The hull remains of Ria de Aveiro A, a mid-15th century shipwreck from Portugal: a preliminary analysis

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In 1994 in the Aveiro *Ria*, a large lagoon on the west coast of Portugal (Fig. 1), the partially-exposed remains of a ship's hull were identified, recorded and provisionally protected in an inter-tidal zone of the Mira channel (Alves, 1999). The site is located close to the Barra Bridge, near a line of dunes separating the lagoon from the Atlantic Ocean. The water depth at high tide is less than 4 m in this area and, during spring low tides, the site is almost dry.

Radiocarbon analyses of four samples collected during the initial survey indicated a date in the middle of the 15th century:

Laboratory Reference	Sample	Material	Age (BP)
ICEN-1105	Hull plank	Wood	340 ± 40 years
ICEN-1116	Oar	Wood	510 ± 45 years
ICEN-1117	Walnut	Nut shell	480 ± 70 years
ICEN-1118	Keg stave	Wood	490 ± 45 years

The laboratory report concluded that "*(...) the four dates obtained are statistically identical at a level of significance of 95% (...). The average considered has the value of 460 ± 24 BP that converted into solar calendar years, using the curve referred to in the date certifications, has the following values: for 1 sigma: 1434-1448 cal AD; for 2 sigma: 1424-1469 cal AD; with the intersection in 1441 cal AD (...)*[1]".

The Ria de Aveiro A[2] site was characterised in 1994 — and until the beginning of its excavation in 1996[3] — by the presence of an oblong tumulus whose longitudinal axis was oriented approximately north-south (22° N *mg*) (Fig. 2). However, the local bottom topography varies frequently as a result of strong tidal currents.

Most of the timbers whose corroded tops were visible around the tumulus obviously corresponded to the ship's frame structure. In the southern part of the site, the frames were almost exposed on the sea bottom. Their open shape and slight curvature indicated that they belonged to the central part of the hull (Fig. 3).

To the north, the breadth between the upper ends of the frames gradually decreased and their upward angle increased to near vertical. In this area, the vestiges appeared to be more deeply buried in the sediment. These observations indicated that the northern part of the site corresponded to one of the hull's extremities and the southern part to the ship's ruptured central section.

During the 1996 and 1997 excavation seasons, documentation of the ship's structure began[4]. During the latter field season, the interior of the hull was completely excavated and all the frames were disassembled and recovered. These timbers are currently being treated and studied at the facilities of CNANS in Lisbon (Alves, 1998a).

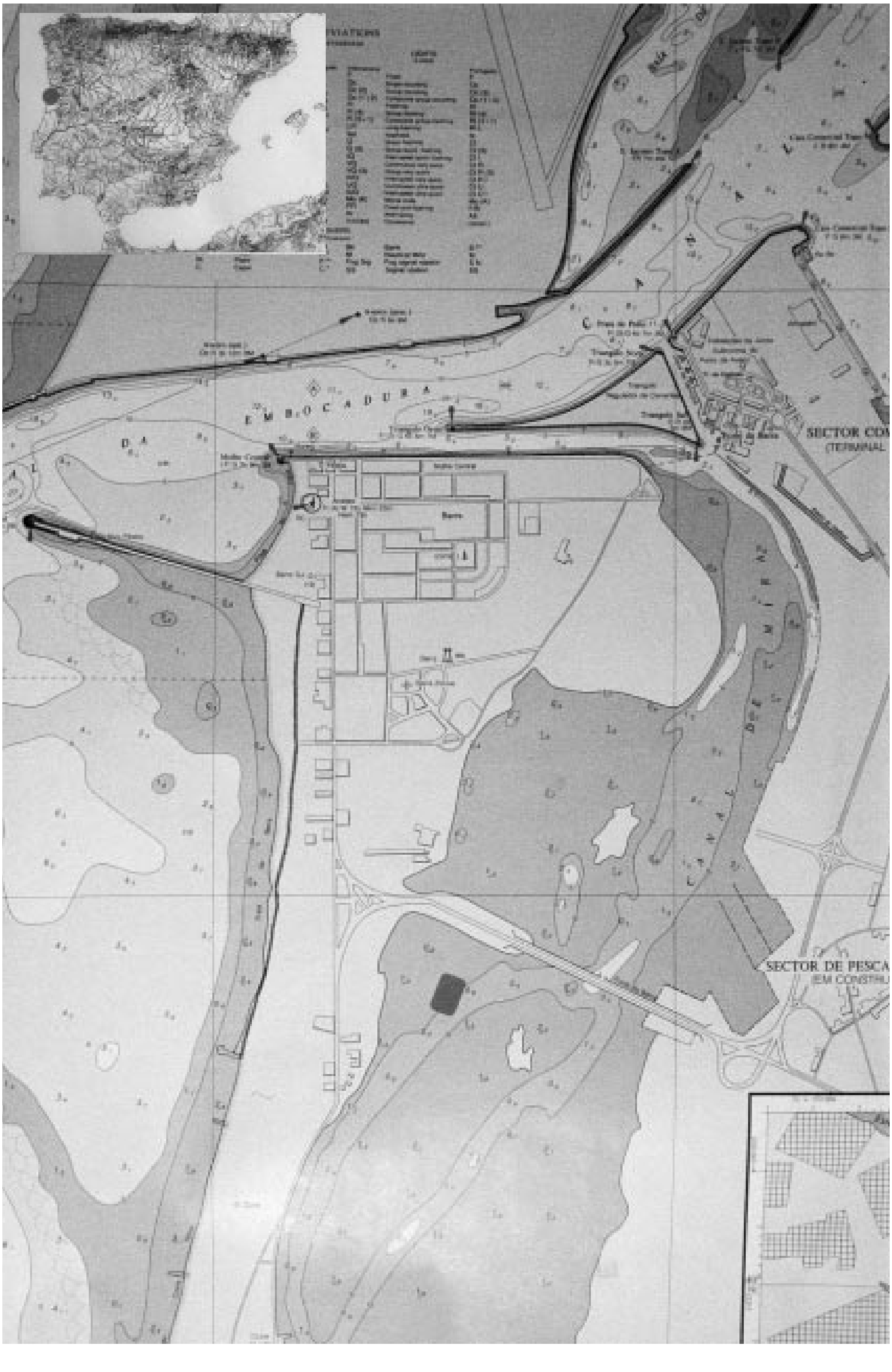


FIG. 1 – Location of the Ria de Aveiro A shipwreck.

FIG. 2 – View of the Ria de Aveiro A site at low tide. *Photo F. Alves.*

FIG. 3 – Elements of the Ria de Aveiro A hull structure visible on the surface in 1994. *Photo F. Alves.*

The ship structure

The Ria de Aveiro A shipwreck occupied an area about 10.4 m long and 2.5 m wide in the zone corresponding to frames 9 and 10 (Fig. 4). The preserved structure represented slightly more than the stern half of the hull. The wreck was more deeply buried at its aft (northern) end and was heeled over to the starboard side. The keel's lateral angle was about 15° and its longitudinal inclination increased from about 3° to 5° in the area of frames 2 to 10, to between 5° and 6° near frames 11 and 12.

The *in situ* vestiges were characterised as follows:

a) at the southern, ruptured extremity, south of the first floor timber preserved *in situ*, the long outer hull planks were almost horizontal. The exterior planking was preserved principally on the starboard (west) side of the keel. In this southern area, no frames were preserved over the planking for a distance of more than 3 m;

b) on the port side (east) of the keel, the framing was almost totally destroyed from the first preserved floor timber as far as floor timber 13. The inclination of the rear of the hull resulted in better preservation on the port side: from floor timber 14, some floors were almost entirely preserved as well as the lower parts of their first futtocks;

c) on the starboard (west) side of the keel, almost all the floor timbers were fully preserved, as well as, to varying degrees, their respective first futtocks;

d) the same asymmetry characterised the preserved remains of the exterior planking: nine starboard hull planks were preserved, while on the port side only three were found and these were in very poor condition.

The vestiges also included a large internal timber, lying almost horizontally, that proved to be the first starboard bilge clamp or stringer. It was poorly preserved along its entire length. The remains of a second clamp, parallel and adjacent to the outboard side of the first, were discovered toward the aft end of the hull.

The area of the first *in situ* floor timber appeared to correspond to the ship's central section. A slight upward curvature in the planking and the ends of the floor timbers was the first indication that the wreck might be related to the Iberian-Atlantic shipbuilding tradition (Oertling, 1989a, 1998). This early impression gained substance as the research continued.

While the remains of the Ria de Aveiro A ship represented only a small part of the hull's structure, the wreck nonetheless represents one of the best-preserved archaeological examples of the Iberian-Atlantic shipbuilding tradition. The bottom of the hull is preserved along an estimated 80% of its original length. Proportionally, these remains are comparable to those of the Highborn Cay wreck (Oertling, 1989b) and are only superseded by those of the Cais do Sodré wreck (Rodrigues, 1998), the presumed *San Juan* (Grenier, 1988) and the *San Diego* (L'Hour, 1994). However, these better-preserved examples all represent larger ships. In fact, the Ria de Aveiro A wreck is smaller than the majority of contemporary shipwrecks known on the international level, being comparable only to the Corpo Santo remains (Alves, 1998b).

The keel

Although the starboard hull planking is preserved over a distance of 10,4 m, the keel is only preserved over a length of 9,15 m. The forward part of the keel has a square section measuring about 12 cm on each side (Fig. 5). Its lateral faces have rabbets defined by two oblique planes, 7 cm from the keel's bottom edge. The lower plane rises about 1 cm, while the upper plane is

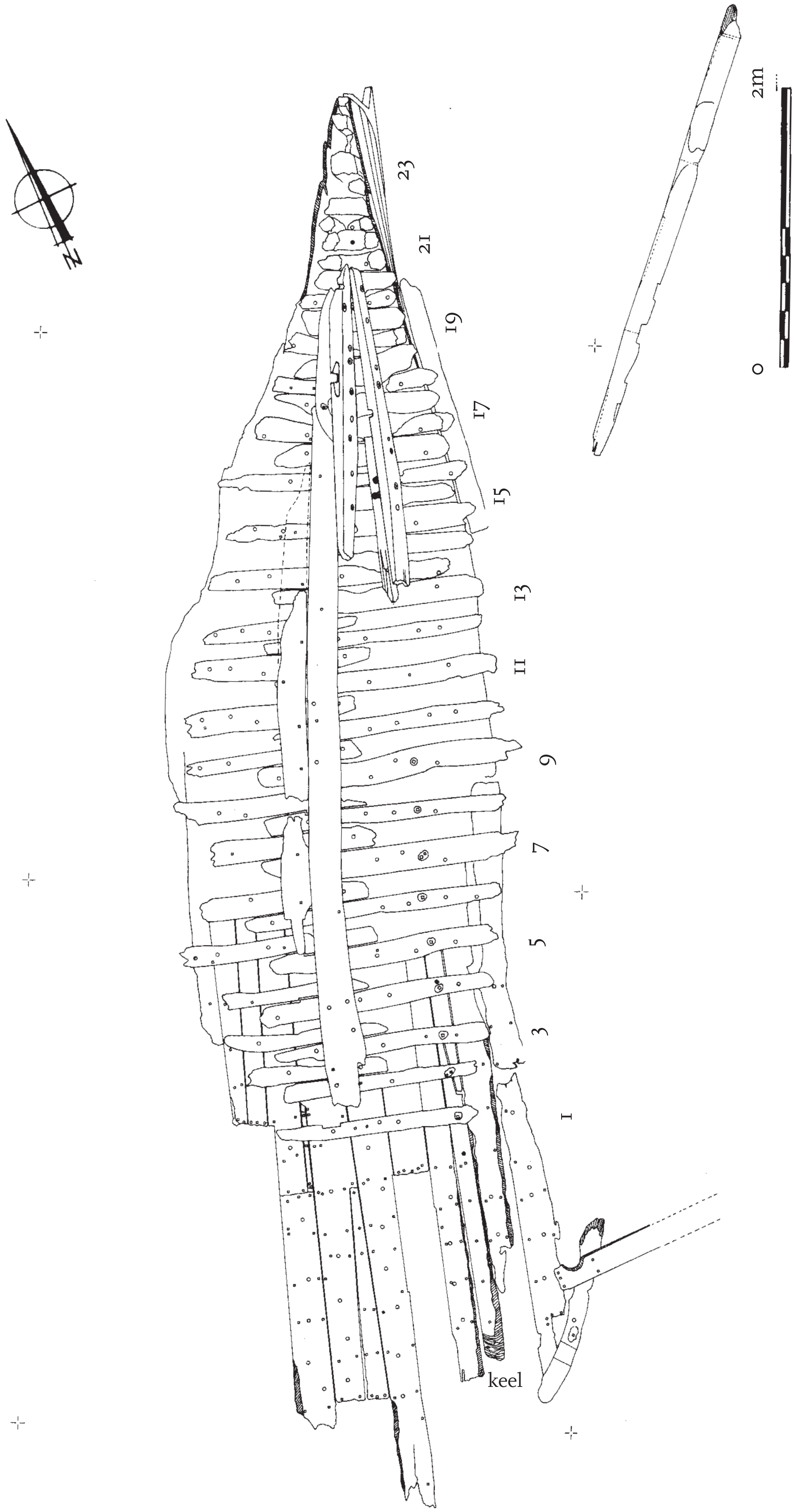


FIG. 4 – General plan of the Ria de Aveiro A shipwreck.

larger, with a steeper angle. They form a rabbet about 2 cm deep that runs about 3.5 cm from the keel's upper edges.

The keel of the Ria de Aveiro A has a relatively small cross section compared to other examples from the Iberian-Atlantic tradition. Smaller keels are found only on the Corpo Santo ship (11 x 11 cm) and on the Culip VI ship (9 x 7 to 9 x 9 cm) (Nieto et al., 1989, p. 320; Rieth, 1996, p. 152). The latter vessel was a coastal trader built in the Mediterranean tradition and dated to the early 14th century, whose reconstructed hull length is comparable to that of the Ria de Aveiro A ship. Presumably, the small size of these keels is a characteristic of small- to medium-sized coastal ships able to navigate inland waters following the traditional trade patterns of the Middle Ages and later. The structures of these ships were not designed to resist the heavy mechanical stresses resulting from navigation on the high seas.

The keel of Ria de Aveiro A is a composite piece, made of several parts joined by vertical scarves of the type known as *lisa* (smooth scarf) or *lavada* (washed scarf) (Fig. 5). In addition to the first scarf in its foremost component, the keel had a second scarf at its aft end, connecting it to the heel.

Similar composite keel structures have also been found on an East Indiaman sunk at the entrance of the Tagus River in Lisbon, provisionally identified as the *Nossa Senhora dos Mártires* (1606) (Alves, et al., 1998b; Castro, 1998), and in other examples of the Iberian-Atlantic tradition such as the Highborn Cay wreck (Oertling, 1989b, p. 247) and the *San Juan* (Waddell, 1986, p. 140, fig. 2; Grenier, 1988, p. 72).

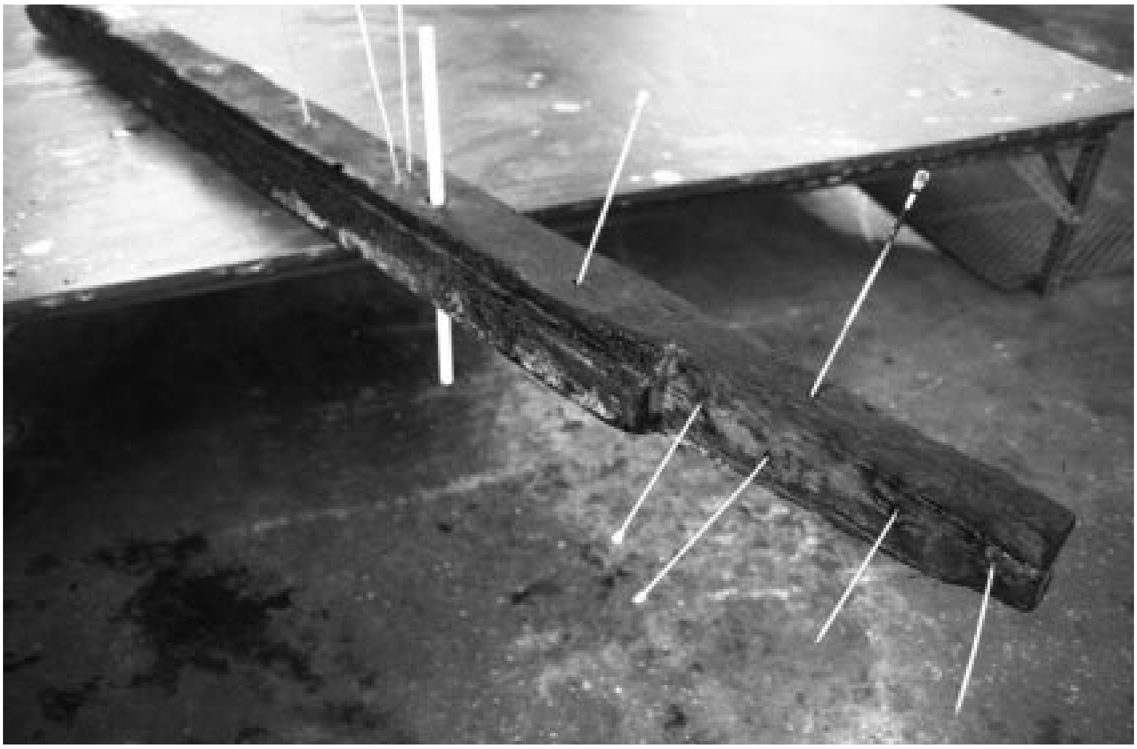
In the Ria de Aveiro A ship, the scarf's foremost (southern) butt is located between floor timbers 1 and 2, and the rear (northern) butt is below floor timber 3. This vertical scarf has a nib or butt 4 cm wide, and an oblique, longitudinal surface 41 cm long.

This type of flat, vertical scarf is a well-documented technical solution and is illustrated in the treatise of João Baptista Lavanha, *O Livro Primeiro de Architectura Naval* (1608-16/1996). The author not only provides a graphic representation of this type of scarf (p. 44, fig. 9 and f° 62v) (Fig. 6), but also describes it: "(...) *[the keel] cannot therefore be of one whole baulk* [pao]*, because one of such size cannot be found, and in any case because the heel and touch have to be integral, and a straight baulk of such size being found, it cannot have the curves* [voltas] *that are required for the said heel and touch. And besides all these causes even when a baulk will be found, with all the conditions from which the keel and curves could be made, it may not be fitting [to do so] other than from pieces, because, like the timbers they might cut from it, it would crack if it were to be whole; and [made] from pieces it gives of itself as much as is necessary, and does not break. These pieces then may be of greater size than the baulks extended to* (...) (*id.*). Farther on, Lavanha states that (...) *since the keel cannot be whole and has to be in pieces, these are adjusted one with another with scarfs (as shown in the following figure) and are fastened with bolts* [pregos] *that go through the whole breadth of the timber and rivet* [rivetão] *the other part, on some iron washers, which method of fastening is called* anielados*, and in this way the entire keel will be made and will be joined with the said scarfs*." (*id.*).

The keel scarf of Ria de Aveiro A was reinforced with 4 iron nails, driven two from each side, practically horizontal and terminating midway through the timber. They were not, apparently, riveted as prescribed by Lavanha.

The heel

Evaluation of the structure's aft (northern) extremity was one of the first research priorities. A one-meter deep excavation trench alongside this extremity allowed its details to be observed and recorded *in situ* (Fig. 7).



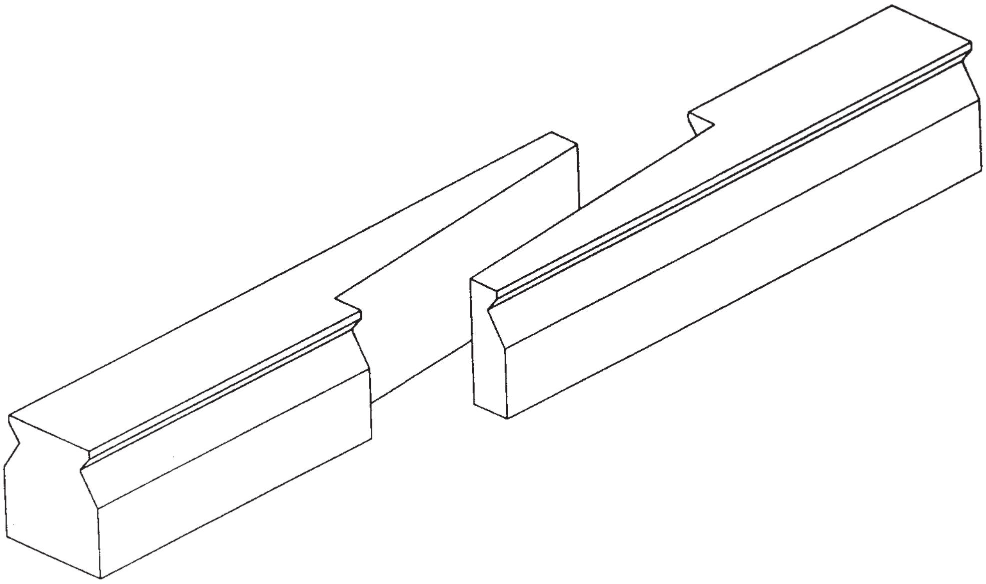


FIG. 5 – The forward end of the keel scarf, showing the pattern of iron nails and an axonometric view.

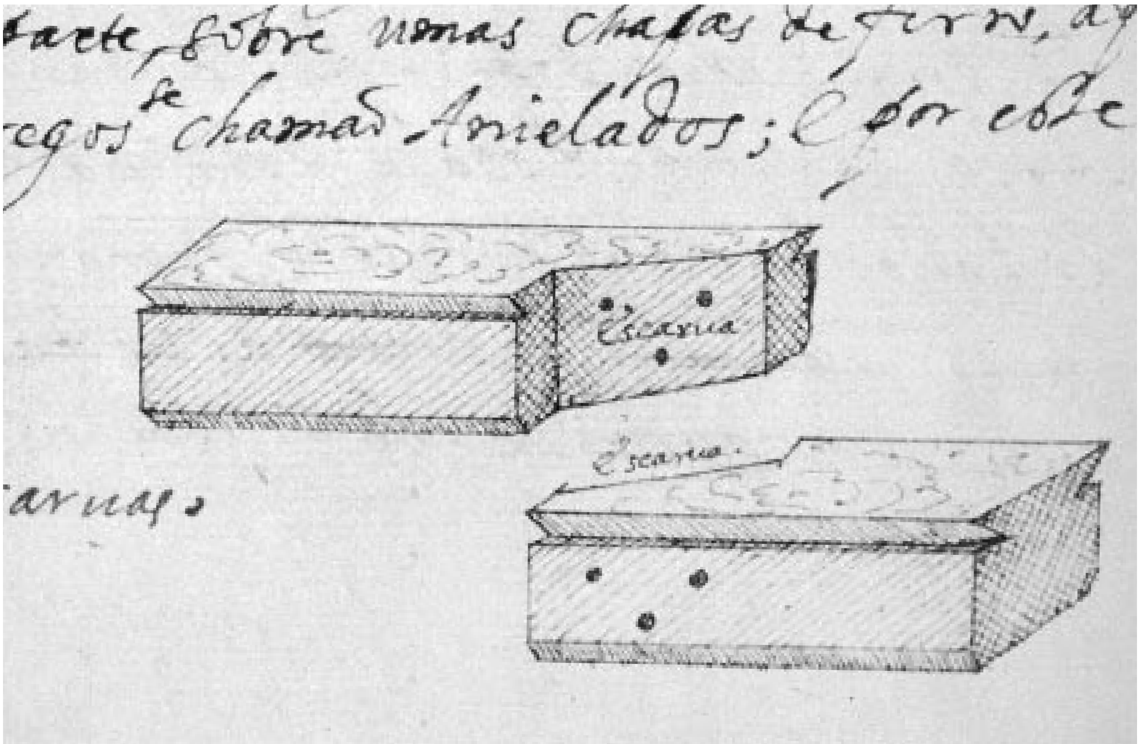


FIG. 6 – A keel scarf after João Baptista Lavanha, *Livro Primeiro de Architectura Naval* (1608-16) folio 62v. Biblioteca de la Real Academia de la Historia, Madrid.

The ship's aft end was preserved to a maximum height of about 74 cm and possessed the classic form of an angled heel. The lower end of the sternpost formed a single piece with the aft end of the keel. In the Portuguese tradition, this heel timber is called a *couce de popa* (heel of the stern), a *couce do cadaste* (heel of the sternpost) or a *couce da quilha* (heel of the keel). At its lower aft angle, the timber possessed a protuberance called a skeg that prolonged the keel. These features closely conform to the classic patterns of Portuguese naval architecture, as described by Lavanha (p. 45, fig. 10 and f° 63) (Fig. 8). They also appear in the magnificent plates in the *Livro de Traças de Carpintaria* of Manuel Fernandez (1616/1989). Archaeological examples have been documented in several shipwrecks belonging to the Iberian-Atlantic tradition, including the *San Juan* (Grenier, 1988, p. 74, fig. 10), the *San Diego* (L'Hour, 1994, p. 141) and the Corpo Santo wreck.

The aft surface of the sternpost is sharply oblique; its upper face is perfectly straight and its lower face, at the skeg, is smoothly curved. The sternpost forms an angle of about 63° relative to the keel's base line, echoing the findings from Corpo Santo.

Due to the incomplete survival of the sternpost, it is not possible to establish its length proportional to that of the keel. Thus, it is not possible to attempt a comparison of the geometric relationship between the keel and the sternpost as described by the classic authors of Portuguese naval architecture (Oliveira, 1580/1991, p. 91-92 and f° 81-82; Lavanha, 1608-1616/1996, p. 35-36 and f° 56v-57) and illustrated by Manuel Fernández.

It is important to emphasise, however, that these sources post-date the Ria de Aveiro A site by more than a century. In addition, all refer to ships with a square, transom stern for which the earliest evidence dates to the late 15th century. Given a likely date in the 1440s, the coastal trader Ria de Aveiro A may have had a round stern without a flat transom. However, we cannot develop a hypothesis regarding the type of stern the wreck may have had because the angle and position of the sternpost were unlikely to have been influenced in any characteristic way by the form of the stern.

FIG. 7 – View of the heel of the Ria de Aveiro A, with its characteristic skeg. *Photo F. Alves.*

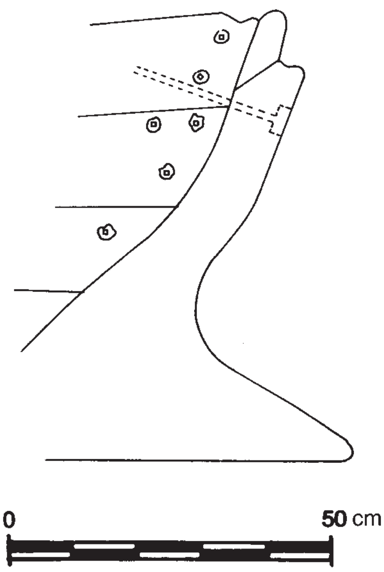


FIG. 7 A – Draw of the heel of the Ria de Aveiro A, with its characteristic after end skeg.

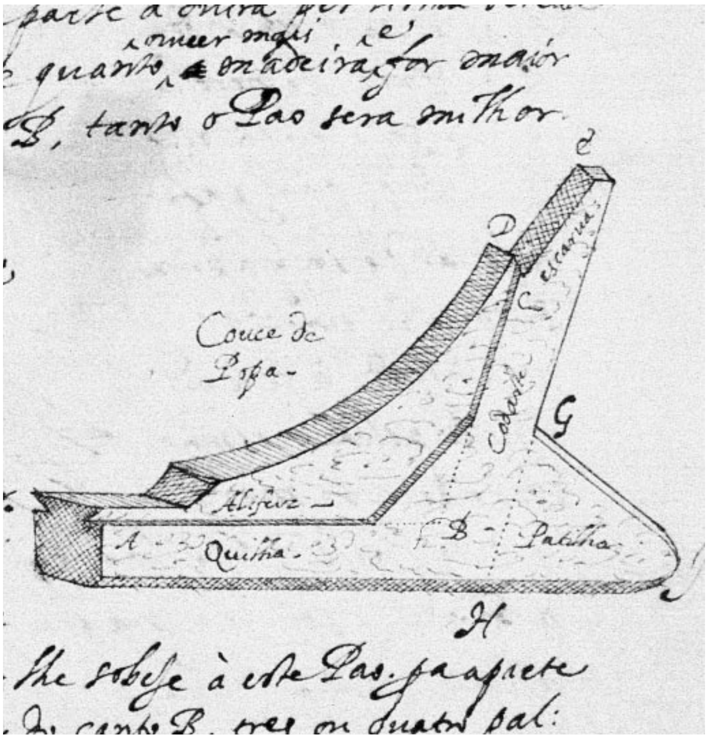


FIG. 8 – Representation of a heel after João Baptista Lavanha *op. cit.* (folio 63).

The sternpost is preserved to a height of 56,5 cm above the base of the keel and has a width of 11 cm, corresponding approximately to the width of the keel in this area.

At about 47 cm above the base of the keel, the sternpost exhibits a countersunk hole for a round iron bolt approximately 2,5 cm in diameter. This bolt was inserted approximately perpendicular to the sternpost (26° from horizontal). It reinforced the heel assembly by fixing the sternpost to the stern knee and to the aftermost floor timber (frame 23).

The hood ends of the hull planks were set into a sternpost rabbet composed of a low, continuous plane extending along the keel and sternpost, widening in the angular area between the two components. A similar arrangement is seen in the Corpo Santo shipwreck and the remains of the *San Esteban* (Rosloff and Arnold, 1984, p. 289, figs. 1 and 2).

The skeg of the Ria de Aveiro A ship has a triangular shape with a rounded point. It has a height of 15 cm, its base measures 20 cm in length, and its upper surface is 24 cm long and rises at an angle of 31° relative to the keel's base line.

A stern knee rested atop the heel's upper face. The upper surface of the knee was the only part observed *in situ*, as the stern of the ship had not yet been dismantled.

The floor-timbers

As stated, the inclination of the hull relative to the sedimentary seabed resulted in the better preservation of the starboard elements. On the port side, only those elements nearest to the keel were preserved. It will be possible to graphically reconstruct the shape of the majority of the frames (Fig. 9). The wreck's lateral angle also led to the greater preservation of the starboard futtocks and the connections between the floor timbers and the first futtocks on that side.

The floor timbers were roughly hewn and, in most cases, the tree's original rounded shape remained visible on surfaces that were not in contact with other timbers. In the case of floor timber 9, the original twisting of the tree was particularly obvious. It is possible that this irregularity in shape reflects a problem in the supply of high-quality wood due to environmental or economic constraints.

At 1.85 m in length, floor timber 6 is the longest preserved. The maximum overall breadth preserved for a combination of a floor timber and its first futtock is 2,35 m, at frame 9. This frame may thus indicate the maximum width of the hull, which can be extrapolated as 3,40 m. Longitudinally, the frame components are preserved *in situ* over a distance of 7,4 m from the heel.

The floor timbers had an average center-to-center spacing of 33 cm, with a maximum of 38 cm (between frames 5 and 6) and a minimum of 28 cm (between frames 2 and 3). The space between floor timbers averages 18 cm, with a maximum of 25 cm (between frames 5 and 6) and a minimum of 15 cm (between frames 8 and 9).

Several interesting observation can be made regarding the assembly of the frames. Firstly, all the surviving floor timbers are laid against the forward (midships) side of their respective futtocks.

Secondly, despite the fact that the futtocks of floor timber 1 have not survived, nail holes in the hull planking immediately forward and aft of this floor timber reveal that it had four futtocks, two forward and two aft.

Finally, in the southern part of the hull, forward of frame 1, where the frames have not survived, preliminary observation of the fastening holes in the planking indicates that the position of the futtocks relative to their respective floor timbers was the opposite of that noted in the stern half. The assembly of the floor timbers and first futtocks is therefore symmetrical forward and aft of floor timber 1.

These observations allow us to conclude that floor timber 1 was, in fact, the master frame.

FIG. 9 – General framing plan of the Ria de Aveiro A shipwreck.

Such a framing pattern, typical of the medieval and modern periods (Fig. 10), has been observed both in Iberian-Atlantic contexts, as at Cattewater (Redknap, 1984, p. 26), Highborn Cay (Oertling, 1989b, p. 249), Western Ledge Reef (Watts, 1993, p. 112), Red Bay (Grenier, 1988, p. 75) and in the *San Diego* (L´Hour, 1994, p. 147), as well as in numerous Mediterranean examples such as the Culip VI wreck. A notable exception is the presumed Genoese ship *Lomelina*, sunk in 1516 at Villefranche-sur-Mer (Guérout, et al., 1989, p. 39).

Interestingly, the first futtock on the forward side of the master floor timber (frame 1) – whose existence is revealed only by nail holes in the hull planking - was simply laid against the floor timber, which has no evidence of nailing on its forward surface. A similar pattern is seen in the Highborn Cay wreck.

On its aft face, however, the master floor timber is joined to the first futtocks using a dovetail mortise-and-tenon assembly. This feature, observed on both the Ria de Aveiro A and the Highborn Cay wrecks, suggests that the forward futtocks could have been installed after the master floor timber and the aft futtocks were positioned on the keel. The poor preservation of the starboard futtocks of the master frame precluded further observations.

The identification of floor timber 1 as the master frame provides a clue to the approximate length of the ship, based on principles set forth in the classic sources of Portuguese naval architecture. The late 16th-century text of Fernando Oliveira states that "(...) *these [master frames] in small ships of fifteen* rumos *or less should not be more than one: and from fifteen to eighteen, two: and from there on three, and no more regardless of the size* (...)" (p. 94). It can thus be inferred, initially, that this is a ship with a keel less than 15 *rumos* long. Additionally, Oliveira (p. 94) indicated that the master frame should be located just forward of mid-keel, using a corrective value of 1/8 of the keel's length in large ships.

This rule may be applied to the Ria de Aveiro A ship. Considering that the master frame was located about 7,4 m from the angle of the heel, we may postulate that the ship had a keel measuring 8 *rumos* or 12,32 m using an estimated value of 1,54 m for 1 *rumo* (Barata, 1989). Following the formula provided by Oliveira, the master frame would be placed 1 *rumo* (1/8 of 8

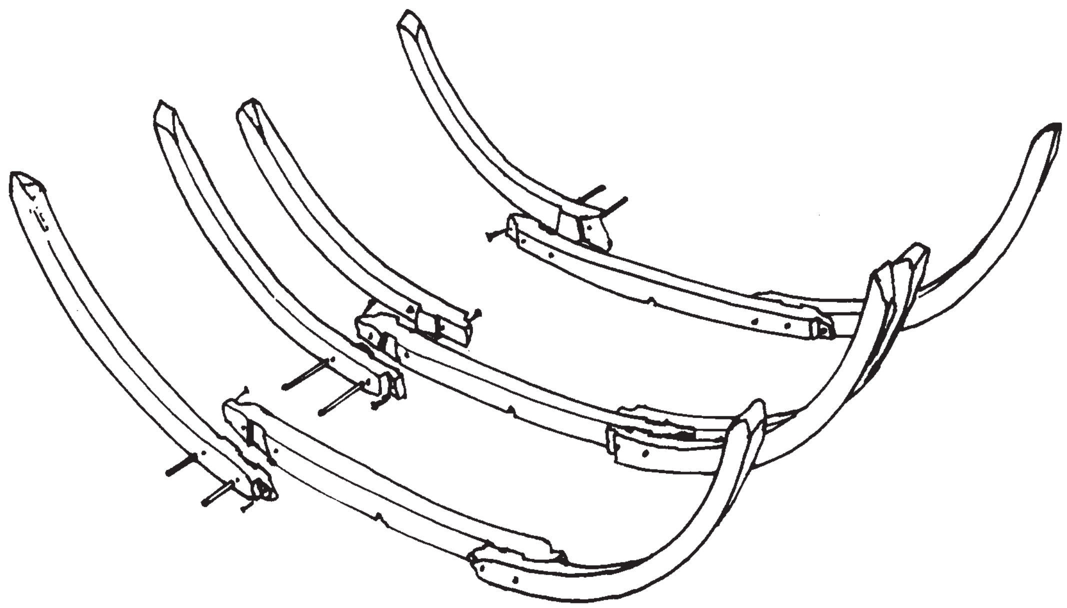


FIG. 10 – Scheme of the typical central framing pattern in the medieval and post-medieval Mediterranean and Iberian-Atlantic shipbuilding traditions.

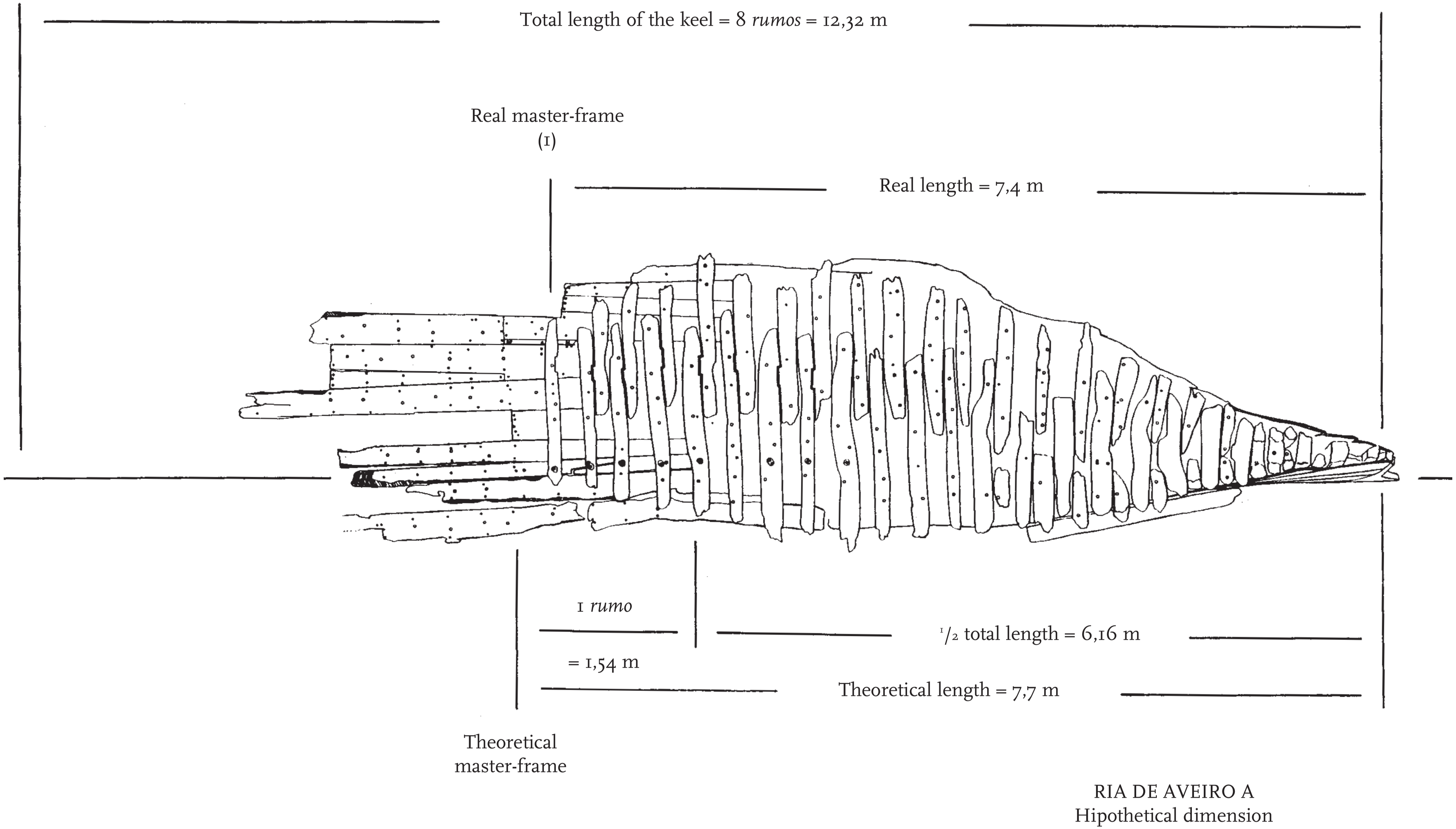


FIG. 11 – Dimensions of the Ria de Aveiro A shipwreck.

FIG. 12 – View of the numerals V, XII and XV engraved on floor timbers 5, 12 and 15. *Photo P. Gonçalves.*

rumos) forward of mid-keel, at a position 5 *rumos* or 7,7 m forward of the stern. The calculated position is close to the true position of the master frame in the Ria de Aveiro A ship, 7,4 m forward of the sternpost (Fig. 11).

This hypothesis seems to be the most acceptable, bearing in mind that the corrective measure forward of mid-keel for this relatively small ship is not known. For example, using the same formula, if the ship had a 9-*rumo* keel, the main floor timber would be 9,62 m forward of the stern; given a 7-*rumo* keel, the main floor timber would be 6,74 m forward. Neither of these hypotheses is supported by the archaeological evidence.

Other evidence, detected after the recovery of the frames in 1997, further supports the identification of floor timber 1 as the master frame. The incised Roman numerals *V*, *XII* and *XV* appear respectively on the aft face of floor timber 5, on the forward face of floor timber 12, and on the upper face of floor timber 15, always on the starboard side (Fig. 12). These marks, not noted on any other floor timbers, indicate a fortuitous correlation between the sequence of preserved floor timbers and the order that was attributed to them in their original architectural conception.

The practice of incising numbers on the floor timbers is referred to by Lavanha: "(...) *They also marked the places of the ends of the floor-timbers OP; and if they mark its number with a chisel; first, second or third, etc., which is in order to know where it has to rest and what its place is* (...)" (p. 53).

However, the reference by both Oliveira and Lavanha that a ship should have gauge marks equal to the number of *rumos* of keel doesn't confirm the hypothesis that the Ria de Aveiro A ship was 8 *rumos* long. This principle, understood in the literal sense used by Oliveira, also raises another objection. According to Oliveira (p. 95), the number of floor timbers with gauge marks excludes the master frame, while the Ria de Aveiro A sequence appears to include it. It is difficult to pursue the comparison between documentary sources and the archaeological data, given the incomplete nature of the remains. However of the remaining rare examples in which similar gauge marks have been identified, such as the Culip VI, Cais do Sodré and the presumed *Nossa Senhora dos Mártires* shipwrecks, the two master floor timbers were preserved only in the first case. Both these master floor timbers exhibit an incised numeral *I*. These examples, dating from the 14th to early 17th centuries, confirm this rule, as suggested by a recent in-depth study of these numbered marks (Rieth, 1996, p. 155).

The *in situ* floor timbers can be divided into two general groups. The first group comprises the first eight frames. The second group includes the remaining floor timbers at the aft end of the vessel, with a characteristic Y-shape typical of the rising and narrowing of the stern of a ship.

With the exception of frame 4, floor timbers 1 to 8 display the mortise of a joint on the stern face of their preserved (starboard) side, where they were connected to their respective first futtocks (Fig. 13*a*). Interestingly, floor timber 4 has the tenon portion of the joint, a pattern also seen on frame 11 of the Cais do Sodré shipwreck.

In floor timbers 1 to 8, the scarf was strengthened using two wooden pegs, placed horizontally on either side of the mortise-and-tenon joint, and reinforced by two fore-and-aft iron nails, also inserted on each side of the mortise on the inside of the treenails, according to the typical Iberian-Atlantic pattern (Oertling, 1989a, 1998). In floor timbers 3 and 4, the iron nail was located within the mortise. A third nail in the lower end of the futtock completed the fastening pattern. This linkage using fore-and-aft treenails and iron nails indicates that the floor-timbers and their respective first futtocks were assembled before the frames were mounted on the keel.

In the Iberian-Atlantic tradition, these mortise-and-tenon scarves are usually of the dovetail type (*rabo de minhoto*), as observed at Cattewater (Redknap, 1984, p. 26), Molasses Reef (Oertling, 1989c, p. 232), Highborn Cay (Oertling, 1989b, p. 249), Western Ledge Reef (Watts, 1993, p. 112), Red Bay (Grenier, 1988, p. 75) and on the *San Diego* (L'Hour, 1994, p. 147). This morphology is also present in examples from Mediterranean contexts, as in the presumed *Lomelina* (Guérout, Rieth et Gassend, 1989, p. 43) and the late 16th-century Calvi I wreck from Corsica (Villié, 1994, p. 37).

Conversely, in the Ria de Aveiro A wreck, these mortise-and-tenon joints are nearly rectangular, although not completely so, as in the case of the double mortise-and-tenon joints in the presumed *Nossa Senhora dos Mártires*.

The Ria de Aveiro A mortises have a depth of 1 to 2 cm. Their average width along the top edge is 14 cm (13,2 to 14,3 cm) and, across the base, 15 cm (13,2 to 16 cm).

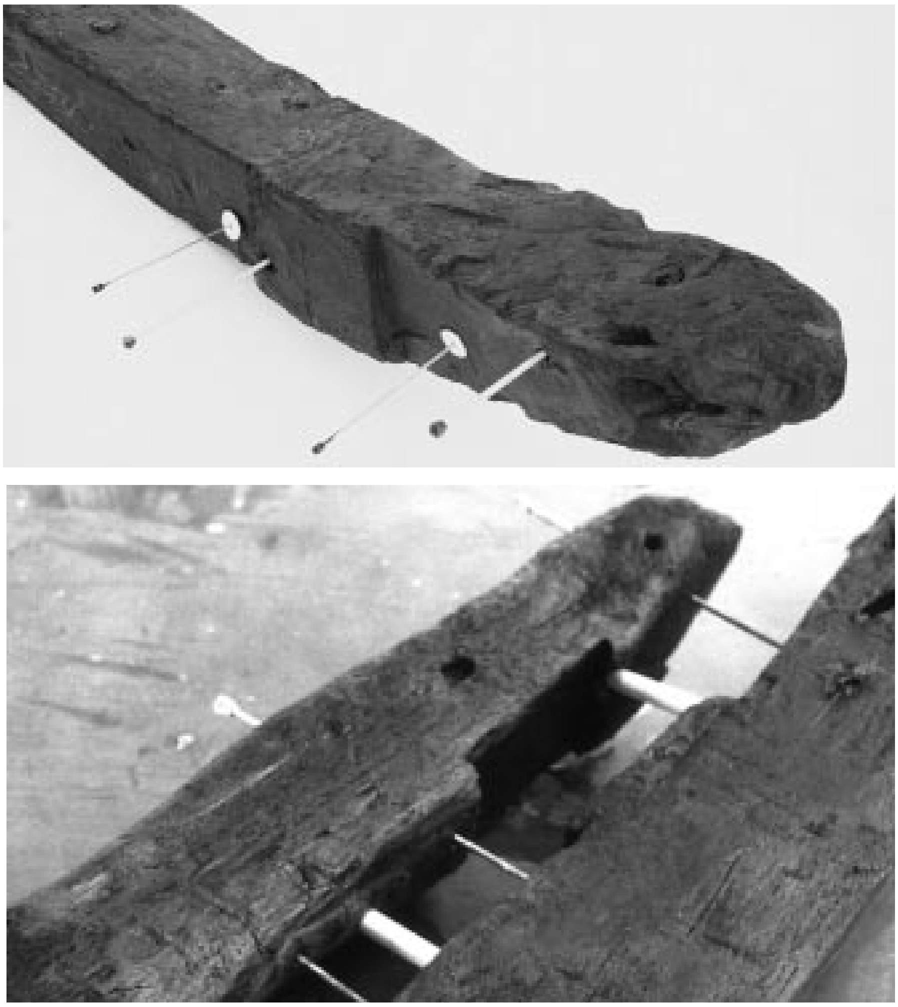
In reference to this method of frame assembly, Steffy (1994, p.139) observed: "(...) *The dovetail joints on the standing frames are curious and bear some consideration. They require a lot of extra work and timber and, in light of the other fastenings, do not at first appear to have been necessary. But they did add some security to the joint and must have made frame assembly easier and more accurate. Their appearance in all of the above wrecks found outside of the Mediterranean indicates that, at least in the minds of their builders, their functional importance must have outweighed the additional labour and timber costs.*"

Despite the regular morphology of these mortise-and-tenon joints, the variability in their location in the frames of the Ria de Aveiro A wreck suggests that they did not have a determining role in the architectural conception of the hull. However, the fastening patterns observed on these joints clearly indicates that these floor timbers and first futtocks were assembled as a complete frame before being placed on the keel. In some manner, then, the joints figured in the logic of the hull's architectural conception and, in particular, in the process of defining its shape. It appears that the use of mortise-and-tenon joints to attach the floor timbers to the first futtocks, in addition to strengthening the joint, may have been linked to the use of a marking gauge, that is to say, to the predetermination of the floor timbers (Barker, 1991, p. 67). Following this hypothesis, the first group of floor timbers may correspond to predetermined floor timbers, or *madeiras de conta*.

The eight floor timbers of the first group have an average reconstituted breadth (sided dimension) of 2,2 m, ranging from a maximum of 2,8 m (floor timber 6) to a minimum of 2,0 m (floor timber 8).

Where they are linked to the first futtocks, these floor timbers have an average fore-and-aft dimension of 12 cm, ranging from a maximum of 19 cm (floor timber 8) to a minimum of 10 cm (floor timber 3). Their average height (moulded dimension) is 12,5 cm, with a maximum of 13 (floor timber 4) and a minimum of 12 cm in the remaining timbers. The relatively slight dimensions of these timbers can be compared, for example, to the floor timbers of the coastal trader Culip VI: 10 to 12 cm wide and 12 cm high (Rieth, 1996, p. 152).

From a morphological and functional point of view, floor timbers 1 to 3 comprise a subset of the first group. They are distinguished, firstly, by having flat floors with no rising and, sec-



a)

b)

FIG. 13 – *a)* Typical mortise-and-tenon joint linking the floor timber and the first futtock on frames 1 to 8, with its nailing pattern. *b)* on frames 9 to 21. *Photo P. Gonçalves and M. Aleluia.*

ondly, by a moulded, tooth-like protrusion on their upper faces, adjacent to the keelson mortise on the preserved starboard side (Fig. 14). A similar feature is seen on the central floor timbers of the 13th-century Contarina I ship (Bonino, 1978, Fig. 14 and Photo 13). The tooth-like protrusions of the three central floor timbers of the Ria de Aveiro A ship flanked the enlarged part of the keelson in the mast-step zone, providing transversal reinforcement. They performed the same role as the transverse buttresses that rested on the floor timbers and reinforced the enlarged section of the keelson serving as a mast step in several shipwrecks of the Iberian-Atlantic tradition, such as at Red Bay (Grenier, 1988, p. 71, fig. 2), Highborn Cay (Oertling, 1989b, p. 246-247, fig. 3) and Western Ledge Reef (Watts, 1993, p. 111, fig. 11). Interestingly, in these three examples there are three pairs of buttresses. It must be pointed out, however, that buttresses of this type exist in other construction traditions, as seen in the Genoese *Lomelina* and the English *Mary Rose* (Rule, 1984). However, in these latter examples the number of buttresses is different.

The floor timbers of the first group (frames 1 to 8), but also the frame 9, of the second group, were attached to the keel using a large iron nail, driven from the top (Fig. 15). The head of the nail was countersunk into the upper face of the timber. The second floor timbers forward and aft of the master frame, and the seventh floor timber aft, were fixed to the keel using two iron nails. In the latter case, the nails corresponded to adjacent parts of the vertical keel scarf.

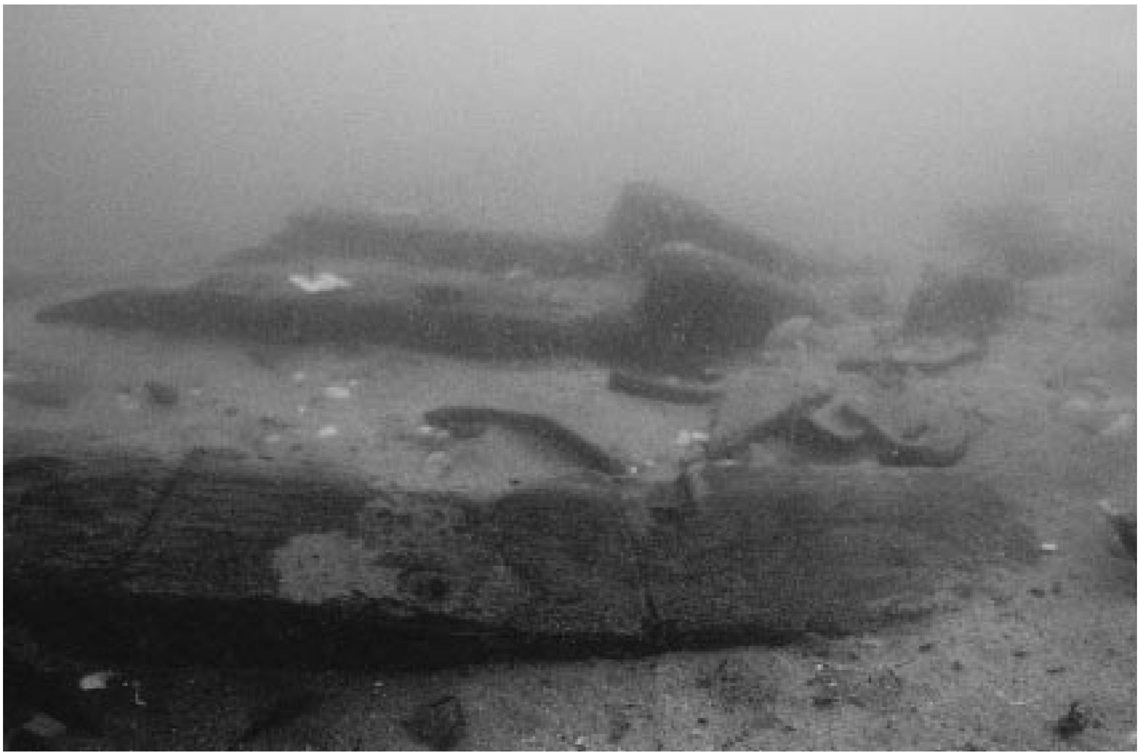
The second floor timber forward and the fourth frame aft were also affixed using two iron bolts driven through the keelson. These bolts were arranged symmetrically fore-and-aft of the keel scarf and were riveted (Lavanha uses the term *anielado*) inside a large countersink in the keel's lower face.

In the second group, which included frames 9 to 21 (the details being until now impossible to observe beyond this frame), the method of attachment between the floor timber and the first futtock is simplified (Fig. 13*b*). These frames don't use neither mortise-and-tenon joints nor fore-and-aft treenails. There are only two iron nails, one toed from the top forward edge of the floor timber, down and forward into the futtock, the second driven in the opposite direction, horizontally. The angle at which these spikes were driven suggests that the first futtocks were nailed to the floor timbers after the latter had been attached to the keel. The limited space between the frames necessitated the oblique placement of the nails, a solution also seen on the *Lomelina* (Guérout, Rieth et Gassend, 1989, p. 47).

The vertical attachment of floor timbers 10 to 21 to the keel generally uses one nail toed into a countersink in the forward or aft face of the floor timbers (Fig. 16). The countersink holes are situated an average of 10 to 11 cm above the top of the keel, with a minimum of 9 cm (floor timber 19) and a maximum of 13 cm (floor timber 13). Two nails are also used in the floor timber 11. In the Y-shaped floor timbers 16 and 21, iron bolts are driven top to bottom and riveted (anielados), in the first case coming from the keelson and in the second driven from the upper surface of the frame. In the floor timber 16 beside the usual nail fixing the frame to the keel, two nails are also driven from the keelson ending in the floor timber. Within the second group of floor timbers, a subset can be distinguished, consisting of floor timbers 10 to 18, in which the toed nail is in the forward face. In the second subset, floor timbers 19 to 21, the nail passes through the aft face of the floor into the forward prologation piece of the stern knee, upon which the frames rest.

According to the working hypothesis, the first group of floor timbers corresponds to the pre-designed frames (*madeiras da conta*), while the second group corresponds to floor timbers defined at the time of construction using ribbands.

Given this hypothesis, the significance of the floor timbers marked *XII* and *XV* in the second group (as well as floor timber 5 in the first group, marked *V*), that appear to have a greater impor-



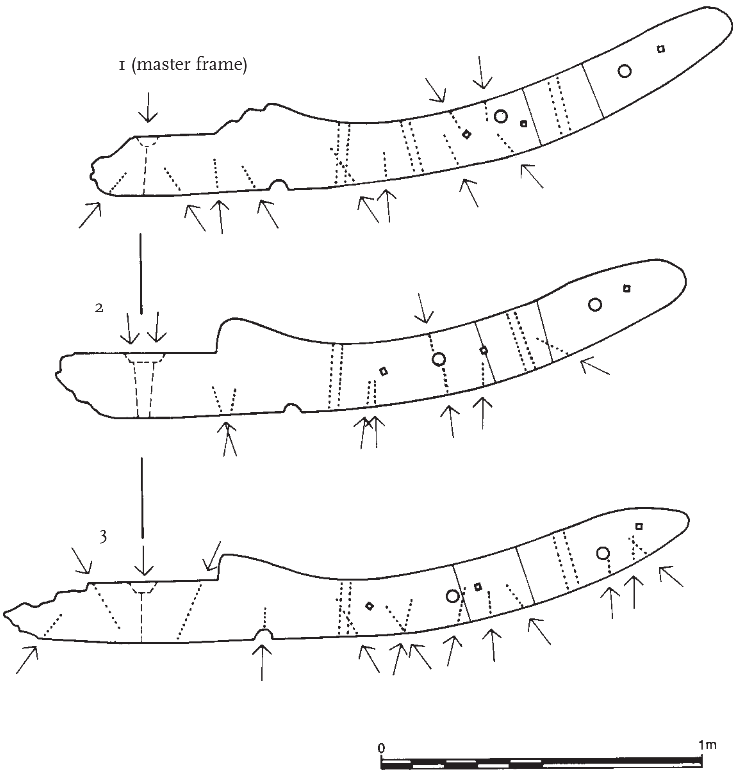


FIG. 14 – *In situ* view, and vertical section of floor timbers 1, 2 and 3 with lateral moulded protrusions to enclose the mast step. *Photo F. Alves.*

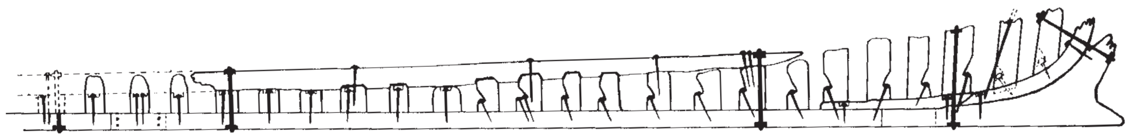


FIG. 15 – Vertical axial nailing scheme of the Ria de Aveiro A shipwreck. *Drawing: Miguel Aleluia.*

FIG. 16 – View of the triangular notch used for nailing floor timbers 10 to 21 to the keel. *Photo P. Gonçalves.*

tance relative to the other frames, remains a mystery for the moment. Aside from these questions, the coherence of the two groups of floor timbers is clear. This coherence results as much from the method of joining the floor timbers to the first futtocks as from the orientation of the joint, the use of spikes to link the timbers and the method of attaching the floor timbers to the keel.

Finally, except on floor timbers 10 and 11, limber holes were observed in the lower faces of the floor timbers, offset to the starboard side. Based on the position of these limber holes, two groups of floor timbers can be identified:

1 – in floor timbers 1 to 3, the limber holes are located 27 to 35 cm from the midship axis, near the joint of the keel and the garboard strake. While only one limber hole per floor timber was observed, the asymmetrical preservation of the timbers leaves the possibility that a second limber hole was located on the port side;

2 – in floor timbers 4 to 21, the limber holes are near the midship axis, slightly offset from 1 to 5 cm to the starboard.

These limber holes have the following shapes and sizes:

1 – in floor timbers 12, 15 and 17 they have a triangular shape with an average width of 3.5 cm and a height of 2 cm;

2 – in the remaining floor timbers from 1 to 21 (except 10 and 11), they have an arched, semicircular shape with dimensions identical to those given above.

The first futtocks

The longest preserved first futtock measures 1,3 m and is located on the starboard side of frame 8. Where they are attached to the floor timbers, the preserved first futtocks have an average cross section of 12 cm in height and width.

In frames 1 to 8, the first futtocks generally exhibit the tenon portion of the dovetail joint that mates with the mortise of the respective floor timber. These tenons are thus oriented forward (south) toward the master frame. Only in one case is this feature inverted: first futtock 4 has a mortise instead of a tenon. This phenomenon is also seen in the Cais do Sodré wreck, as previously mentioned. The corresponding floor timber has a tenon, contrary to the typical configuration. No explanation can be offered for this anomaly in the construction pattern: no explanation relating to the available raw material appears to be fully satisfactory.

The keelson

A keelson segment measuring 3,5 m in length was found immediately to the east of the hull structure (Fig. 4). Roughly hewn, abraded and exhibiting greatly eroded, irregular edges, the timber has a squarish cross section about 12,5 cm high and 13 cm wide (Fig. 17). The relatively small dimensions of this keelson are immediately apparent when compared to other keelsons belonging to the Iberian-Atlantic tradition, even when the different sizes of the ships are taken into consideration.

The lower surface of the keelson is characteristically notched to fit over the floor timbers. The notch widths vary from 11,5 cm to 15 cm and are highly irregular, in accordance with the parts of the floor timbers upon which the keelson was seated.

The upper surface of the keelson has three longitudinal mortises about 50 cm long and 4 cm wide, which begin at intervals of 0,76 m and 1 m. The bottom of each cavity is flat and sloped downward from the upper surface to its deepest part where it forms an ogee rabbet, about 2,5 cm deep, where a deckpost tenon could be inserted (Fig. 18). Therefore this feature suggests that the Ria de Aveiro A ship was equipped with a deck.

Similar mortises have been documented on the upper surface of the keelson of the frigate *Santo António de Tanna*, sunk in 1697 in the vicinity of Mombassa, Kenya (Piercy, 1977, p. 332 and 333, fig. 2) and on two keelson fragments from the Cais do Sodré shipwreck.

A second keelson element, with a scarf still preserved at one end, was found near its original position and revealed that the aft end of the keelson lay near frame 17.

These two parts of the keelson contained three types of iron fastenings:

1 - a single nail, about 1,5 to 1,6 cm square in section (in floor timbers 7, 11, 14 and 16), here with a pair of them and the next third one;

2 - a longer nail ending in the keel, reinforcing the keelson's aftermost attachment to floor timber 16;

3 - two iron bolts already mentioned, 2,5 cm in diameter, symmetrically placed forward and aft of the keel scarf, on the second (missing) floor timber forward of the master frame and the fourth floor timber aft, and riveted inside a large countersink in the keel's bottom face.

Evidence indicates that the mast step, although not recovered, was located over floor timbers 1 to 3. The morphology of these floor timbers, particularly the tooth-like, moulded protrusions on their upper faces, recalls a similar feature on the Contarina I wreck that served to buttress the mast step. The distance between these protrusions, about 30 to 32 cm, is greater than the width of surviving keelson segments from further aft, in keeping with the typical Iberian-Atlantic practice of

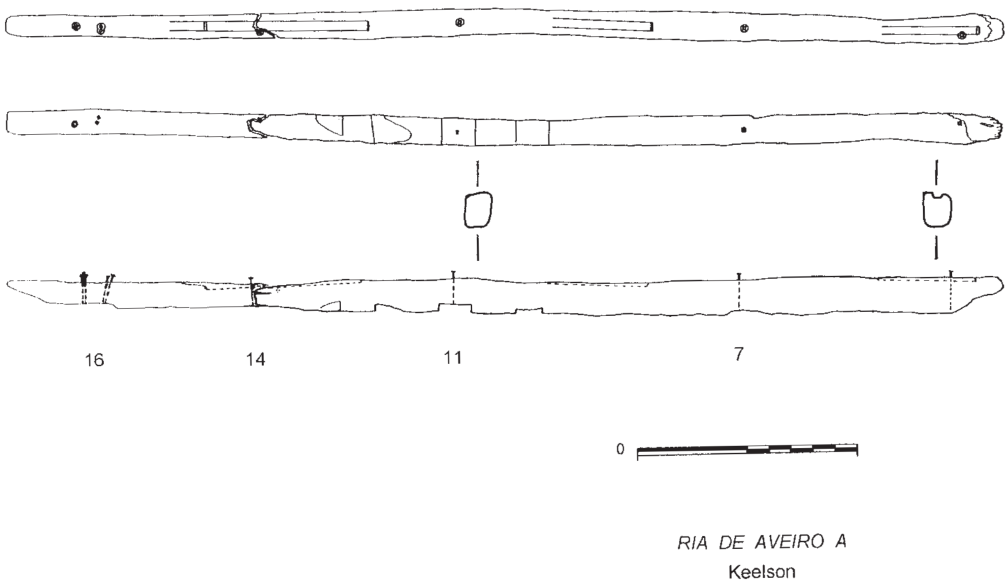


FIG. 17 – Drawing of the preserved parts of the keelson of the Ria de Aveiro A shipwreck.

FIG. 18 – Detailed view of one of the mortises on the upper surface of the keelson for a deckpost tenon. *Photo M. Aleluia.*

stepping the mast in an enlarged central portion of the keelson. Finally, an unusually large bolt hole in the forward end of the preserved keel timber supports the assumption that this part of the keelson, here at its widest point, represents the mast step. Thus, the keelson of the Ria de Aveiro A had the enlarged section required for the mast step in the area of the first three preserved floor timbers. This enlargement, while very pronounced (widening from 13 cm to between 30 and 32 cm), is typical, and is seen in other examples of the Iberian-Atlantic tradition such as the Cattewater wreck (widening from 30 cm to 54 cm), the Highborn Cay wreck (widening from 16--21 cm to 40 cm) and the *San Diego* (widening from between 20-25 cm to 35 cm).

In 1997, after the interior of the ship was excavated, the rear keelson timber was discovered *in situ*. This timber is 115 cm long with a height of 11,5 cm and a width of 12,5 cm. Its upper surface, beginning at 73 cm from its aft end, contains an extended cavity, identical to the three found in the first keelson segment. This cavity measures 37 cm long and 3,5 cm wide, with a maximum depth of 2,5 cm at the forward end. Its lower surface is flat and sloping, although starting from 95 cm there is a projection, also flat, with a height of less than 2,5 cm. The timber's lateral faces, between 22 and 75 cm, slope inward so that the transversal cross section is adapted to the fastening of the first futtocks with the Y-shaped floors of the stern, and corresponds to the progressive elevation of the aftermost floors.

At 25 cm from the aft end of the keelson, there is a hole, offset to the port side, corresponding to the head of an iron nail with a cross section of 1,5 cm. Similarly, the heads of two more iron nails are found at 32,5 cm and 37 cm on the starboard side. These fasteners correspond to floor timber 16. At 99 cm, there is another nail hole, also on the starboard side, corresponding to floor timber 14.

The stringers

The Ria de Aveiro A ship had two bilge stringers that lay side by side, although poor preservation makes it impossible to evaluate whether they originally had equal lengths.

The stringer lying closest to the keel, preserved from floor timber 2 to the 17, is an integral part of the hull's internal reinforcement system, both laterally and longitudinally (Fig. 19). Acting together with the planking, this piece clenched the floor timbers and the first futtocks where they overlap. The stringer's breadth exactly covered the area of the mortise-and-tenon joints of the central frames (Fig. 20). In the floor timbers further astern, this stringer did not cover the mortise-and-tenon joints. It is perhaps for this reason that a second stringer was added to cover the joints left exposed by the first stringer.

At the southern end of the Ria de Aveiro A shipwreck, this stringer is a large plank with a rectangular section measuring 5 cm by 30 cm. Toward the stern, the stringer loses its rectangular cross section and its upper surface becomes rounded. In this area, the stringers have an average width of 24 cm and a thickness of about 6 cm. The inboard stringer ends at floor timber 17, where an overlapping extension continued the strake up to Y-shaped floor timber 20.

The inboard stringer was attached by round treenails 2,2 cm in diameter and by square iron nails 9 mm in cross section. The latter had squarish or rounded heads about 4 cm across that left impressions in the wood. The treenails traverse both the floor timbers and the exterior hull planking, and were inserted from the outside of the hull. The iron nails found in the stringers were driven in the reverse direction, from inboard to outboard. The fasteners were always situated toward the sides of the stringers, about halfway between the timber's edges and its central axis.

Despite the incomplete preservation of the stringer and the obviously irregular presence of two types of fastenings (wooden and iron), some preliminary observations can be made:

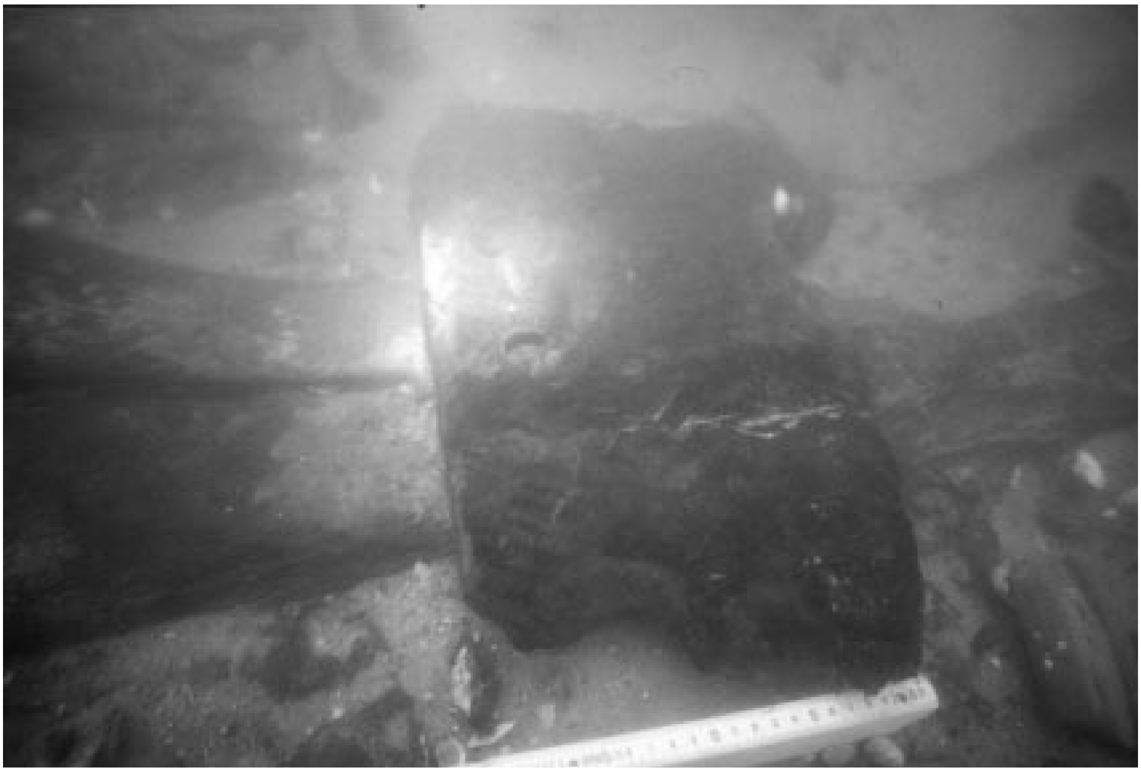


FIG. 19 – View of the inboard bilge stringer preserved on the starboard side. *Photo F. Alves.*

FIG. 20 – View of the inboard bilge stringer covering the area of the dovetail mortise-and-tenon for the joint of the floor timber and the first futtock.

a) from frame 2 to frame 9, both fastener types occur on the same framing piece (floor timber or first futtock) and thus lie on approximately the same transversal axis;
b) frame 2 is the only one that has a double fastening, in the floor timber and the first futtock;
c) starting with frame 10, only iron nails are found;
d) starting at frame 10, the pattern by iron nails becomes irregular and seems to occur randomly on either the floor timbers or the first futtocks, although frequently respecting an alternating transversal relationship;
e) in the aftermost stringer piece, the nailing occurs on every second frame.

It was observed that the outer face of the stringer nearest the keel has a batten, whose section may be described as triangular with a curved hypotenuse, at least at its better-preserved forward end. The batten is almost completely split longitudinally. Its function may have been to suppress the curved edge of the stringer on this same side (Fig. 21).

Alongside the first stringer is a second, with an identical cross section averaging 25 cm wide and attaining a maximum thickness of 5 cm in its central area (fig. 4). Two fragments of this stringer are preserved between frames 8 and 13. The fasteners follow a pattern of transversal alternation as in the first stringer, corresponding here to the sequence of frames 6 to 7 and frames 9 to 12. During the 1997 excavation, the fore-and-aft extent of the stringers could not be determined.

The absence of limber boards or mast-step buttresses between the keelson and the first stringer is noteworthy. Such features are often found in wrecks belonging to the Iberian-Atlantic tradition, as in the Red Bay (Grenier, 1988, p. 71, fig. 2) and Cattewater vessels (Redknap, 1984, p. 17, fig. 10).

The roughly-hewn outboard stringer may reveal a certain artisanal archaism in the Ria de Aveiro A ship. In contrast to the carefully-cut inboard stringer, which covers the mortise-and-tenon joints of the *madeiras da conta*, the second stringer was roughly cut. The crude workmanship of the second stringer is atypical within this construction tradition: typically, the stringers are carefully cut and finished, as seen at Molasses Reef and Highborn Cay.

The planking

There is no indication in the Ria de Aveiro A shipwreck of the existence of ceiling planking, not even between the keelson and the bilge stringers. Except for the *San Diego*, built in the Philippines, there are no other recorded examples of ships built in the Iberian-Atlantic tradition that completely lack ceiling planking.

The outer hull planking has a thickness of 5 to 5.5 cm. In only two archaeological examples has a lesser thickness been noted: in the Molasses Reef (4.5 cm) and in the Western Ledge Reef (3,5 cm). The latter wreck is particularly interesting as its stern heel has a width of about 29 cm, much greater than the 12-cm width of that found at Ria de Aveiro A.

The preserved planks in the central part of the hull include nine strakes on the starboard side and three on the port. At the stern, next to the sternpost, only three strakes were fully preserved on each side. The average plank width is 22 cm. The garboards measure 22 cm wide on the port side and 16 to 18 cm on the starboard.

The butt ends of the planks, as observed from the nail holes visible on the interior surface of the planks at the southern end of the wreck, are always centred on a frame. This pattern can be seen on planks T2, T4, T17, T5, T6 and T7 on the starboard side (Fig. 9).

Plank T4 is either a stealer installed during construction, or a repair filler, as it mates with a cut-out segment of plank T5. This feature is also seen in a small part of T6 that underlies floor timbers 1 and 2. In the latter instance, the absence of extra nail holes in floor timbers 1 and 2 indicates that this filler plank was installed at the time of the ship's construction.

The fastening

The Ria de Aveiro A hull contains both wooden and iron hull fasteners. This observation echoes that of other examples belonging to the Iberian-Atlantic tradition, namely Cattewater, Molasses Reef, Highborn Cay, Western Ledge Reef, Red Bay and, in Portugal, the Corpo Santo wreck. In contrast, only iron nails were used in the Cais do Sodré wreck, the *San Diego*, and the presumed *Nossa Senhora dos Mártires*. As mentioned, round treenails with a diameter of 2,2 cm are found both as fore-and-aft fasteners, joining the floor timbers to the first futtocks, and as transversal fasteners for the hull planks, the floor timbers and the bilge stringers, where the treenails were used with parallel iron fasteners (square nails and round spikes).

While the treenails always have the same diameter, the iron nails occur in two sizes:

a) the smaller ones have a square shape, 8 to 9 mm to a side next to the head, and were used to hold the planking and the keelson to the frames;

b) the thicker ones are 15 to 16 mm large and probably only square on the end, and their use has only been noted in the attachment of the frames to the keel, of the floor timbers to the futtocks, and of the keelson to the keel through the frames;

Another type of iron fastening consists of round iron bolts, 25 mm in diameter, used to connect the keelson to the keel through the frames, a Y-shaped floor timber to the stern knee (*couce de popa*), and the sternpost (heel) to the last floor timber through the stern knee.

The general fastening pattern of the Ria de Aveiro A wreck is shown in Figures 13 and 15.

Wood identification

Twenty-four wood samples from seven different parts of the hull were examined by Paula Fernanda Queiroz and Carlos Pimenta of the Centro de Investigação em Paleoecologia Humana e Arqueociências of the Instituto Português de Arqueologia.

Almost all of the major structural components were made using a single wood species, the *carvalho roble* or European oak (*Quercus robur*). This species is typical of northern Portugal, including the Douro basin. The species was identified in the keel, the keelson, the two bilge stringers, five floor timbers, five futtocks, one outer hull plank and one treenail.

Two samples from the stanchions were found to be of *castanheiro*, or chestnut (*Castanea sativa*), a species common throughout Portugal.

Two stowage billets found in the cargo, measuring less than 8 cm in diameter, were of *pinheiro manso*, or umbrella pine (*Pinus pinea*), a southern European species that is also widespread throughout Portugal.

Two samples of *urze branca* — briar or tree heath (heather; *Erica spp, cf. E. arborea*) — were found in the cargo, measuring less than 2 cm diameter.

The extensive use of European oak for the hull structure is similar to that found in the 14th century *Corpo Santo* shipwreck, made of three Portuguese typical oak species, and is significant for several reasons. From the perspective of the history of technology, these archaeological findings describe a reality that is rather different from what may be inferred from the classic written sources of late 16th and early 17th century Portuguese naval architecture, specifically in Fernando Oliveira's *O Livro da Fabrica das Naos* (c. 1580/1991, p. 64) and in João Baptista Lavanha's *Livro Primeiro de Architectura Naval* (c. 1608-1616/1996, p. 27). Both of these authors, in recommending what wood is to be used for a ship's framing, specify the *sobreiro*, or cork oak (*Quercus suber*). Oliveira and Lavanha both refer to the use of umbrella pine (*Pinus pinea*) for the hull planking. It must be pointed out that this combination was only verified in the *Nossa Senhora dos Mártires* wreck. These two species are both very common in Portugal, the cork oak being especially abundant in the central and southern parts of the country. Interestingly, Oliveira discusses the difficulty of finding adequate wood of this species for shipbuilding, as its common use was to produce charcoal. Naturally, by the late 16th century, the European oak was even more rare and it would be an uncommon luxury to build an oak ship. Thus it should be emphasised that the European oak (*Quercus robur*) is present above all in the valleys of northern Portugal, where it reaches the southern limit of its range.

We may therefore suggest that, even though the pre-16th century Portuguese shipwrecks at Corpo Santo and Ria de Aveiro A represent a very small sample of the shipbuilding methods of their age, the oak structure of these wrecks illustrates the productive conditions of the premodern economy. Nevertheless, it is important to remember that Portuguese forest resources, and notably oak stands, were intensively exploited between the middle of the 15th century and the middle of the 16th century, a period that corresponds to the great age of Portuguese discovery and expansion and, *mutatis mutandis*, to an equivalent development in shipbuilding activity.

Conclusions

Although the Corpo Santo vestiges are older, the Ria de Aveiro A shipwreck is much better preserved and, as such, may be considered the oldest best known example of the late-medieval and early-modern Iberian-Atlantic construction tradition, being more than a century older than the overwhelming majority of the examples known throughout the world.

Moreover, the fact that this is a typical ship intended for regional coastal trade gives it exceptional importance from the perspective of history of technology. It provides archaeological support for the hypothesis that the Iberian-Atlantic tradition is rooted in an even earlier regional tradition - exemplified by the numerous archaisms, the rough characteristics and the weaker construction of the Ria de Aveiro A wreck, that can be compared with later examples of the same tradition designed for ocean navigation. This hypothesis is additionally corroborated by the discovery of the Corpo Santo remains in 1996.

In conclusion, the Ria de Aveiro A vessel, a contemporary of the ships of discovery, represents an important contribution to our knowledge about the spread of Mediterranean shipbuilding methods in Atlantic Europe, and a testimony that the west coast of the Iberian peninsula was a center for synthesising knowledge, experience and technical innovation at the close of the Middle Ages (Alves, 1998c).

NOTES

1 A. Monge Soares of the Instituto de Engenharia e Tecnologia Industrial.

2 The designation Ria de Aveiro A reflects the fact that in 1993 there was a discovery in another area of the main channel of the Ria de Aveiro that was designated Ria de Aveiro B (Alves, 1993a). It had an unusual concentration of scattered finds, predominantly of ceramics from various periods and sources, with a particular prominence of distinctly old local commonware. In general, the ceramics from Ria de Aveiro B presented overwhelming similarities with those from Ria de Aveiro A (Alves et al., 1998a). These findings seem to be related to disturbances caused upstream of this location by dredging carried out in 1970 – an event during which a large number of ceramics was collected and deposited in the Misericórdia of Aveiro, where it is still stored. As an aside, it deserves to be mentioned that on one of the banks of the Ria de Aveiro B site, there is a saltpan called *Gran Caravela*. In addition, in 1995, in an immediately contiguous area named Ria de Aveiro C, a nautical astrolabe was found in a perfect state of preservation engraved with the date of 1575 – the second to have been discovered in Portuguese waters. Of the five astrolabes currently known in Portugal, three were discovered between 1996 and 1997 at São Julião da Barra, on the sandbar of the Tagus River, in the framework of an underwater archaeological project directed by one of the authors (F.A.) and by Filipe Castro of CNANS, and developed within the scope of the programme of the Pavilion of Portugal for Expo'98 (Alves et al., 1998b).

3 In light of the existing political context in Portugal, an archaeological research project could only be started in 1996 (Alves, 1994b). In 1993, legislation was passed in Portugal that favoured commercial exploration of underwater cultural heritage (Decree-Law no. 289/93, of August 21). This legislation was later repealed (Decree-Law no. 164/97, of June 27) within the scope of a general restructuring of the services of the Cultural Heritage of the Ministry of Culture that led to the creation of the Centro Nacional de Arqueologia Náutica e Subaquática (CNANS) within the Instituto Português de Arqueologia (IPA) (Decree-Law no. 117/97, of May 14). 1993-1995 was a dark period for underwater archaeology in Portugal (Alves 1993b and c, 1995a and b, Alves et al., 1995a and b). The facilitation of the Ria de Aveiro project was due to the concern of the Universidade de Aveiro (UA). In 1995, the university proposed to the Instituto Português do Património Arquitectónico e Arqueológico (IPPAR) an agreement for collaboration in the scope of an interdisciplinary project centred on the underwater archaeological investigation in question (currently transferred to IPA and assumed by CNANS). This project, for which one of the authors (F.A.) is the co-ordinator and another a consultant (E.R.), involves several departments and areas of the University. The project was accepted and has been supported financially by the Junta Nacional para a Investigação Científica e Tecnológica (JNICT) — actual Fundação para a Ciência e Tecnologia (FCT) through the Praxis XXI programme. The project was also supported by the Calouste Gulbenkian Foundation, by the City Council of Ílhavo and, in the logistical plan, by the Junta Autónoma do Porto de Aveiro and the Capitania do Porto de Aveiro. The excavation of the Ria de Aveiro A had or has the permanent or intermittent collaboration of archaeologist Catarina Garcia and of archaeological assistants Miguel Aleluia and Ricardo Rodrigo, as well as periodically from the Italian archaeologist Edoardo Riccardi. The Ria de Aveiro A project has, however, been developed by the personnel of CNANS with the support of several external collaborators, namely members of the *Arqueonáutica* association.

4 Spring storms resulted in the cancellation of the 1998 field season, and preparations for the International Symposium on the Archaeology of Medieval and Modern Ships of Iberian-Atlantic Tradition made it impossible to publish a report later that year.

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