.N. Shipwreck Reconstruction Based on the Archaeological Record: Mediterranean Whole-Molding and the Kitten Wreck Case Study. In *The Oxford Handbook of Maritime Archaeology*; Ford, B., Hamilton, D.L., Catsambis, A., Eds.; Oxford University Press: Oxford, UK, 2013; pp. 251–266.
26. Kocabaş, U. The Yenikapı Byzantine-Era Shipwrecks, Istanbul, Turkey: A preliminary report and inventory of the 27 shipwrecks studied by Istanbul University. *Int. J. Naut. Archaeol.* **2015**, *44*, 5–38. [CrossRef]
27. Pulak, C.; Ingram, R.; Jones, M. Eight Byzantine Shipwrecks from the Theodosian Harbour Excavations at Yenikapı in Istanbul, Turkey: An introduction. *Int. J. Naut. Archaeol.* **2015**, *44*, 39–73. [CrossRef]
28. Evren, T. A group of Early Medieval Ships without Planking Edge Fasteners from the Theodosian Harbour. In Proceedings of the XVth International Symposium on Boat and Ship Archaeology, Marseille, France, 22–27 October 2018; Archaeonautica, CNRS Editions: Paris, France, 2021. in press.
29. Vence, J. *Construction et Manœuvre des Bateaux et Embarcations à Voilure Latine*; Challamel, A., Ed.; Reprinted; Oméga: Nice, France, 1998.
30. Guérout, M.; Rieth, E.; Gassend, J.-M. Le Navire Génois de Villefranche. Un Naufrage de 1516? Archaeonautica, Editions du CNRS: Paris, France, 1990; Volume 9.
31. Villié, P. *Calvi 1*; Editions De Boccard: Paris, France, 1994.
32. Cazenove de la Roche, A. *The Mortella Wreck: A Spotlight on Mediterranean Shipbuilindg in the 16th Century*; International Series; BAR: Oxford, UK, 2020; p. 2976.
33. Daeffler, M. Deux exemples de conception des navires de la seconde moitié du XVI^{e} siècle. *Cahiers d'Archéologie Subaquatique* **1993**, *11*, 141–158.
34. La Madeleine. Tablettes de Marine, c. 1712, Musée National de la Marine, Paris, Bibliothèque, ms R 711.
35. Basch, L. Ancient wrecks and the archaeology of ships. *Int. J. Naut. Archaeol.* **1972**, *1*, 1–58. [CrossRef]
36. Steffy, R.J. *Wooden Ship Building and the Interpretation of Shipwrecks*; TAMU Press: College Station, TX, USA, 1994.
37. Chiggiato, A. Contenuti delle architetture navali antiche. *Ateneo Veneto* **1991**, *178*, 141–211.
38. Bellabarba, S. The Ancient Method of Designing Hulls. *Mar. Mirror* **1993**, *79*, 274–292. [CrossRef]
39. Rieth, E. Mediterranean Ship Design in the Middle Ages. In *The Oxford Handbook of Maritime Archaeology*; Catsambis, A., Ford, B., Donny, H., Donny, L., Eds.; Oxford University Press: Oxford, UK, 2011; pp. 406–425.
40. Beaudouin, F. *Bateaux des Côtes de France*, 2nd ed.; Editions Glénat: Grenoble, France, 1990.
41. Gaspard, W. Usage du Gabarit de Saint-Joseph. Manuscript Note, to the Author. 26 January 1998; 13p.
42. Rieth, E. La Fabrica di galere. In *Utilis est Lapis in Structura. Mélanges Offerts à Léon Pressouyre*; Editions du CTHS: Paris, France, 2000; pp. 381–393.
43. Bondioli, M. L'arte della costruzione navale veneziana tra il XV e il XVI secolo. In *Navalia. Archeologia e Storia*; Ciciliot, F., Ed.; The International Propeller Club of Savona: Savona, Italy, 1996; pp. 139–155.
44. Bondioli, M. Le galee: Storia degli studi. In *Le Navi della Serenissima. La "Galea" di Lazise*; Capulli, M., Ed.; Marsilio Editori: Venice, Italy, 2003; pp. 82–85.
45. Bondioli, M. Introduzione allo studio della costruizone delle galee veneziane: Il contributo dei manoscritto. In *Le Navi della Serenissima. La "Galea" di Lazise*; Capulli, M., Ed.; Marsilio Editori: Venice, Italy, 2003; pp. 92–95.
46. Bondioli, M. The Art of Design and Building Venetian Galleys from the 15th to the 16th century. In *Boats, Ships and Shipyards, Proceedings of the Ninth International Symposium on Boat and Ship Archaeology, Venice 2000*; Beltrame, C., Ed.; Oxbow Books: Oxford, UK, 2003; pp. 222–227.
47. Bondioli, M. The Libro di navigar. A new treatise on Venetian shipbuilding from the 14th century. In *Ships and Maritime Landscapes, Proceedings of the Thirteenth International Symposium on Boat and Ship Archaeology, Amsterdam 2012*; Gawronski, J., van Holk, A., Schokkenbroek, J., Eds.; Barkhuis Publishing: Eelde, The Netherlands, 2017; pp. 215–223.
48. Chiggiato, A. Le "Ragioni Antique" dell' Architecturra Navale. In *Ragioni Antique Spettanti all' Arte del Mare et Fabriche de Vasselli*; Bonfiglio, D.G., Ed.; Il Comitato Editore: Venice, Italy, 1987; pp. 56–79.
49. de Zuanne, S. *L'Archittetura Navale*; British Library: London, UK, 1686; p. 38655.
50. Barkaoui, A.; Rieth, E. *Histoire et Mémoire de la Construction Navale Vernaculaire aux îles Kerkenna, Tunisie*; arabic edition; Medi Ali Editions: Sfax, Tunisia, 2014.