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# A New Type of Construction Evidenced by Ship 17 of Thonis-Heracleion

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Ship 17 is the first of 63 vessels from the submerged city of Thonis-Heracleion in Egypt to have been excavated. The peculiar constructional features of this ship, which dates to the Late Period (722–332 BC), allow us to argue for a previously undocumented type of construction that finds parallels in Herodotus' description of a Nilotic freighter known as a *baris* (History, 2.96, *c.*450 BC). The aim of this article is to outline the main characteristics and the possible sequence of construction of Ship 17.


*Key words:* Maritime archaeology, ancient shipbuilding, shipwrecks, Late Period in Egypt, Herodotus.

Ship 17 was discovered in 2003 during a survey carried out by the Institut Européen d'Archéologie Sous-Marine (IEASM) in the port area of the submerged city of Thonis-Heracleion at a depth of 7–8 m (Goddio, 2007: 114, fig. 3.85) (Fig. 1). The ship belongs to a group of about a dozen boats, mostly of the same type, that were probably intentionally scuttled to reclaim land, or to divide the harbour or into several basins (Robinson, forthcoming).


*Figure 1.* Map showing the location of the site of Thonis-Heracleion in the Mediterranean. (Author)

The construction of the ship was studied over three excavation seasons (2009–2011). The ship was found under 0.30–1.05 m of sediment. A layer of sand (0.30–0.50 m thick) overlay a layer of dense clay that sealed the major part of the hull and secured its good state of preservation. Neither cargo nor the crew's belongings were found on board. Several artefacts, in addition to ceramics, discovered during the excavations in the layer of sand, cannot be definitely associated with the ship. Radiocarbon calibrated dates range from 804 to 416 cal BC at 2 sigmas (probability of 95%).[1] It has been possible to narrow down this time span by dating the ceramic material found in the clay layer immediately adjacent to the inner surface of the planking and preserved *in situ* under fallen timbers inside the hull. According to the conclusions of C. Grataloup, ceramics expert with IEASM, two amphoras found in contact with the inner planking and within this layer (a Corinthian type B amphora, artefact L1.11752, and an amphora of Aegean type [Cos], artefact L1.12056), provide a *terminus ante quem* for the sinking of the ship of the middle of the 4th century BC. Other ceramic material forming a coherent group (total of 18 vessels), indicates the middle of the 5th century BC for the initial deposition of the sealing layer. Defining the *terminus post quem* for the ship is much more problematic. Calibrated radiocarbon dates leave a wide range of 794–540 BC even at 1σ (probability of 68%). It is also necessary to keep in mind that contracts of the lease-sale of ships (*misthoprasia*) propose that in Roman Egypt the longevity of ships could reach 50–60 years (Arnaud, 2012: 95). It can be concluded that *stricto*


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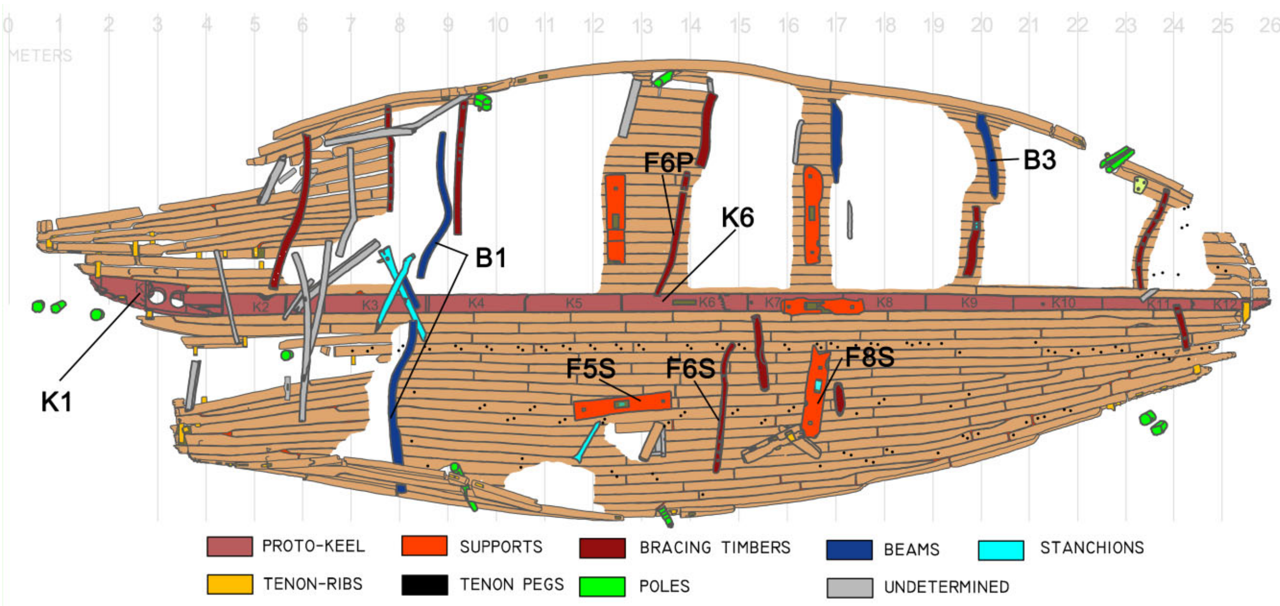


*Figure 2.* General plan of Ship 17 of Thonis-Heracleion. (Drawing by Patrice Sandrin/Alexander Belov © IEASM)

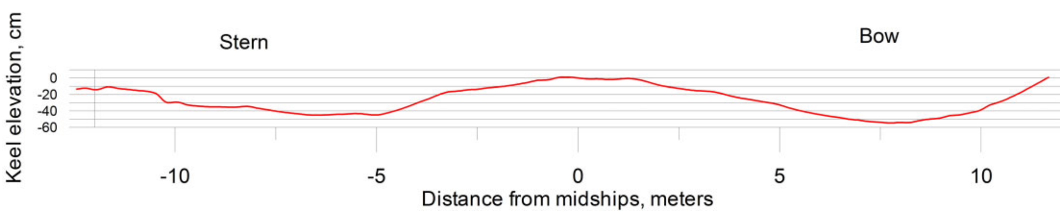


*Figure 3.* Profile of the proto-keel of Ship 17 *in situ*. Vertical axis is exaggerated in this view. (Author)

*sensu* Ship 17 is currently dated between the middle of the 8th and the middle of the 4th century BC. However, the ceramic material clearly suggests a sinking between the beginning of the 5th and the middle of the 4th century BC.

Low visibility, usually not exceeding 1.5–2 m, and the shallow depth were major hindrances during the excavations. The site is situated in the open part of the bay at a distance of 6 km from the nearest shore, and northern winds can lead to a high swell that causes turbulence that stirs up the bottom. The entire starboard of the ship and some parts of its port side were uncovered, corresponding to about 70% of the entire surface of the hull (Fig. 2).

The bow of the ship points towards 240° (compass degrees), with the hull lying approximately SW-NE. The stern was identified on the grounds of the pronounced tapering in the width of the proto-keel from one end to the other, and the presence of two shafts for the axial rudder in the end segment at the wider end (K1). The width of the ship's keel is greater than its thickness (sided vs moulded dimension) and can be classified as a proto-keel. The proto-keel consists of 12 segments. When excavated, the ends were lower in the sediment than the midship section (Fig. 3). The outward collapse of the hull is observed in the transversal axis due to the burial processes (Fig. 4). The general plan of the ship at a 1/20 scale was drawn using the triangulation method. It was complemented by large-scale drawings of the major hull components. All of these were drawn under water with the exception of the central segment of the proto-keel, which was temporarily lifted to the surface to be drawn and photographed. Several photomosaic surveys of the ship have also been carried out (Fig. 5). The 3D-position of the ship's remains was recorded using a goniometer at 1-metre intervals. Four sections of the hull were drawn in selected areas to study the fastenings of the proto-keel and the planking. The planking width was measured at 1-m intervals along the hull's length.

Fourteen acacia poles (*Acacia sp.*) surround the ship and many of these pierce the planking (see Figs 2 and 5). The poles are circular (diameter 0.12–0.25 m) or square (0.15 x 0.15 m on average) in section. One of the acacia poles, excavated in the clay, was 3.40 m long and formed from a branch that ended in a pointed fork. It appears that the poles served to secure the ship to the clayey bottom.

The preserved part of the hull has a length of 25.2 m and a breadth of 9.4 m. The most conspicuous damage to the hull, probably caused by a pole being driven through it, is observed on the starboard aft where a

 

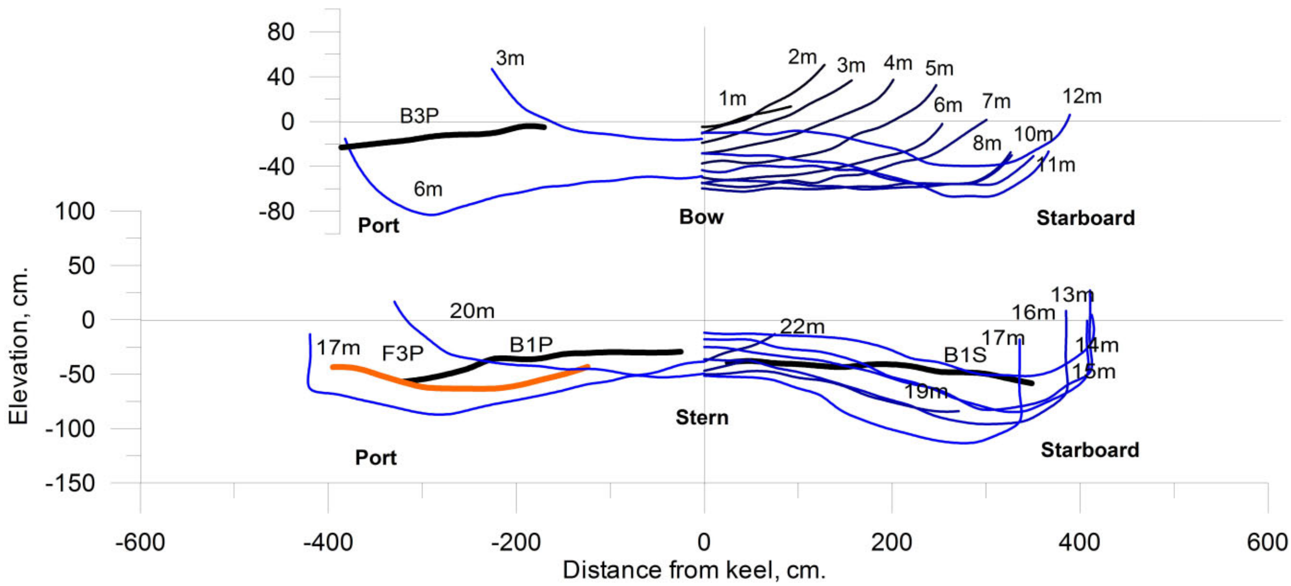


*Figure 4.* Sections of the hull of Ship 17 *in situ* taken at 1-metre intervals. Numbering of the sections starts at the preserved bow extremity. (Author)

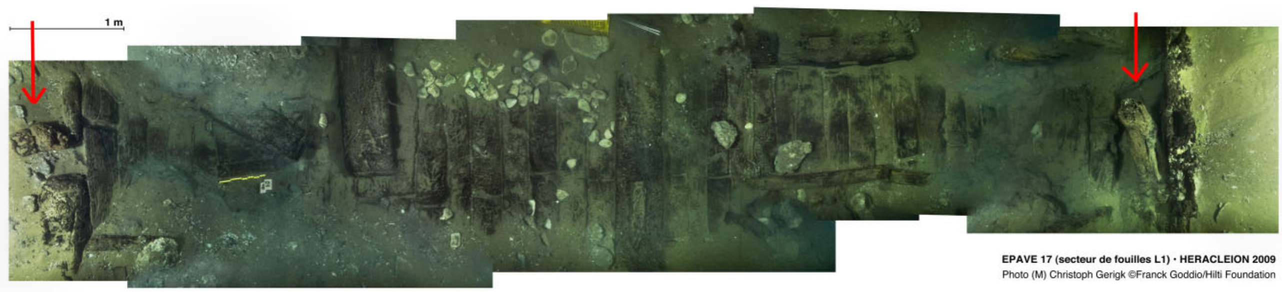


*Figure 5.* Photomosaic of a slice through the middle section of Ship 17, with proto-keel segment K6 in the centre, port to the right. Red arrows indicate position of the vertical poles. (Photomosaic by Christoph Gerigk © Franck Goddio/Hilti Foundation)

wide gap can be seen between strakes S3 and S5 (Fig. 2). In the same region, the upper portions of preserved strakes S21–S24 are broken and lean into the hull, probably due to the impact of the prow of Ship 63 discovered nearby. The preserved remains of the ship include 12 segments of proto-keel, 24 starboard and 22 port strakes of planking, five supports, ten bracing timbers, four stanchions and three through-beams. The choice of these terms will be explained in the following paragraphs. The purpose of seven other pieces of construction timber remains difficult to determine.

Ship 17 is nearly contemporary with the description given by Herodotus of a *baris* in the mid 5th century BC (*History*, 2.96). Both Herodotus' *baris* and Ship 17 were Nilotic freighters built of acacia and share many constructional features in their longitudinal and transversal structures (Belov, forthcoming a, c). Among the features which allow us to classify Ship 17 as a freighter can be noted the choice of the hardwood acacia as a boatbuilding material, the ruggedness and strength of the thick planking, the strong asymmetry of all constructional details, the absence of a deck, and the presence of an axial rudder. The methods used for assembling the planking and making the hull watertight seem to be very similar in the two ships, as do the steering systems (Belov, 2014a). These similarities strongly suggest that Ship 17 belongs to the same generic type as the *baris,* and justify an attempt to outline the major characteristics of this previously archaeologically unattested construction type.

## Longitudinal structure

The proto-keel of Ship 17 is cut of acacia (*Acacia sp.*). Its preserved length is 24.2 m and it consists of 12 short segments ranging in length from 1.63 to 3.05 m. The proto-keel is considerably thicker than the planking and reaches 0.265 m (moulded) with an average value of 0.191 m, while the planking has an average thickness of 0.147 m.[2] It is also much wider than the latter, especially in the after-part of the ship. The proto-keel is 0.348 m sided on average, while the planking is only

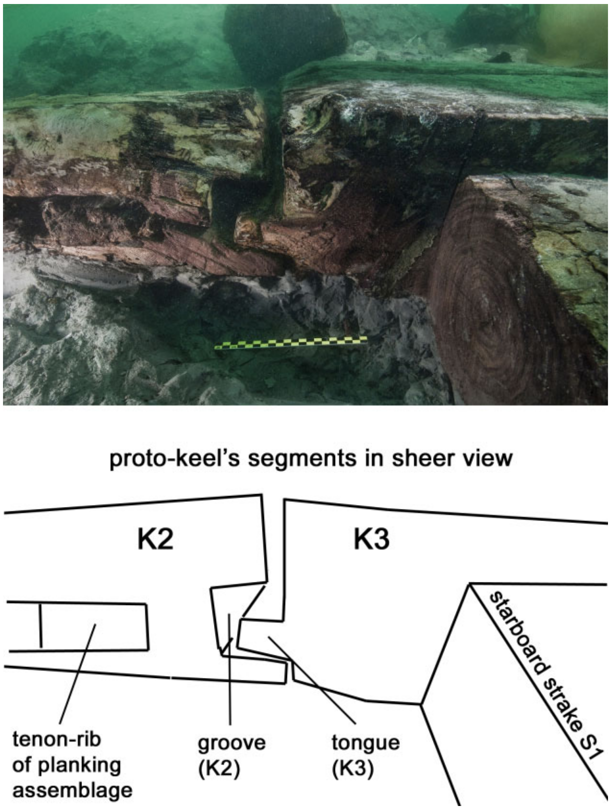


*Figure 6.* Sheer-view of the tongue-and-groove joint between segments K2 and K3 of the proto-keel of Ship 17. (Photo by Christoph Gerigk © Franck Goddio/Hilti Foundation, drawing Author)

0.182 m thick. The keel projects *c.*12 mm inside the hull and is flush with the outboard of the planking. In section it resembles the proto-keel of the Bronze-Age shipwreck of Uluburun (*c.*1300 BC) (Pulak, 1988; Pulak, 2002: 636, fig. 3, 4). It seems that, in spite of the short lengths of the segments, the proto-keel played an important structural role in the construction of Ship 17 (Belov, forthcoming b). This conclusion is supported by the solid assemblage of the proto-keel and the planking. Segments of the proto-keel are assembled longitudinally with tongue-and-groove joints (Fig. 6). On average, the grooves are 55 mm wide and 61 mm deep, while the tongues are 43 mm wide and 54 mm long.

The planking of Ship 17 consists of short, thick planks from squared logs of acacia (*Acacia nilotica, A. raddiana*: IFAO 144, 2008; IFAO 373–377, 2010). The inboard surfaces of the planks appear to be flat, while their outboard surface is sometimes slightly curved. Many planks follow the wood's grain and contain knots and fissures. The length of the planks on the starboard side varies from 0.49 to 3.77 m (Table 1). The majority of planks, 75.5% of all starboard planks, measure between 1.70 and 2.20 m in length. The average length of the starboard planks is 1.92 m (Table 2).

The width of the planks measured at 1 m intervals along the keel varies between 0.09 and 0.29 m (0.182 m on average). The data on the thickness of the planks is incomplete as it has been measured only for the uppermost preserved planks and in the four areas measured for the hull sections. It ranges from 0.10 to 0.18 m with an average value of 0.147 m. The planking joints are staggered producing a 'brick wall' pattern corresponding exactly to the description by Herodotus and to Egyptian iconographic evidence (Boreux, 1925: 248).

The planking plan is characterized by many stealer strakes, some of which end with knife-shaped planks (Fig. 7). This can be seen towards the end of S8/S9, and S12/S13, for example, where a single plank is shaped to curve around the end of the adjacent plank thus reducing two strakes to one. This serves as a good illustration of a common boatbuilding principle of diminishing the number of strakes towards the extremities of a vessel. Parallels in Egyptian archaeological material can be found in the construction of the Khufu I boat (Ward, 2000: 102), the boats from Lisht (Haldane, 1992: pl. 122–3, 131), the planks from Mersa Gawasis (Ward and Zazzaro, 2010), Ayn Sukhna (Pomey, 2012), and of the Mataria boat (Ward, 2000: 130, fig.72).

The half-lap joint, which was widely employed for the longitudinal joints between the planks of Ship 17, may provide another parallel with the construction of the Mataria boat (*c.*450 BC) (Ward, 2000: 131). The overlap ranges between 20 and 45 mm. However, several planks are assembled with more complex scarfs judging by their broken line in sheer-view.

The most intriguing part of the construction of Ship 17 is the manner in which the planking is assembled. The planks are joined transversally using very long pieces of wood that we may temporarily call 'tenons'. They are installed in rectangular channels cut in the centre of the plank edges that are 111–310 mm wide (199 mm on average) and 40–80 mm thick (59 mm on average). The wide variation in the width of the channels is explained by the phenomenon of ordinary and double-sized channels discussed below.

The visible tenons, within their channels, at the bow and stern extremities of the hull were apparently not preserved to their full length. In order to document a complete tenon, one was chosen on the starboard side, 9 m from the preserved bow extremity (Fig. 8). The channels were half-opened on the inboard using a saw. The tenon measured 1.99 m in length and passed through 11 strakes of planking (Belov, forthcoming a) (Figs 9 and 10).

The tenon was wedged inside the channels in some of the strakes with small slips of wood of triangular profile and rectangular section. The extremities of the tenon were secured to the planking in strakes S4 and S15 with pegs of 35 mm diameter that seem to have been driven from the interior of the hull. A fragment of another pegged tenon, which rises towards the sheerstrake, was found in strake S15.

The planking tenons can still be seen in the channels of the uppermost preserved strakes. Together with

 

**Table 1.** *Length of the starboard planks of Ship 17 in m. Shortest and longest in bold. Colours indicate plank length groups (see Table 2)*

| | Plank No. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Strake | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average for strake |
| S1 | 1.894 | 1.839 | 1.601 | 1.952 | 1.935 | **0.490** | 2.074 | 1.962 | — | — | 1.72 |
| S2 | 1.650 | 0.700 | 1.102 | 1.801 | 1.860 | 1.850 | — | — | — | — | 1.49 |
| S3 | 1.945 | 1.718 | 1.738 | 1.918 | 1.818 | 2.118 | 1.862 | 2.081 | — | — | 1.90 |
| S4 | 1.941 | 1.571 | 1.874 | 1.826 | 1.912 | 1.998 | 2.011 | — | — | — | 1.88 |
| S5 | 1.267 | 1.779 | 1.756 | 1.774 | 1.863 | 1.956 | 2.051 | 1.978 | 2.122 | — | 1.84 |
| S6 | 3.075 | 1.847 | 2.028 | 2.000 | 2.088 | — | — | — | — | — | 2.21 |
| S7 | 2.154 | 1.358 | 1.779 | 1.792 | 1.934 | 1.955 | 2.095 | 2.096 | **3.773** | 2.288 | 2.12 |
| S8 | 1.676 | 1.892 | 2.063 | 1.766 | 2.335 | 2.447 | — | — | — | — | 2.03 |
| S9 | 2.013 | 1.854 | 1.912 | 2.004 | 2.173 | 1.907 | — | — | — | — | 1.98 |
| S10 | 1.861 | 1.573 | 1.756 | 1.839 | 2.087 | | — | — | — | — | 1.82 |
| S11 | 2.206 | 1.790 | 1.576 | 1.876 | 1.991 | 2.076 | 2.052 | 2.128 | — | — | 1.96 |
| S12 | 1.951 | 1.876 | 2.012 | — | — | — | — | — | — | — | 1.95 |
| S13 | 1.724 | 1.460 | 1.569 | 1.881 | — | — | — | — | — | — | 1.66 |
| S14 | 2.192 | — | | — | — | — | — | — | — | — | 2.19 |
| S15 | 1.801 | 1.962 | 1.255 | 1.814 | 2.619 | | — | — | — | — | 1.89 |
| S16 | 1.940 | 1.921 | 2.193 | 2.225 | | — | — | — | — | — | 2.07 |
| S17 | 3.137 | 1.980 | 2.481 | — | — | — | — | — | — | — | 2.53 |
| S18 | 1.829 | 1.944 | 1.121 | 2.067 | — | — | — | — | — | — | 1.74 |
| Average starboard | | | | | | | | | | | 1.92 |

**Table 2.** *Dimensional groups for the starboard planks of Ship 17. Total of 102 planks*

| Length in m | Number | Percent | Average in m |
|---|---|---|---|
| <170 | 15 | 14.7 | 1.331 |
| 170–220 | 77 | 75.5 | 1.936 |
| 220–270 | 7 | 6.9 | 2.372 |
| >270 | 3 | 2.9 | 3.328 |

those studied while recording the hull sections, a total of 57 tenons were analysed. The width of these tenons varies from 75 to 200 mm and their thickness from 12 to 52 mm (128 x 41 mm on average). It will be shown that the length of the tenons can be estimated from the position of the tenon pegs.

In my own translation, Herodotus describes the assemblage of the planking of the *baris* in the following terms: 'From this acacia, then, they cut planks two cubits long and arrange them like bricks, building their ships in the following way: on the strong and long tenons they insert two-cubit planks' (Belov, forthcoming c). The Greek word *γόμφος* used by Herodotus has a general meaning of 'fastening' and a non-exhaustive list of suggested translations includes a 'stake' or a 'pole' (Rawlinson, 1880: 154; Godley, 1921: 383), a 'pin' or a 'dowel' (Casson, 1971: 14; Lloyd, 1979: 48), a 'peg' or a 'treenail' (Larcher, 1889: 160–1; Boreux, 1925: 248, *cheville* in French) and a 'tenon' (Lloyd, 1976: 385; Vinson, 1998: 256). As will be shown, the constructional elements in question are of primary importance for the transversal structure of the ship. Their function as internal frames is even more obvious than in the case of the Uluburun ship (Pulak, 1988; 2008: 303). Taking this into consideration, I propose the term of 'tenon-rib' ('*tenon-côte'* in French) for this constructional element (Belov, 2014b). The planking of the Mataria boat was probably similarly assembled with very long tenons (Ward, 2000: 133). Keeping in mind that two millennia separate Ship 17 from the vessels depicted in the tombs of the Old Kingdom, it is interesting to note that the boatbuilding scenes of the period may also contain depictions of elements resembling the tenon-ribs in question (Belov, forthcoming a).

The remains of the two strakes of planking of both boards that are preserved above the level of the through-beams seem to correspond to the bulwark (Fig. 11). These strakes are considerably wider than the others (0.250–0.273 m compared to an average of 0.182 m for all the planking). In traditional Egyptian boats, the bulwark played an important role in the longitudinal structure and was an effective solution for countering hogging of the sickle-shaped hulls (Haldane, 1993: 234–5; Vinson, S., 1997). However, the poor state of preservation of this part of Ship 17 precludes it from providing a convincing argument for an important structural function of the bulwark.

## Transversal structure

As stated, the tenon-ribs used to assemble the planking played a primary role in the transversal structure of the

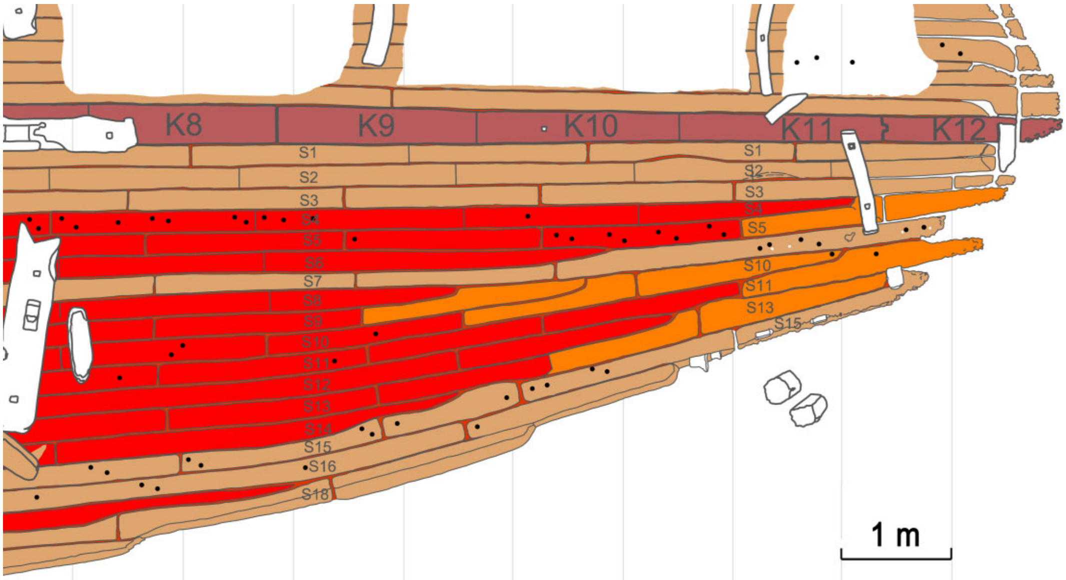


*Figure 7.* Bow area of Ship 17 with the stealer strakes of the planking in red and the knife-shaped planks in orange. (Drawing by Patrice Sandrin/Alexander Belov © IEASM)


*Figure 8.* Position of the transversal cut made in the planking at the bow of Ship 17 to investigate the tenon-rib structure, in red. (Drawing by Patrice Sandrin/Alexander Belov © IEASM)

ship and we will return to this point in the following section.

Three through-beams are preserved, although it can be suggested on the grounds of their distribution pattern and the necessity to support a centrally positioned mast that there were at least seven of them initially. Their form is characterized by the natural curvature of the large branches and trunks of acacia of which they are made (Fig. 12). In section the beams preserve their natural round or oval form and only their ends were squared. It seems that through-beam B1, 7.57 m long, was almost completely preserved. Its dimensions change from 180 x 105 mm near the starboard end to 120 x 50 mm near the port one. Through-beams are quite characteristic of Ancient Egyptian

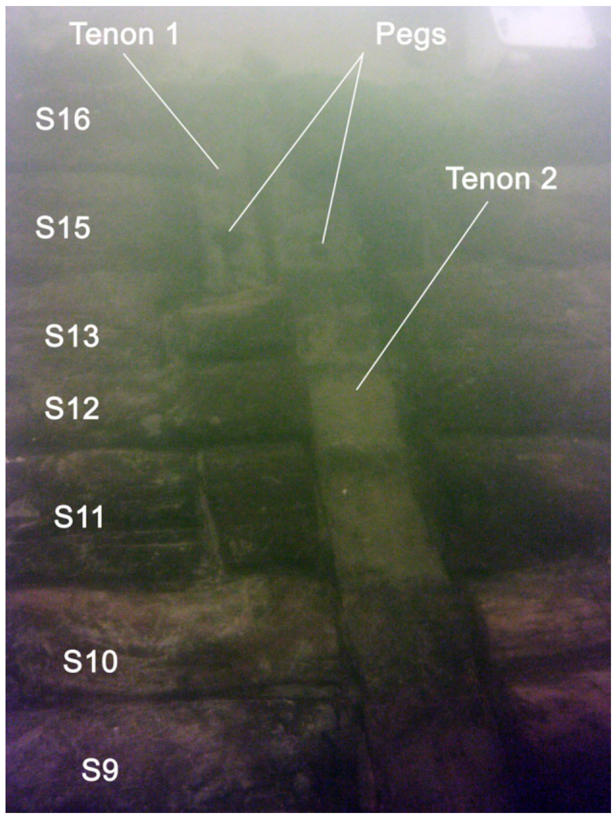


*Figure 9.* Tenon passing through the channels of the starboard strakes of Ship 17. The inner face of the planking has been removed to reveal the tenon-rib. (Photo by the Author © Franck Goddio/Hilti Foundation)

 

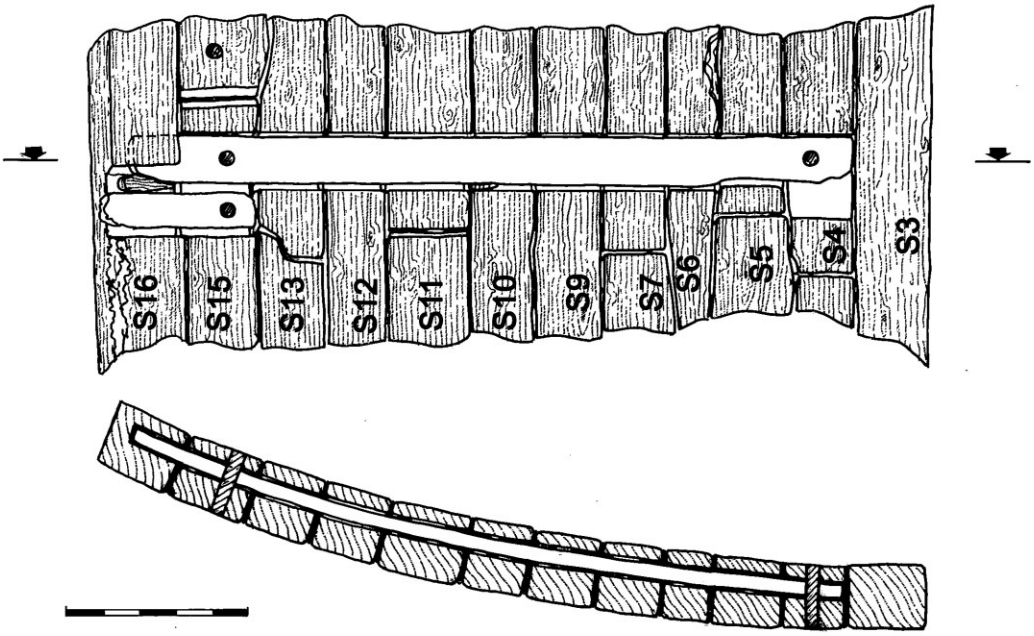


*Figure 10.* Plan and profile of the section at the bow of Ship 17 corresponding to Fig. 9. Scale 0.5 m.(Drawing by Patrice Sandrin © IEASM)

boatbuilding (Boreux, 1925: 306; Landström, 1970: 147). The weight of the beams was distributed across the surface of the planking by means of stanchions installed in mortises in five short, massive supports (Fig. 13) which were found in the central part of the hull, and in some of the bracing timbers. The supports were made of apparently reused planks of acacia, probably from a larger boat than Ship 17. These elements are identified as reused planks by their rectangular shape, presence of rectangular channels (Fig. 13-4) and shaped extremities for assembling adjoining planks (half-lap and joggles). The extremities of the supports, lying on their wide faces, were attached to the planking with two square pegs of *c.* 50 x 50 mm section (Fig. 13-1). Rectangular mortises (260–300 mm long, 105–140 mm wide and 50–70 mm deep) (Fig. 13-3), destined to receive the stanchions of Ship 17, were cut in their upper surfaces (Fig. 13-2 and Fig. 14).

The remains of ten bracing timbers of different dimensions and form bear witness to transversal reinforcement of the hull. Bracing timbers are much longer and thinner than the supports. Their length varies from 0.71 to 3.28 m, their width from 0.11 to 0.20 m and their thickness from 0.07 to 0.10 m. With the exception of a pair of bracing timbers situated on either side of the mast-step, they were not attached to the proto-keel. The bracing timbers were attached to the planking by squared pegs with a short side of 35–70 mm and a long side of 40–120 mm (mode average for both would be about 50 mm), that did not pass through the planking. The upper ends of the tenons projected 10–90 mm above the upper surface of the timbers (Fig. 15). The peculiar polygonal section of half of the preserved bracing timbers is noteworthy as a characteristic feature of this construction type. The remaining bracing timbers are characterized by a rectangular or oval section.

A mast-step notch of elongated shape (0.46 x 0.13 x 0.05 m) has been discovered in the centre of the keel's segment K6, thus exactly in the middle of the hull.

The steering system consisted of an axial rudder. The rudder-stock passed through one of the two shafts cut in the aftermost segment of the proto-keel of Ship 17. Here again, the information provided by Herodotus is corroborated by the evidence of Ship 17 (Belov, 2014a).

## Construction sequence

This type of archaic construction is not attested in the archaeological record (perhaps with the exception of the fragmentary data from the Mataria boat) and the only contemporary parallels are provided by the text of Herodotus. The planking of Ship 17 provides the strength of the hull, while reinforcing constructional members, such as bracing timbers, supports and through-beams, are of secondary importance. The ship is built of local timber and there is evidence for a frugal use of building material (Ward, 2004: 14). The five massive supports of the ship are built of reused planks, which might be considered another typical feature of Egyptian boatbuilding (Ward, 2000: 140; Creasman, 2013).The information at our disposal is insufficient at present to provide a definitive construction sequence, so the following observations are preliminary reflections to be corrected and refined in the future as further evidence emerges.

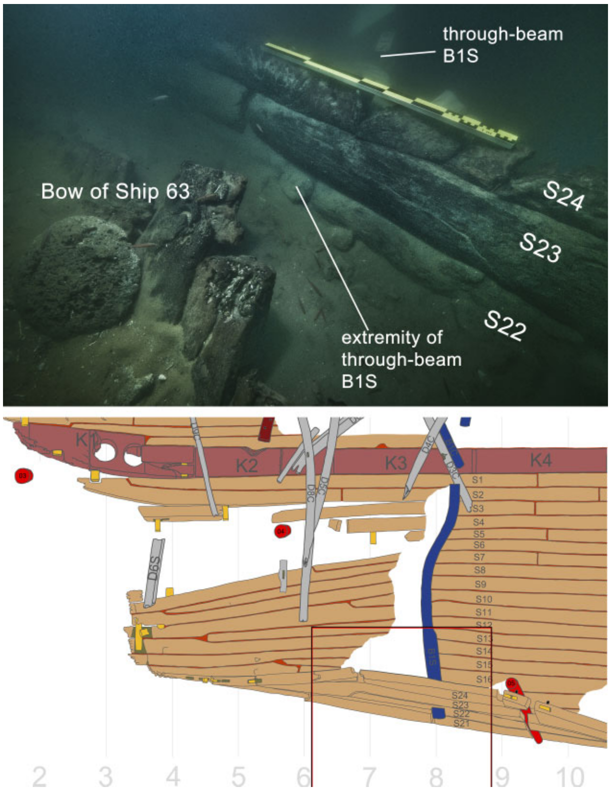


*Figure 11.* Photo (taken from the exterior of the hull) and plan of the uppermost preserved strakes of Ship 17 (S21–S24). These strakes are broken, probably by the bow of Ship 63 (left bottom corner of the photo) and are leaning into Ship 17 (rectangle on the plan corresponds to an area covered by the photo). (Photo by Christoph Gerigk © Franck Goddio/Hilti Foundation, drawing by Patrice Sandrin/Alexander Belov © IEASM)

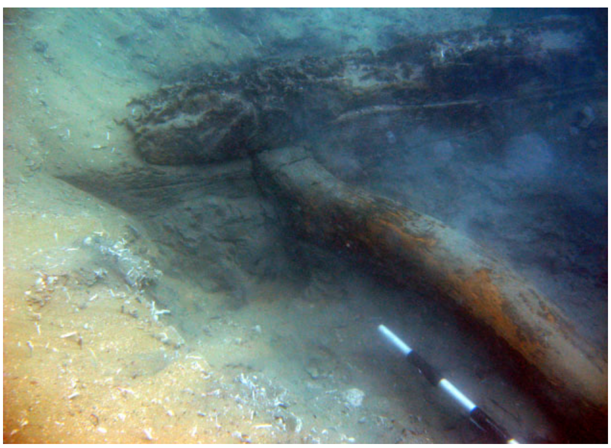

*Figure 12.* Beam B3 still in its mortise in strake P21 on the port side of Ship 17. (Photo by the Author © Franck Goddio/Hilti Foundation)

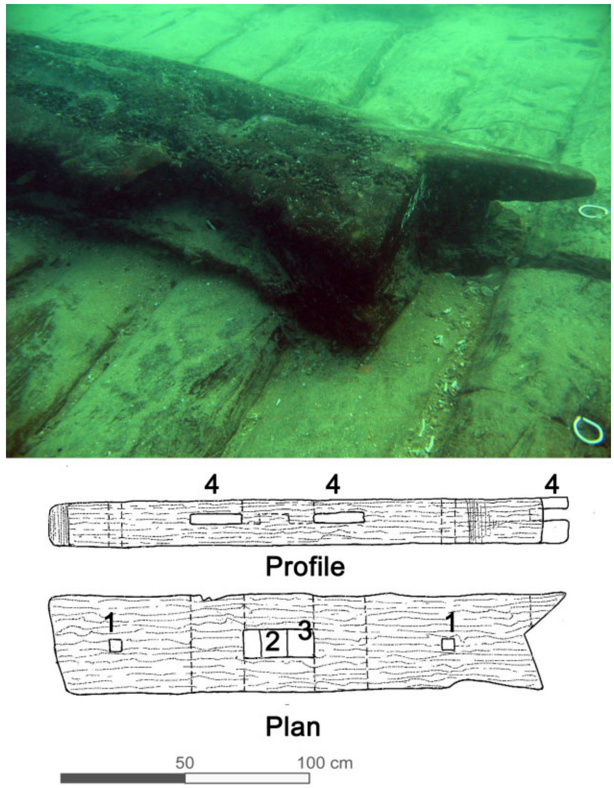


*Figure 13.* Support F8S of Ship 17 made from a pre-used plank. Note the joggled right extremity of the support. (Photo by the Author © Franck Goddio/Hilti Foundation, drawing by Patrice Sandrin © IEASM)

***Stage 1***

First, the transversal tenon-rib channels were cut in the lower third of the keel's thickness (moulded dimension). Four or five channels were cut in each segment of the keel depending on the length of the latter. The channels were distributed in a regular fashion with an average centre-to-centre distance of 0.47 m. The constructors appeared to cut the two outer channels very close to the extremities of each segment (Fig. 16). After that, all segments of the keel were assembled. Keeping in mind the short lengths of the keel segments, it seems probable that it was easier to assemble them all lying flat on the ground and then to raise the extremities in order to obtain the desired curvature of the hull, rather than joining them one after another. The segments are assembled with tongue-and-groove joints that are not deep and leave enough play to allow for this process.

The keel ended with massive stem and stern timbers that were not preserved in Ship 17 but are attested from other, yet unpublished, vessels of the Late Period from Heracleion. These pieces, installed as a direct continuation of the keel, are characterized by a triangular shape in plan and, probably, that of a half cone in volume. Their function was to close the crescent-shaped hull by receiving strakes with quite varying angles of entry, from the flat bottom strakes to the

 


*Figure 14.* Central part of support F8S at starboard of Ship 17. Note the rectangular mortise in its upper surface with the remains of a stanchion within. (Photo by Christoph Gerigk © Franck Goddio/Hilti Foundation)

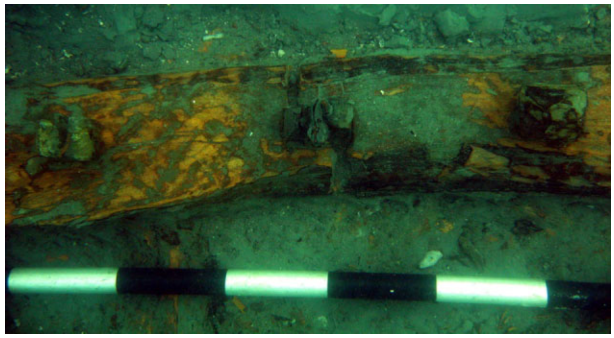

*Figure 15.* Three tenons fixing bracing timber F6S to the planking viewed in plan. Note that upper ends of these tenons are not flush with the upper surface of the bracing timber. Dimensions of the tenons are as follows (from left to right): 40 x 35 mm, 55 x 30 mm, 45 x 35 mm. (Photo by the Author © Franck Goddio/Hilti Foundation)

quasi-upright bulwark. A parallel with papyrus rafts, which is very prominent for some aspects of Egyptian shipbuilding, seems to be pertinent in this case, as these pieces bunch the strakes in a similar way to the bundles of papyrus are tied together at the extremities of a raft (for raft construction see Landström, 1970: 17–9). Also at this stage, the housings for two shafts for the axial rudder were cut in the stern segment of the keel, K1, seen in the specific box-like configuration of segment K1 (Belov, 2014a). Thus the boatbuilders started with a clear idea of the draught of the constructed craft and of its final position in the water.

***Stage 2***

The proto-keel was laid out in the form of a crescent with supports placed under it (Fig. 17). Taking into consideration the considerable length and weight of the acacia keel, a device of some kind must have been employed to support the hull during the construction. It could have been a rope truss, as is seen on many reliefs of the Old Kingdom (Landström, 1970: 39; Sliwa, 1975: 58). A rope truss could have been used only during the construction and, thus, should not to be confused with a hogging truss. Although this element disappears from the iconographic record after the Old Kingdom, Egyptians probably continued to use it for larger vessels (Rogers, 1996: 99–104). As the tongue-and-groove joints between the segments of the keel are not deep, it is possible that the first strake was added to the keel before it was raised into its curved form (see Stage 4a below).

The outer surface of the keel was shaped using adzes (note the workmen under the hull on Fig. 17). This stage is evidenced by adze marks discovered on the outer surface of keel segment K6, which was temporarily lifted from the water for detailed study. It is worth noting that the adze marks followed the grain of the wood, and thus the outer surface of the keel is rather uneven (see Clarke, 1920: 46).

***Stage 3***

A first set of tenon-ribs was inserted into the channels cut in the proto-keel so that the proto-keel lay at the middle of each tenon-rib (Fig. 18). The ends of the tenon-ribs were slightly rounded using a knife to facilitate the subsequent insertion of the planks. Each tenon-rib was secured very tightly inside the mortises by four wedges (Figs. 19 and 20). The wedges are 150–170 mm long, 12–60 mm wide and 25–59 mm thick. The garboard (which does not differ morphologically from the other strakes) must have been added at the next stage, once the wedges had been driven into place. However, it is quite possible that Stage 3 took place simultaneously with Stage 4 and that the tenon-ribs were installed in the keel in groups, and planks attached gradually starting from the centre of the ship.

***Stage 4a***

The planks for the garboard strake were sawn to length so that the joint between the segments of the proto-keel would correspond exactly to the centre of each plank. Therefore, joints in the plank and the proto-keel would be offset. The extremities of the planks were shaped to form the half-laps (in the majority of cases) used to join planks in a strake. These joints were not deep; the overlap ranged between 20 and 45 mm. It is probable that the primary adjustment between the planks of the garboard strake and the proto-keel was carried out before the tenon-ribs were inserted. Then the planks of the garboard strake had channels cut to correspond to the position of the tenon-ribs installed in the proto-keel. The installation of the planks probably started from the centre of the ship with planks added one after another, rather than as a complete strake. It would be impracticable to insert an entire strake consisting of short, thick planks assembled by loose half-lap joints while simultaneously aligning the numerous tenon-ribs with their channels. This conclusion is further supported by iconography, including the boatbuilding

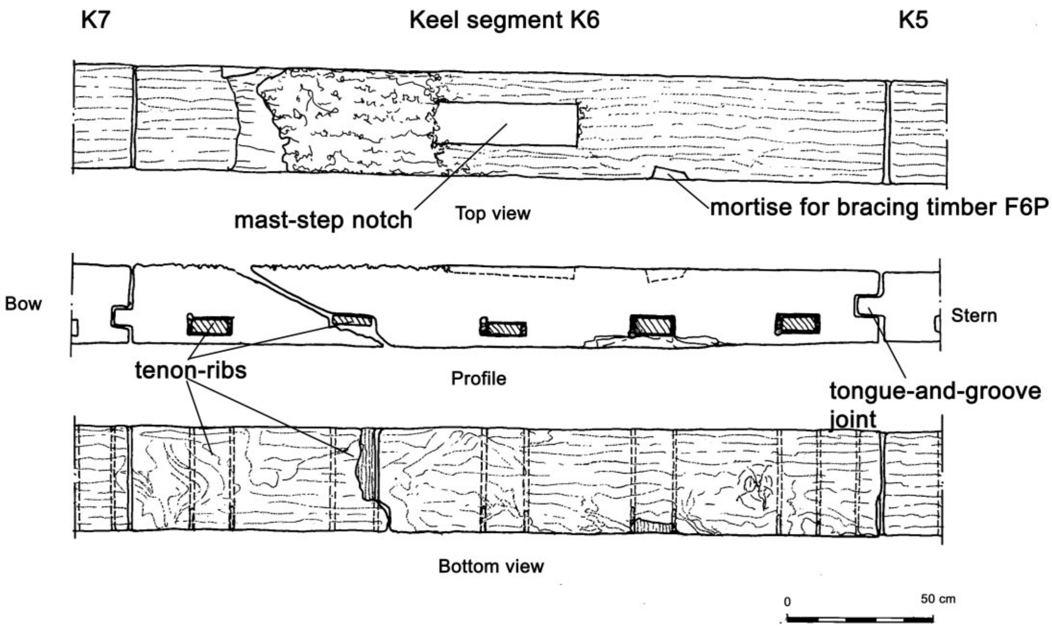


*Figure 16.* Plan and profile of keel segment K6 showing its joints with adjacent segments. (Drawing by Patrice Sandrin © IEASM)

*Figure 17.* Fragment of a boatbuilding scene from the tomb of Ty (5th Dynasty, *c.*2465–2323 BC). Note the stocks under the keel. (Author)

scene from the tomb of Khnumhotep from Beni Hassan (Middle Kingdom) among others (Fig. 21), which suggests that in the Old and Middle Kingdom planks of the Egyptian boats were joined in a 'pyramidal style' moving from the centre of the ship towards the extremities.

In the Mediterranean conceptions of boatbuilding, this would have appeared a very strange thing to do, but such a practice is reported by Herodotus' narrative ('on the strong and long tenons they insert two-cubit planks') and is evidenced by the iconographic record (see also Vinson, 1994: 34 and a representation dating from the Old Kingdom in Basch, 1996: 3). Moreover, this specific technique has been identified in the construction of the Khufu I ship (Ward, 2000: 47–56). It resembles brickwork not only in its final appearance but also in the way the planks were assembled (brick after brick), which may explain why Herodotus was

 

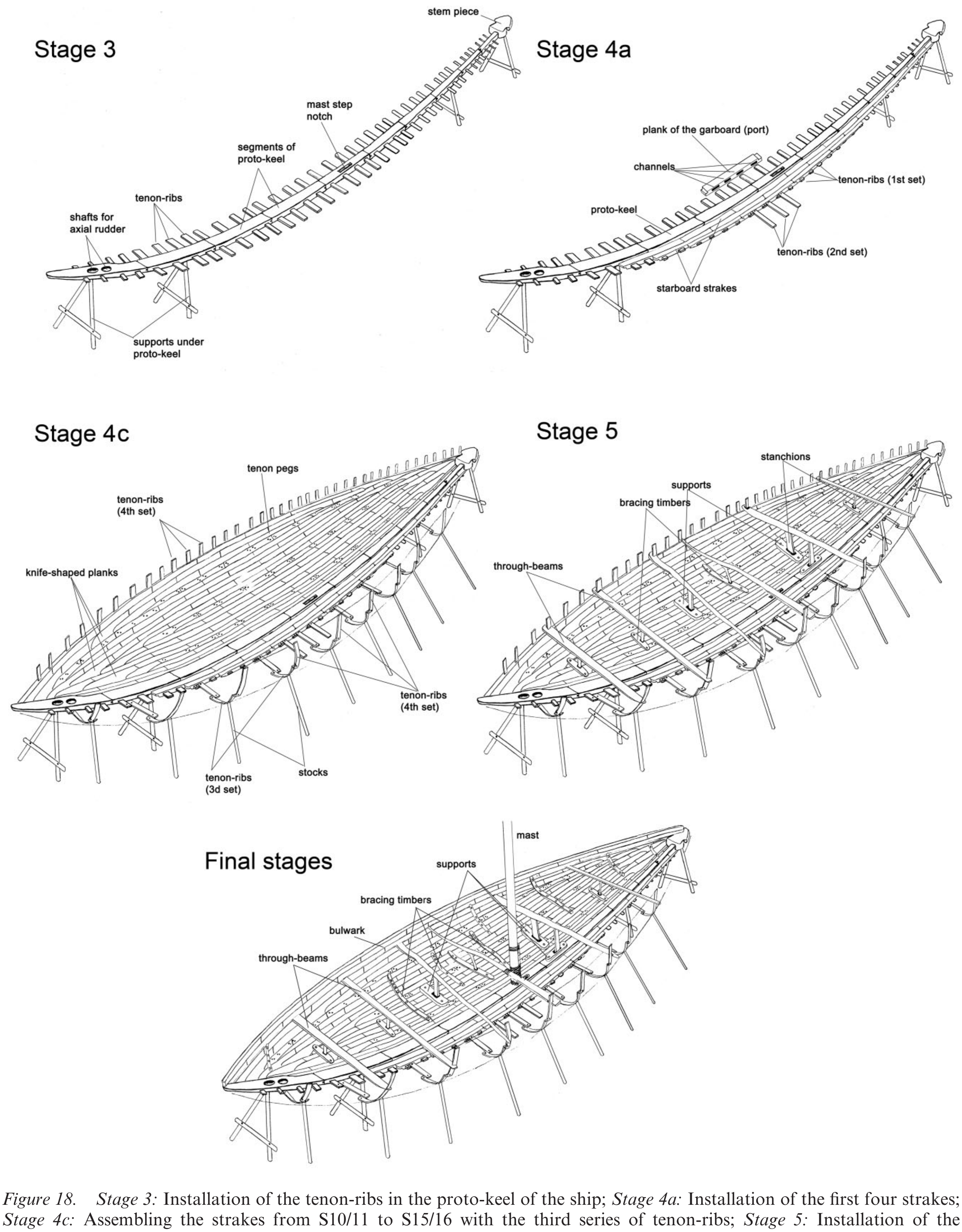


*Figure 18.* *Stage 3:* Installation of the tenon-ribs in the proto-keel of the ship; *Stage 4a:* Installation of the first four strakes; *Stage 4c:* Assembling the strakes from S10/11 to S15/16 with the third series of tenon-ribs; *Stage 5:* Installation of the through-beams; *Final stages.* Not to scale. (Author)

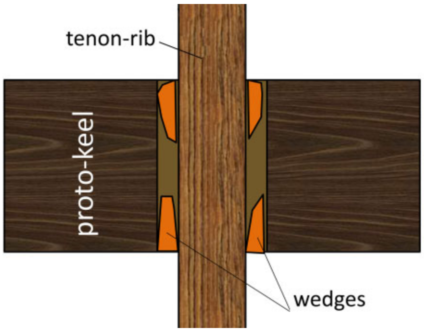


*Figure 19.* Schema showing the interior of one of the channels of the proto-keel (viewed from above). A tenon-rib is secured within the channel with four wedges. (Author)

*Figure 20.* Fragment of a tenon-rib (right) and wedge (left) that secured it inside a channel in segment K6 of the proto-keel of Ship 17. Shown fragments were removed from the channel for separate staging of this image. (Photo Author © Franck Goddio/Hilti Foundation)

*Figure 21.* Boatbuilding scene from the tomb of Khnumhotep from Beni Hassan (Middle Kingdom). (After Newberry, 1893: pl. 29)

sufficiently surprised to leave a detailed description of the technique.

The rectangular sections of the proto-keel and of the planks of the first four to five strakes, assembled using the same tenon-ribs passing through rectangular channels, attest that this area of the bottom was flat in the transversal axis.

Preliminary adjustment was necessarily followed by the precise fitting of each plank. Simple wooden compasses, like the *sheba* used by the Sudanese boatbuilders, could have been used to help obtain the correct curve along the lower edge of the next plank to be added to obtain tight joints (Hornell, 1943: 29). Such a system of assemblage did not allow for the channels to be cut with much accuracy and this might explain the considerable room left for the tenons inside the channels. Thus, the average width of the regular channels of the starboard is 191 mm while the average width of the respective tenons is only 128 mm. After the next plank was added, the tenon-ribs were wedged into the channels, thus maintaining the strength of the planking.

Planks making up the garboard strake were added in this way, working towards the vessel's extremities. It seems that assembling planks to the massive stem and stern pieces was an important stage. The last planks of the strake were probably joined to them after the central planks of the subsequent strakes were already in place. The boatbuilders must have used shorter tenons that were inserted with a different angle than for the rest of the strake and this part of the construction requires further research.

The planks of the first four to five strakes in the bow area were assembled as described above.

Luting the joints must have accompanied the assemblage of the planking and corresponds to the words of Herodotus ('They obturate the seams from within with papyrus.') (Belov, forthcoming c). The alternative translation of this sentence reads 'They bind in the seams from within with papyrus' (Haldane and Shelmerdine, 1990); however no internal lashings of the hull were found elsewhere in the construction of Ship 17. An ethnographic parallel is provided by the traditional Sudanese craft called *nuggar* (Clarke, 1920: 50; Hornell, 1943: 29). Vegetal material was applied in the seams in the form of strands and is visible only from the interior of the hull, where it can reach 60 mm in width (Fig. 22). It seems that only selected joints were luted; primarily luting was applied in the joints between planks with complicated shapes, or of those with defects that might cause a leak (see Santamaria, 1995: 149). A specialist study is indispensable to obtain more information on the details of this technique.

Before passing to the next stage, it should be underlined that, unlike Syro-Canaanite and Greco-Roman boatbuilding traditions, the pegs of Ship 17 are concentrated on specific strakes. Thus, strake 4 contains more than one third of all the starboard pegs recorded. Strakes 5, 10, 11, 15 and 16 contain each between 8.3% and 12.4% of all the pegs (Fig. 23 and Table 3). It has been noted that the pegs in the planking of the Mataria boat were also found in specific strakes only (Ward, 2000: 133).

Pegged tenons are not characteristic of Ancient Egyptian shipbuilding (Ward, 2000: 133), while there

 

**Table 3.** *Distribution of the pegs in the starboard strakes of Ship 17*

| Strake | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Σ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **No of Pegs** | 0 | 0 | 0 | 44 | 10 | 2 | 6 | 0 | 1 | 14 | 13 | 0 | 0 | 1 | 15 | 15 | **121** |
| **Percent** | 0.0 | 0.0 | 0.0 | 36.4 | 8.3 | 1.7 | 5.0 | 0.0 | 0.8 | 11.6 | 10.7 | 0.0 | 0.0 | 0.8 | 12.4 | 12.4 | **100** |

exist many examples of free tenons, such as those used in the construction of the Khufu I ship (Ward, 2000: 50), and the sea-going ships of Mersa Gawasis (Ward, 2007) and Ayn Sukhna (Pomey, 2012). In the latter two cases the authors connect the use of free tenons with the necessity of assembling and disassembling these ships for transportation or storage. At the same time, even where tenons were pegged, it has been proposed that pegs did not pass completely through the planking to keep the hull watertight (Ward, 2000: 98–100, 115, 119). However, the pegs of Ship 17 definitely pass through the planking and, together with the proto-keel, this indicates a radical change in boatbuilding technology. Iconographic evidence allowed Wachsmann to suggest that this practice may have been abandoned towards the end of the New Kingdom (1989: 199).

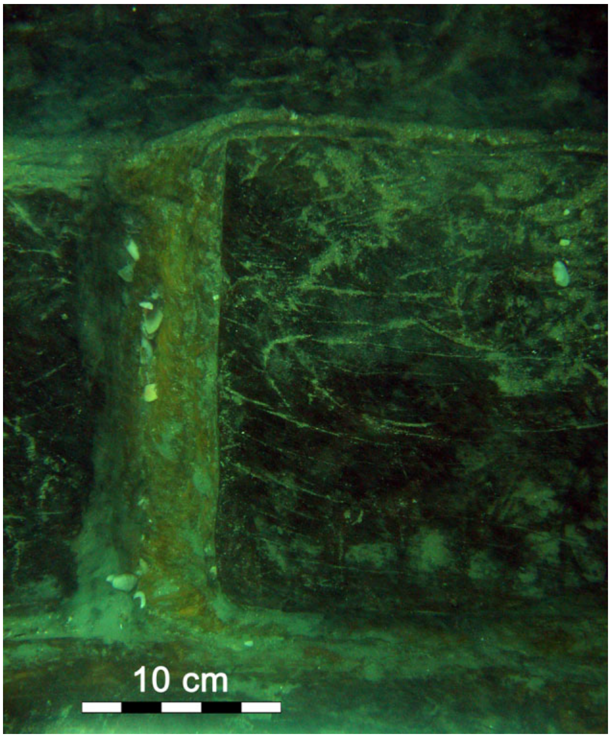


*Figure 22.* Vegetal luting material visible inside of the hull of Ship 17 between the abutting planks of the starboard strake S13. (Photo by the Author © Franck Goddio/Hilti Foundation)

The transversal section of the hull shows that the tenon-ribs of Ship 17 are not pegged at each strake but only at their ends, which explains the peg distribution. Thus the peg distribution provides information on the position and pattern of the tenon-ribs inside the planking.

***Stage 4b***

At strake four, the tenon-ribs which pass through the keel were pegged and a second series of tenon-ribs was installed and also pegged. For this purpose, a double-sized channel was cut in strake four, having an average width of 310 mm (Fig. 24). The tenon-ribs of the first series ended in closed mortises within strake five. Thus adjacent tenon-ribs had a two-strake overlap (S4 and S5). The second series of tenon-ribs assembled the planking from strakes S4/S5 to strakes S10/11 (in general seven to eight strakes). Starting from S5, knife-shaped planks were employed to close the bow and stern areas of the hull.

***Stage 4c***

At the next stage, the third series of tenon-ribs comes into play, assembling the starboard strakes from S10/11 to S15/16. The upper end of one rib-tenon and the lower end of its neighbour were pegged to the planking. Note

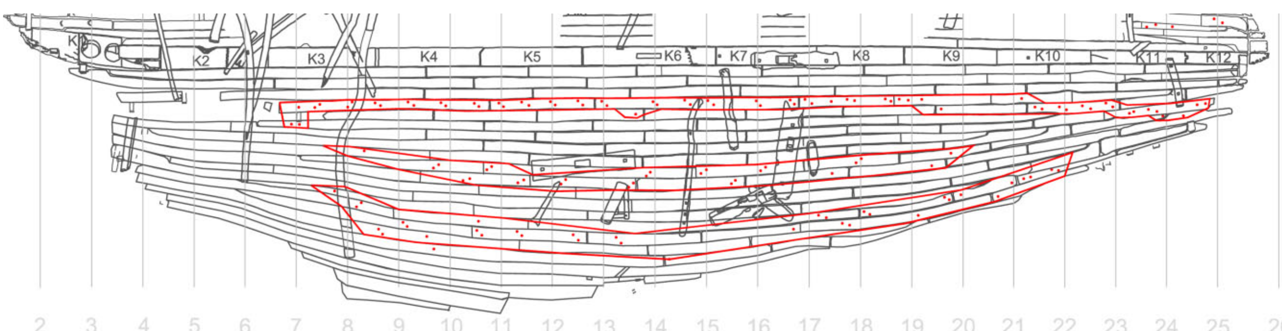


*Figure 23.* Distribution of the tenon-rib pegs inside the planking of Ship 17 with peg zones outlined. (Drawing Patrice Sandrin/Alexander Belov © IEASM)

*Figure 24.* Two tenon-ribs pegged in a double-width channel at the stern area of Ship 17 (port strakes P3 and P4). (Photo by Christoph Gerigk © Franck Goddio/Hilti Foundation)

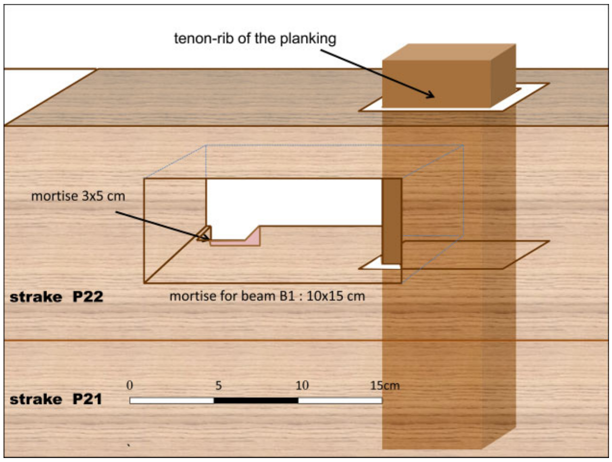


*Figure 25.* Schema of the locking of beam B1 in the mortise of the port strake P22 viewed from the inside of the hull. (Author)

that in the bow, and probably also in the stern area, the tenon-ribs could assemble more strakes than in the central part of the ship. Thus, at the bow strakes from S4 to S16 were assembled by a single series of tenon-ribs.

It seems that the floor remained relatively flat until at least strakes 11–13. Arguments in favour of this conclusion include the length of the completely preserved through-beam B1 (that limits the beam of the ship), the position of four of the massive and inflexible supports made of reused planks between strakes 4 and 12/13, and the distribution of the squared pegs fixing the bracing timbers to the planking. These pegs are placed more densely from starboard strake S13 (or port strake P11) towards the bulwark, probably indicating the increased curvature of this region. At this stage of construction, it was necessary to support the sides of the ship to maintain the desired shape. It seems unlikely that the constructors applied cross-spawls like those used during the construction of *Kyrenia II* (Steffy, 1994: 49), because they would be ineffective with short planks assembled one after the other as suggested here. Shipyard stocks supporting the hull from the outside seem more likely.

A few pegs were preserved in the subsequent strakes (S17–S18), suggesting that the fourth series of tenon-ribs assembled the strakes from S15/16 to S24. It should be emphasized that the four series of tenons-ribs from Ship 17 form a system of internal composite frames spaced at 0.47 m on average (centre-to-centre).

***Stage 5***

Through-beams, made of naturally curved compass timber, were installed at the level of the starboard strake S22 and port strakes P20–P22. The extremities of the through-beams were locked in place inside the planking by the fourth series of tenon-ribs, (Fig. 25). Five massive supports were attached to the planking in the central part of the hull under beam B2P and under two other hypothetical beams at 12 and 14 m from the preserved aft extremity. The latter beam, of which only fragments remain, probably supported the mast. Stanchions were installed in the upper mortises found in the supports and of some of the bracing timbers in order to distribute the weight of the beams onto a larger area of the planking.

This construction stage also finds a parallel in Herodotus' description: '. . . they stretch beams over the planks' (Histories, 2.96; Belov, forthcoming c). We can see that the beams are integrated into the shell of the ship and this provides an additional argument in favour of a 'planking first' type of construction (Pomey, 2004: 32), if any were necessary in the case of Ship 17.

The fourth series of tenon-ribs probably assembled the bulwark strakes. The representations of the Old Kingdom show the process of installation of a bulwark as an entire strake, rather than plank-by-plank as for the previous strakes (see Fig. 17, analysed in Rogers, 1996: 59). The poor state of preservation of the upper strakes makes it difficult to judge whether this was the case for Ship 17, but it cannot be excluded. The last preserved strakes seem to indicate that the bulwark was quasi-vertical.

***Stage 6***

The bracing timbers were attached to the hull apparently to reinforce weaker points recognized by the shipbuilder. In the central part of the hull, a pair of bracing timbers corresponding to the mast-step was joined to the proto-keel.

***Stage 7***

Most probably the ship was not decked, as shown by the irregular form and inclination of the beams, as well as by the complete absence of any surface traces of deck beams and planking. The centrally positioned mast and rigging were set up at this final stage of the construction.

 

## Vessel type and conclusions

Ship 17 belonged to a type of river-going freighter as evidenced by the frugal use of local constructional material, and the roughness and ruggedness of all of its constructional elements. As there was no necessity to disassemble the ship, the extremities of the tenon-ribs of the planking were pegged, in contrast to the free tenons of Khufu I ship and the sea-going ships from Mersa Gawasis and Ayn Sukhna. According to iconographic data, an axial rudder, as seen here, was quite typical for Egyptian river freighters. The outboard surfaces of the proto-keel and of the planking of Ship 17 show no traces of shipworm attack that could attest the use of the ship in a marine environment. The proto-keel is not abraded either, testifying that the ship was rarely if ever beached on a rocky or even a sandy coast.

A 3D model is currently being developed; according to preliminary results, Ship 17 of Heracleion is characterized by a crescent-shaped hull with considerable overhangs at the extremities. The ship had a flat bottom and a pronounced chine that was, however, not too hard. The reconstructed overall length of the ship is *c.*27–28 m with a beam of 8 m, giving a breadth to width ratio of around 3.4. The ship had a displacement of about 150 metric tonnes, a draft of 1.6 m and a tonnage of approximately 112 metric tonnes.

Numerous similarities between the construction of Ship 17 and the boat described by Herodotus (*History*, 2.96) allow it to be identified as a *baris* (Belov, forthcoming a). References to the *baris* in Demotic, Ptolemaic and Roman papyri (see Casson, 1971: 340; Vinson, 1998: 252–4; Arnaud, forthcoming) seem to indicate that these ships could transport different cargo or passengers. It has been suggested that larger ships of this type were probably more rarely met on the Nile than is generally believed; however, they could be of quite varying dimensions (Arnaud, forthcoming). A proposed identification of a boat depicted on the Nilotic mosaic of Preneste (*c.*100 BC) as a *baris* provides additional information about the form of the hull and rigging of this vessel (Pomey, forthcoming).

Many aspects of the constuction of a *baris* need supplementary research. It is necessary to understand the function and the joints of the massive pieces at the extremities of the ship, the distribution pattern of the bracing timbers, the structure and composition of the luting layer, etc. One hopes that the excavation of other *barides* from Thonis-Heracleion will help clarify these questions in the near future.

## Notes

1. Analysed by the Laboratoire de Datation par le Radiocarbone de l'Institut Français d'Archéologie Orientale (IFAO). Analysis reports IFAO143 (2008)—planking, calibrated date 766-540 cal BC (1σ); 786–416 cal BC (2σ) and IFAO144 (2008)—tenon-rib, calibrated date 794–556 cal BC (1σ); 804–518 BC (2σ).
2. The *mean* average is used throughout unless otherwise stated.

## Acknowledgements

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