The remains of a Portuguese Indiaman at the mouth of the Tagus, Lisbon, Portugal (*Nossa Senhora dos Mártires*, 1606?)

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1.Introduction

Belying its beauty and spaciousness, the mouth of the Tagus river has always bedeviled those who wish to enter or leave the port of Lisbon by boat (Fig. 1). Two channels constitute alternative entries to the port — the larger southern passage, and the smaller northern passage. A submerged shoal, the Cachopo Norte, which blocks the progress of large vessels, separates the two channels.

Opposite the Cachopo Norte on the rocky northern shore of the Tagus, the fortress of São Julião da Barra was built during the 16th and 17th centuries, just at this narrow channel, extremely difficult to navigate and where strong currents and southerly storms can produce violent breakers.

For several decades, since the rise of amateur scuba diving, the archaeological potential of this channel has been known. In 1993-1994, the Museu Nacional de Arqueologia, aided by the non-profit organization *Arqueonáutica*, carried out a survey in the area near the fortress, under the direction of Dr. Francisco Alves, and identified two important archaeological sites.

The first site, designated SJB1, consisted of several pieces of iron anchors and artillery found in shallow water beneath the fortress walls. Associated with this concentration were several treasure finds such as silver coins dated to the mid-17th century and a variety of objects dating from the late 16th century to recent times.

The second site, designated SJB2, contained the remains of a wooden hull and fragments of Chinese porcelain from the Wan-Li period (1573-1620). This hull was the central artifact of a

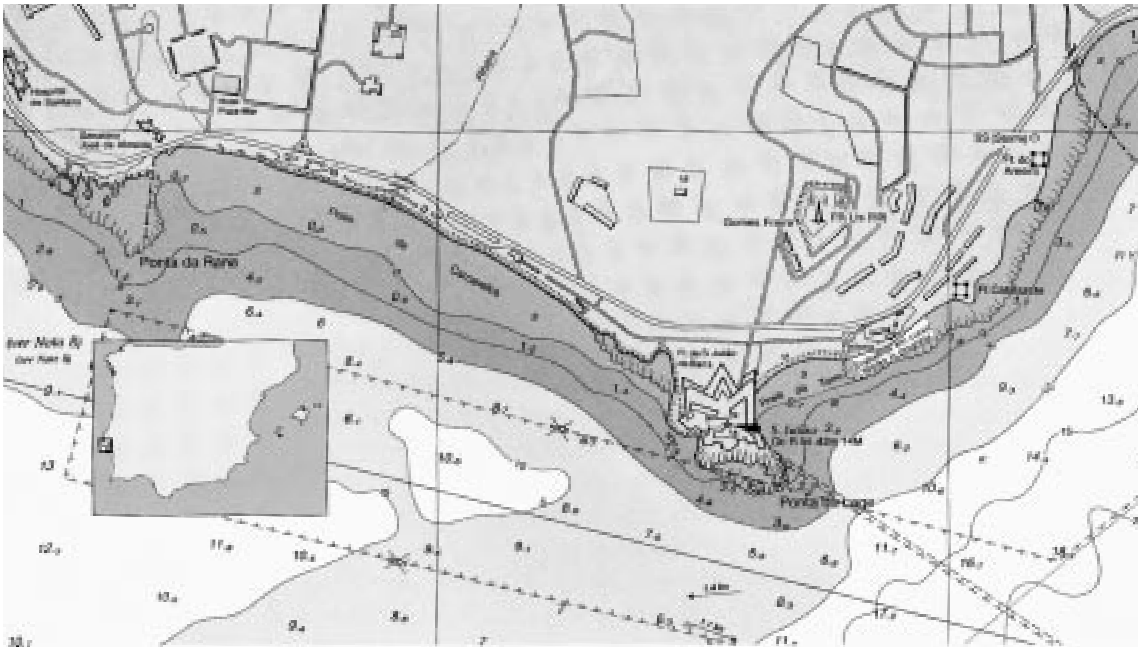

FIG. 1 – Location map of SJB2 wreck, identified as the *Nossa Senhora dos Mártires*, and India *nau* lost in 1606 at the mouth of the Tagus, in Lisbon.

larger deposit, defined by lead sheeting and straps used to protect the hull and by a quantity of peppercorns, forming a lens of variable thickness.

Among the many documented shipwrecks at the mouth of the Tagus, that of the nau *Nossa Senhora dos Mártires* is the only one to be described as being lost precisely at this place, on September 14, 1606, at the end of its return voyage from Cochim in western India with a cargo of pepper and other goods from the Far East.

The archaeological excavation of the São Julião da Barra area, based on the strong possibility that the site contained the remains of a Portuguese Indiaman from the early 17th century, was included in the program of the Portuguese pavilion at the 1998 world's fair at Lisbon. The excavation was carried out between October 1997 and October 1998[1].

Despite a limited timeframe, excavation proceeded on two fronts: one which focused on the preserved hull fragment, the second consisting of the excavation of an area of about 100 square meters just north of the hull remains.

The excavation in this second area lead to the discovery of numerous artifacts, most of which could be dated to the late 16th or early 17th centuries. Especially worth mentioning are stoneware and sandstone materials of Oriental manufacture, Chinese porcelain from the Wanli period (1573-1620), bronze and iron artillery pieces, and navigational instruments. In addition, large numbers of domestic and cooking utensils, gaming pieces, coral fragments, furniture and organic materials were found.

Among the nautical instruments that were recovered are three astrolabes, one of which, in perfect condition, carried the date of 1605, the year in which the armada of Brás Telles de Menezes, including the nau *Nossa Senhora dos Mártires*, sailed from Lisbon to Cochim under the command of Captain Manuel Barreto Rolim. This important artifact assemblage strongly suggests that we are dealing with the remains of the nau *Nossa Senhora dos Mártires*.

This paper will concentrate on the structural remains of the hull, which was partially dismantled and raised in preparation for a detailed laboratory study.

2.Description of the remains of the hull

The preserved structure appears to represent the floor of the ship, immediately forward of the master frame (or frames). Due to the morphology of the sea bottom, the remains are better preserved on the east side of the keel, presumably the portside.

The east side is divided by a longitudinal fracture and, at the south end, the hull planks are completely splintered in a fracture zone (Fig. 2). The wreckage occupied an area of about 50 square meters, measuring about 12 m long on its North-South axis and having a maximum width of about 7 m.

The preserved hull remains consist of the keel, eleven frames, and twenty-six strakes of hull planking. To the south, the presumed direction of the bow, a large isolated timber with a symmetrical shape was tentatively identified as an apron or one of the longitudinal timbers forming the interior of the stem.

A dark colored layer of silt, mixed with peppercorns, filled the spaces between the floor timbers and was observed in a large area around the hull, constituting a well-defined archaeological layer whose thickness varied from as little as 3 or 4 cm to as much as 20 to 25 cm.

The data we are presenting here derive mainly from analysis of the *in situ* observations, since during this phase of the project only two-floor timbers and their respective futtocks were recovered and recorded, as well as the apron. Already at this early phase in the excavation, analysis of the retrieved data made it possible to establish parallels between, on one hand, the meth-

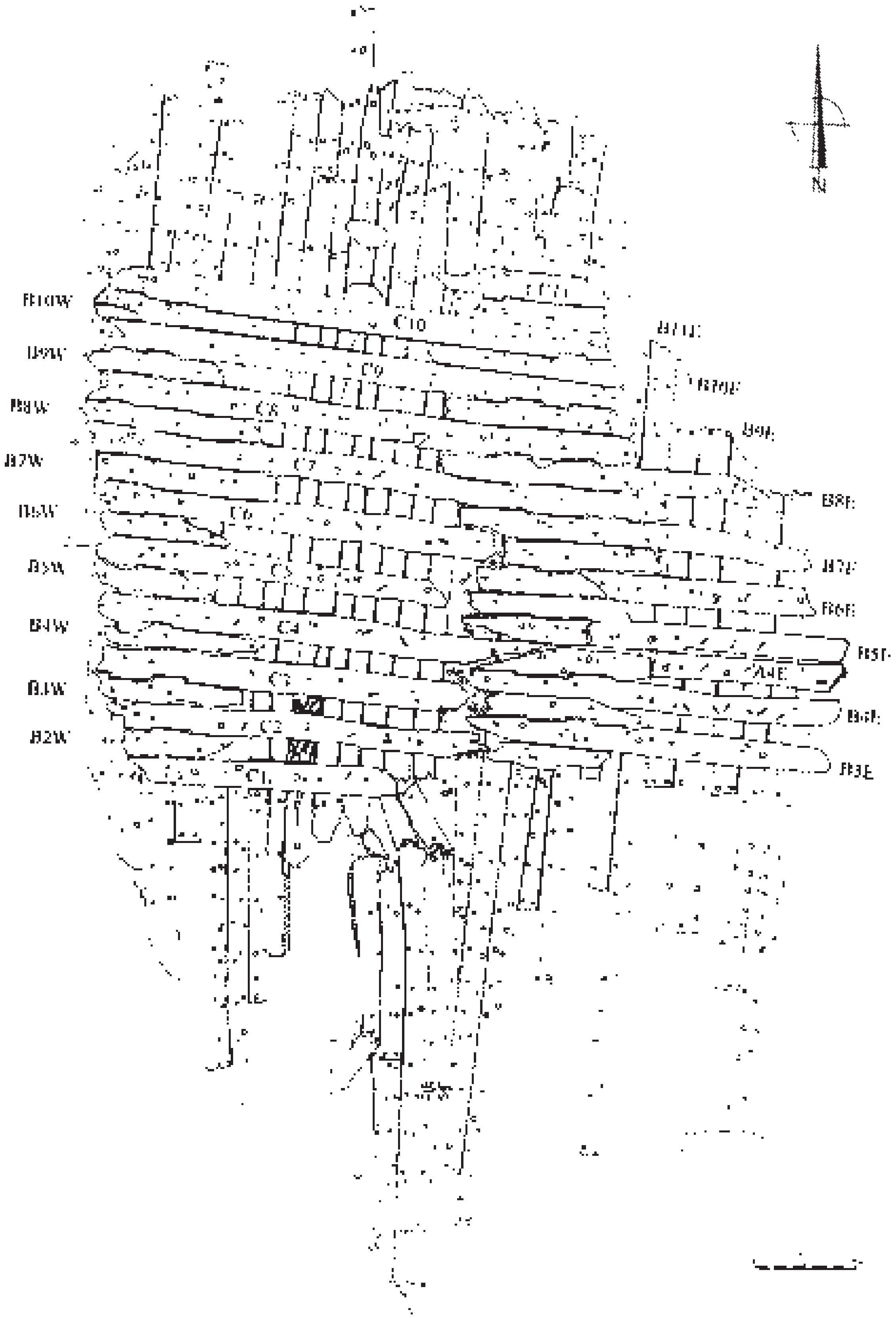

FIG. 2 – Plan of the SJB2 wreck.

ods used during the hull's architectural conception and construction and, on the other, the guidelines given in some texts and Portuguese naval construction treatises of this period.

For this purpose, we have studied three of the most important texts of Portuguese naval architecture from the transition period between the 16th and 17th centuries: the *Livro da Fábrica das Naus* by Padre Fernando Oliveira (ca. 1580), the *Livro Primeiro de Architectura Naval* by João Baptista Lavanha (ca. 1608-1615) and the *Livro de Traças de Carpintaria* by Manoel Fernandez (1616).[2]

2.1. Dimensions

The most remarkable feature of wreck is the large dimension of its scantlings, which belong without any doubt to a large ship, possibly a *nau* with a keel of eighteen *rumos* (27.72 m) and a capacity of six hundred or more *tonéis* (tons).

In analyzing the wreck's dimensions, we have considered the system of measure that was used in Portuguese shipyards during the 16th and 17th centuries. The system was based on the *palmo de vara* (22,0 cm), the *palmo de goa* (25,67 cm), the *goa* (77 cm) and the *rumo* (1,54 m). One *goa* equaled three *palmos de goa*, and one *rumo* equaled six *palmos de goa* or seven *palmos de vara*. Texts from the period also mention smaller measures, particularly the *polegada* (inch), the *dedo* (finger) and *grãos de cevada* (grains), although their precise value is unclear. Following the views of J. Barata and of H. Leitão and J. Lopes[3], I have considered the *polegada* as the difference between the *palmo de goa* and the *palmo de vara* (3,67 cm) and the *dedo* as 2/3 of a *polegada* (2,44 cm) or four *grãos de cevada* (0,61 cm each).

The *tonel* (ton) was a barrel measuring six *palmos de goa* in length (*H*) and four *palmos de goa* at its maximum diameter (2*r*), with an approximate capacity of 1 m^3. The cylindrical volume occupied by one *tonel* can thus be calculated as $H \times p \times r^2$, or $1{,}54 \times p \times 0{,}513^2 = 1{,}275\ m^3$. One *tonel* could be divided into smaller casks, namely two *pipas* or four *quartos*.

The cask equivalent is an important concept when we consider the way in which the Portuguese calculated the capacity of a ship in the 16th century. Their method was fairly accurate: a number of expert surveyors would board the ship and measure its cargo space by projecting cask hoops of appropriate diameters at every *rumo* of the ship's length, in order to determine how many *tonéis*, *pipas* and *quartos* would actually fit inside the hold.

The standard keel length of a *nau* designed for the *Carreira da Índia*, as proposed by Portuguese treatise writers of the 16th and 17th centuries, could be either 18 *rumos* according to Oliveira or 17 1/2 *rumos* according to Lavanha and Fernandez[4]. All three authors indicate very similar scantlings for these *naus da* Índia, whether of 17 or 18 *rumos* of keel. Moreover, their recommended measures are very close to the archaeological dimensions recorded *in situ* for the keel, floor timbers, futtocks, and planking of the wreck at São Julião da Barra. Our hypothesis that the this might be a *nau* of 17 or 18 *rumos* of keel is further supported by other features, less obvious in the first phase of the excavation, such as the risings of the floors as measured above the keel and the curvature of the (only) futtock that was recovered.

Several references to the tonnage of the *naus da Índia* are known. About a quarter of a century before the wreck of *Nossa Senhora dos Mártires*, Fernando Oliveira stated that "*(…) in the time of King Don Manuel and King Don João, his son, when the voyage to India began and flourished, it was entrusted to men of singular understanding and knowledge, who did not neglect the profit: (…) From that time until now, that voyage has always been made in ships of more than 500 tons, and some 800 and 1000: and these have always been the ones that make the best and safest voyages: for they cope with the sea better which, on that route, is great and requires large ships to dominate it.*" (p. 85, 164)[5].

Concerning the relation between ship's tonnage and keel length, Oliveira continues: *"(...) Therefore, when they ask or order that a ship of 600 tons be built, the carpenters know that a keel of 18* rumos *is required to reach that capacity, by calculations which we shall make further on"* (p. 86 and 165).

João Baptista Lavanha considered that as far as these Indiaman were concerned: *"(...) in the construction of a nau with four decks for cargo, of 17 ¹/₂* rumos *keel (which is the length most convenient for the size of* naus *of this burthen) there is more difficulty then in all the others"* (p. 34-35 and 148) (fl. 56).

Manoel Fernandez states about such vessels: *"In the first place it will have a keel of seventeen and a half to eighteen* rumos *from end to end, and, being seventeen and a half* rumos*, it will have one hundred and five* palmos *(...)"* (p. 23).

2.2. *The keel*

The surviving portion of the keel has a trapezoidal section with a maximum width of about 25 cm across the upper surface and a height estimated at 11 to 12 cm. The lower surface is about 16 cm in width, due to the inward angle of the lateral surfaces as they form the rabbets.

In the first phase of the archaeological work it was not possible to observe the keel's intact section at either the North or the South end of the piece. The keel's vertical thinness lead to presume the existence of a square or rectangular keel underneath this keel deadwood, as it may have been the case in the galleon *San Diego* lost in 1600 off the coast of Luzon in the Philippines[6]. In the subsequent excavation campaign of 1999, when it was recovered, we found it to be one full section. It was very eroded from gauging against the rocky bottom, and the only clue for its full dimension was a concretion that preserved the shape of one of its bolts. It was 47 cm long but we cannot say if it was pulled down after the keelson was smashed, and preserved in a longer length than the actual height of the keel (Fig. 3).

Concerning the keel section, João Baptista Lavanha is clear: *"They may be worked very well for a* palmo *in breath, and everything more than a* palmo *in height that will be able to get, because the rest of the* palmo *serves for a morticing that is carved in the said keel, called a rabbet (*alefriz*), where the first plank of the skin of the nau is lodged, which is called the garboard (*risbordo*), and the greater and the higher this rabbet can be, the better"* (p. 44 and 154) (fl. 62 v°). Oliveira is less clear on this point, suggesting that a keel should be heavier than the frames *"(...) just as the backbone or spine must be heavier than the ribs of the flanks"* (p. 116 and 197).

This keel is made up of several segments connected by vertical flat scarfs. The longest segment measures 3,16 m, including the scarfs at both ends. This length of about 2 *rumos* appears small when compared to the length of a keel of around 18 *rumos* (27,72 m).

The scarfs have lengths of between 70 and 75 cm, and strongly resemble those illustrated by João Baptista Lavanha in his *Livro Primeiro da Arquitectura Naval*.

TABLE I

Keel – Relative length of the scarfs

Timber	Estimated length of the south scarf	Length of the keel timber between scarfs	Estimated length of the north scarf	Percentage of the total length occupied by scarfs
1.1	34 cm	–	–	?
2.1	≈ 70 cm	176 cm	≈ 70 cm	≈ 44 %
3.1	≈ 70 cm	≈ 150 cm	≈ 70 cm	≈ 48 %
4.1	≈ 70 cm	157 cm	?	?

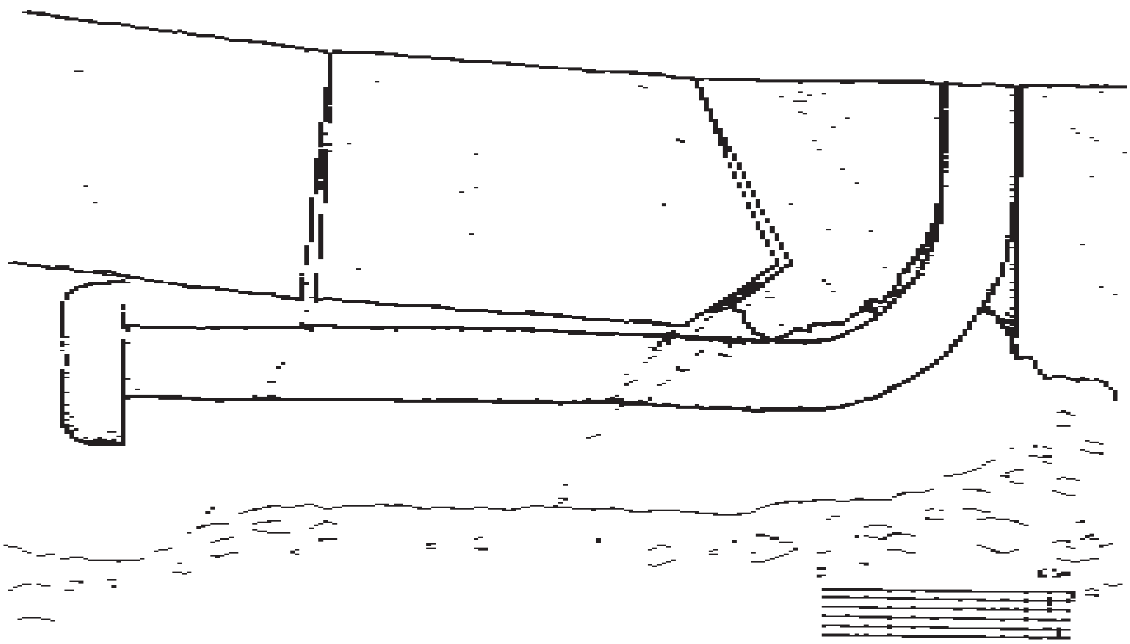

FIG. 3 – Presumed section of the keel of the SJB2 wreck.

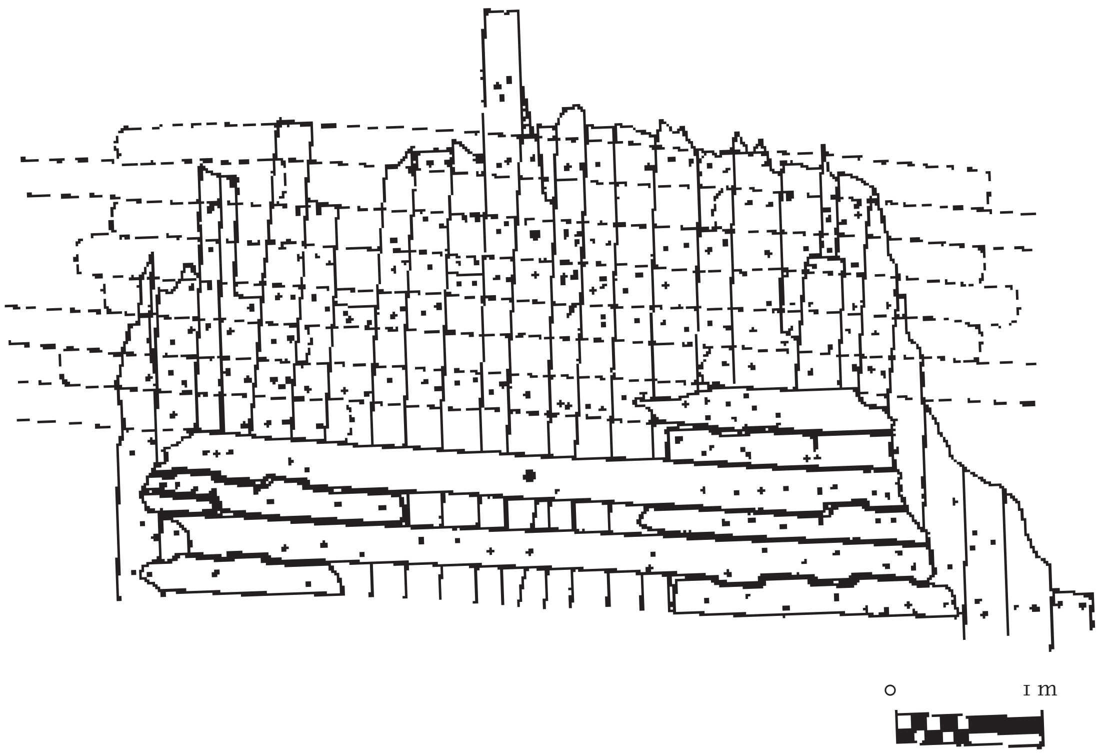

FIG. 4 – Presumed position of the master frames of the SJB2 wreck.

Table I shows that the successive scarfs, in connecting the relatively short keel segments, occupy nearly half the keel's total length. We can thus say that the length of the overlaps certainly ensured a solid link between keel segments.

Among the three Portuguese authors, only Lavanha is of the opinion that, even if one solid single timber can be found which has the right size and shape to fashion the keel as far as the stem and the stern post (the *couces*), the ship's "spine" should nevertheless be built with firmly connected pieces. *"(...) (E)ven 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"* (p. 44 and 154) (fl. 62 v°). It is clear that Lavanha did not prefer a scarf between the keel and the stem or the sternpost, and that these connections should be shaped out of curved or angled timbers, called *couces*. Lavanha continues: *"(...) and as the keel cannot be entire, and has to be in pieces, these are adjusted one with another with scarfs (...) and are fastened with bolts that go through the whole breath of the timber and they rivet the other part, on some iron washers, which method of fastening is called* anielados*, and in this way the whole keel will be made and will be joined with the said scarfs"* (p. 44 and 154) (fl. 62 v°).

Fernando Oliveira was in favor of using timbers as large as possible for the construction of keels which, *"(...) if possible, should be a single baulk: if not, the parts required to make it strong must be well joined and nailed together (...)"* (p. 90 and 169). The required timbers were certainly hard to find, both in Portugal and in Spain. This led King Philip I of Portugal (who was also Philip II of Spain) to issue legislation protecting long and straight trees[7]. But straight trees do not seem to have been the only problem. After describing the cork oak (*Q. suber*) as the wood best suited for shipbuilding, Fernando Oliveira writes: *"(...) this timber is so appropriate for the work and is necessary on this earth, and as, furthermore, we have no other that is equal for this use, it should be saved and the felling of cork-oak trees for charcoal or tanning bark, or any other purpose less necessary than our naval construction, should be proscribed"* (p. 63 and 141). We gain a good idea of the scarcity of suitable timbers for the shipping industry in these times from David Macaulay's character[8], a desperate shipwright who finds it truly amazing that Noah ever finished his ark in time for the Deluge.

2.3. Frames

2.3.1. General description

Eleven floor timbers were conserved on the keel (designated C1 to C11), fastened with iron spikes with square sections, measuring 1,8 to 2,0 cm to a side. Round holes with a diameter of around 4 cm were visible in some of the floor timbers, close to the square spikes, which probably represented bolts that clenched the keel and the keelson together by way of the floor timbers. No pattern has yet been found for the placement of these round bolts.

All the futtocks were linked to the southern side of their respective floor timbers. To the north of the preserved frames, the hull planking contained nail holes that revealed the placement of four other floor timbers, not preserved (which would correspond to floor timbers C12, C13, C14 and C15). The first three of these unpreserved floor timbers were juxtaposed without any spaces in between them (Fig. 4). In the space between the unpreserved floor timbers C14 and C15, nail holes were visible toward both the port and starboard, presumably corresponding to the futtocks of floor timber C14.

The floor timbers and futtocks were united by a double square (dovetail-like) mortise-and-tenon joint and were firmly fastened with three to four iron spikes (Fig. 5). Like those which connected the floor timbers and the keel, these spikes had square shanks with sides of 1,8 to 2,0 cm. The imprint of their squarish heads with rounded corners appeared in the wood of the floor timbers, within a circular countersink about 1 to 2 cm deep and 5 to 6 cm in diameter. On the face of the futtocks, the spikes' leading points were double-clenched and embedded in grooves.

Lavanha discusses the execution of these joints: *"(...) all the eleven floors of account are joined with their* braços *[futtocks] on the ground (...) with great care, and have to come one on another very precisely, and account has to be taken only of these lines of the wrongheads [the surmarks] in the joining together of the floors with the* braços*, and in some, and in others, mortises are made, with which they are adjusted"*[9] (p. 55 and 161) (fl. 70). There is no mention to the shape of the joints, whether dovetail or square.

Due to the degraded state of the upper face of the floor timbers and futtocks, and the wide variation in the depth and extension of the tenons, it is difficult at this early phase to determine in some cases whether the mortise-and-tenon morphology is truly double or whether the tenons are found only on the futtocks and not on the floor timbers. We recorded one filler piece (A4), which extended floor timber C4 to the east, between futtocks B5E and B4E.

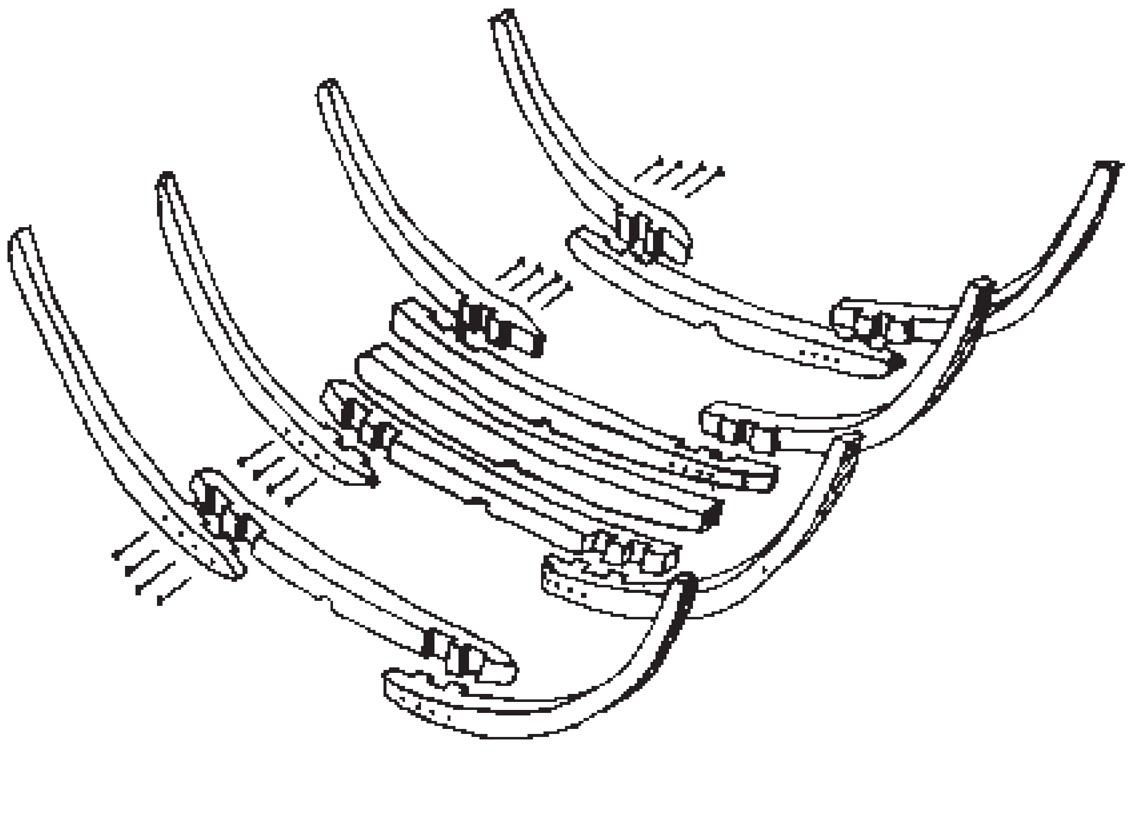

FIG. 5 – Presumable position of the master frames of the SJB2 wreck.

2.3.2. Dimensions

As measured *in situ*, the sided dimensions of the floor timbers, futtocks and room-and-spaces (*pares*) varied widely, depending on the position along the timber at which the measures were taken. This may be explained by the natural irregularity of the wood and the possible distortion of the hull during and after the shipwreck, as a result of the process of the collapsing of the sides. Illustrating the irregular shape of the trees that were employed, the upper face of futtock B3E contained a zone in which the natural, rounded surface of the tree still bore its cork bark. Lavanha, as shown in these archaeological remains, also confirms the use of irregularly shaped and inadequate timbers in shipbuilding. He explains in detail how to trace the outline of the floors on the timbers from a mould, or pre-designed wooden template with the form of a half floor. When the inadequate section of the timber does not allow the mould to touch all the perimeter to be drawn, he recommends the use of a prismatic weight: *"And when on the frames of the said timbers there may be wany edges (which often happens) (...) a small stick may be used, with four faces, ending in a point, called in this Art* chincho, *hung along the template (...)"* (p. 42 and 153) (fl. 61 v°).

The sided dimension of the floor timbers, as measured *in situ*, was very close to one *palmo de goa* (25,67 cm). The average measure was 24,6 cm, roughly 4% shorter than the *palmo de goa*, and the median measure is 25 cm (less than 3% shorter). On this Oliveira comments: "*In large vessels, especially if they are merchant ships with long voyages to be made, to India, the frames must be strong, both to sustain the body of the ship itself and the weight of its cargo, and also to stand up to the work of the voyage. These timbers are usually made one goa palm square, that is with one palmo to each face (...)"* (p. 116 and 197). Lavanha confirms this measure: *"(...) one* palmo *for the thickness of the timbers (...)"* (p. 3 8 and 150) (fl. 58 v°).

TABLE II

Frames. Size (room) of the floors timbers, space between floor timbers, room-and-space

Timber	Sided dimension (room)	Dist. between frames	Room-and-space	Centre-to-centre frame interval
C11	26 cm	20 cm	46 cm	45,5 cm
C10	25 cm	24 cm	49 cm	47,5 cm
C9	22 cm	22 cm	44 cm	45,5 cm
C8	25 cm	20 cm	45 cm	45,5 cm
C7	26 cm	24 cm	50 cm	50 cm
C6	26 cm	23 cm	49 cm	48 cm
C5	24 cm	23 cm	47 cm	47,5 cm
C4	25 cm	18 cm	43 cm	42,5 cm
C3	24 cm	20 cm	44 cm	44,5 cm
C2	25 cm	20 cm	45 cm	44.5 cm
C1	24 cm	–	–	–

Another result of the uneven shape of the floor timbers is the variable length of the overlap between floor timbers and futtocks. Neither the mortise-and-tenon joints nor the fore-and-aft spikes seem to have been exactly positioned relative to the location of the turn of the bilge (*couvado*).

TABLE III

Floor timbers. Lengths (West and East of the keel's central axis). Moulded dimension (above the keel's central axis).

Floor	Timber's length to axis (West)	Distance to the dovetail mortise (West)	Timber´s preserved height (moulded dim. at the axis	Distance to the dovetail mortise (East)	Timber's length to axis (East)
C11	–	–	–	129 cm	155 cm
C10	223 cm	130 cm	31 cm	180 cm	231 cm
C9	224 cm	153 cm	25 cm	144 cm	246 cm
C8	228 cm	127 cm	27 cm	139 cm	264 cm
C7	225 cm	Not visible	36 cm	165 cm*	108+170 cm*
C6	206 cm	132 cm	31 cm	140 cm*	152+134 cm*
C5	206 cm	145 cm	35 cm	148 cm*	119+120 cm*
C4	197 cm	129 cm	37 cm	164 cm*	205+88 cm*
C3	188 cm	115 cm	39 cm	150 cm*	148+112 cm*
C2	175 cm	98 cm	42 cm	163 cm*	165+77 cm*
C1	150 cm	97 cm	46 cm	-	89 cm

* broken; the estimated distance between the ruptured surfaces has been discounted

2.3.3 Construction marks

Some of the floor timbers had carpenters' marks engraved on the northern faces, west of the keel's axis, presumably facing the master frame(s) and on the starboard side. These marks were observed in two types, consisting respectively of vertical lines and Roman numerals.

The vertical lines were positioned at the keel's central axis and at one or both of the edges of the keel. On floor timber C10, marks indicating the keel's axis and one of its edges were visible and on floor timber C9, the axis and both edges of the keel were marked. Lavanha indicates that marking the timbers was a routine part in the construction of the pre-assembled frames: *"(...) then the straight line MS, the middle of the floor, may be marked with a scribe* (escopro)*, and two others on each edge of the rising square* (astilha)*, set off from MS half a palmo each side, which make the breath of the keel, and thus with the same* escopro *the straight line OP of the wronghead may be marked too (...)"* (p. 52 and 159) (fl. 68 v°). These second marks at the wronghead ("OP"), certainly much more important for our understanding of the hull's architectural conception, were not observed in this phase of the excavation.[10]

The second type of mark, consisting of Roman numerals, was found on five of the eleven floor timbers. The numeral III appears on floor timber C9, IIII on C8, V on C7, what may be a VIIII on C3 and X on C2. The numerals thus rise in order from north to south, forming a sequence according to which the numeral I would correspond to floor timber C11. This sequence points to the unpreserved floor timbers C12, C13 and C14 which lay edge-to-edge and were located immediately north of the surviving frames, as the master floor timbers, in which case we may suppose that these three floor timbers were not numbered.

Lavanha explains the necessity of numbering the floor timbers during construction: *"And at each floor with the same* escopro *its number may be marked on it, first, second or third, etc, whatever it may be, so that it may be known where it has to be set, and what its place is"* (p. 53 and 160) (fl. 69).

TABLE IV

Floor timbers. Carpenter's marks

Floor	Mark
C9	Roman numeral III
C8	Roman numeral IIII
C7	Roman numeral V (inverted)
C3	Roman numeral VIIII (incomplete)
C2	Roman numeral X

The finding that the numeral V on floor timber C7 was oriented in an upside-down position suggests that the other marks may actually also be inverted, although the composition of these numerals does not vary according to their orientation. In fact, the numerals are also inverted in other archaeological examples, such as the Culip VI[11], Ria de Aveiro A[12] wreck and Cais do Sodré[13] shipwrecks.

TABLE V

Carpenter's marks. Comparison of known parallels

Name of the ship	Preserved marks	Master frame	Position
N.ª S.ª Mártires (1606)	2 types:	probably 3 master frames	On the side facing the master frames
	1) numbering the floor timbers, numerals III, IIII, V, VIIII(?), X	probably not numbered	On the starboard side At least one inverted
	2) vertical lines marking the keel, on floor timbers III and IIII	not preserved	On the side facing the master floor
Cais do Sodré (late 15th C.)	2 types:	not preserved	On the side facing the master frame
	1) numbering the floor timbers, numerals XVI, XVII and XVIII to the bow and a sequence from IIII to XVIII to the stern		Both port and starboard ends Both inverted and upright
	2) marking the keel, vertical lines on almost all 18 numbered floor timbers (fore and aft) and on some unnumbered floor timbers	not preserved	On the side facing the master frame
Ria de Aveiro A (middle 15th C.)	Numerals of the first type, on floor timbers V, XII and XV aft	1 master frame numbered 1	Numeral V facing away from the master frame (to the stern), XII on the timber's upper face, XV facing the master frame Numerals V and XV on starboard side, XII on port side Numerals V and XV inverted
Culip VI (early 14th C.)	Numerals of the first type on the floor timbers: I to X aft, I to XXVI forward	2 master frames both numbered I	Facing the master frame On port side to the bow and on starboard side to the stern (away from the master frame) Inverted

The hypothesis that this *nau* had three master frames (Fig. 5) appears to substantiate Fernando Oliveira's comment: *"Those (floor timbers) that are flat (on the* plão*) before the scrivings begin to rise are called main floors. In small ships of less than eleven* rumos *there should not be more than a single main floor: and two in ships of fifteen to eighteen* rumos*: and three above that, but no more, no matter what size of the ship is (...)"* (p. 94 and 174).

However, we must dismiss the hypothesis that the three timbers indicated only by nail holes in the hull planks correspond to a single master floor timber reinforced on either side by a *entremicha*, or filling piece. If such were the case, we should have observed the imprints of a continuous floor of five timbers on the hull planks for, according to Lavanha, *"(...) the master frame (...) set with its* entremichas *on one side and the other, attached with those of both sides, another two frames, which are the five of account may be set: and then the rest are to be placed, leaving as much space between one and another as is the breath of each of the said floors, which is said to be one palmo: and all are squared; and fastened on the keel, and their props are put on them, so that they may always be in their position, and open what may be necessary, and no more"* (p. 57 and 163) (fl. 72).

2.3.4 Details

The floor timbers and futtocks recovered during this first excavation season (floor timbers C2 and C3 and their respective futtocks) showed four construction details of great interest that may be mentioned, and will be fully analysed at a later phase.

Firstly, we may note the marks of double-clenched nails on the upper face of the floor timbers. Nevertheless, Oliveira advises against the use of nails that completely traverse the timbers: *"For thick wood, long and thick nails are required, so that they almost go right through the timber: and in some parts go beyond*[14]*: and the longer they are, the thicker they must be: for length weakens the heads and the stems, in iron just as in wood (...)"* (p. 117 and 197). Thus, there seems to have been a need to clench some of the nails used to fix the hull planks to the floor timbers, prior to the installation of the ceiling planks.

The second detail concerns the shape of the limber holes which have a semi-elliptical form, 7 to 8 cm wide and 5 cm high. They seem very small and they were cut with a curved blade less than 1 cm wide (akin to a gouge) in an apparently very labour-intensive way. Other limber holes known from this period were usually cut with adzes or axes, sometimes after the lateral faces were cut with a saw[15].

Thirdly, we note the wooden pegs that plug unused iron-nail holes in the lower face of floor timber C3. This practice is recommended by Oliveira who refers to the extreme care that must be taken with the caulking: *"Even the nail holes must be looked for, to see that they are filled with their nails: for it happens that holes are bored without having nails put in them: and therefore, when checking, attention must be paid to everything"* (p. 119-200).

The fourth detail is the existence of a piece added to the lower surface of futtock B3E. This piece, with a length of 95 cm and a maximum thickness of 7, was nailed in a concave area in the timber's lower surface in order to give the futtock its desired curvature.

2.3.5. Graminhos

The *graminho*, an important element in designing a hull, is defined by Oliveira: *"(...) our carpenters call* graminho *(...) the distribution of increments by which the bottom, and the waist and the beam, of the ship are raised and narrowed. Which distribution is marked on a board, following the art that is indicated now. This art results in the making of an instrument which is also called* graminho*: for it indicates the apportionment by lines of certain fractions of the* compartida *(or length that is divided)"* (p. 95, 174).

Although a pronounced dead rising was visible in this hull, the upper face of the floor timbers was fairly horizontal in their central sections. This observation leads us to compare the measures obtained *in situ* for the moulded dimension of the floor timbers above the keel's central, with the theoretical values obtained from Oliveira's treatise. Thus, we shall consider the floor of a *nau* of 18 *rumos* of keel and, therefore, with 18 pre-designed frames (*madeiras da conta*) forward and aft of a set of three perfectly flat master frames. The *graminho* was calculated according to the *besta* method, an equivalent to the *mezzaluna* mentioned in Italian texts, and the total deadrise (*compartida*) was adopted following Oliveira's rule: *Each of the scales related to the rise of the bottom has its own* compartida*: one for the stern and another for the bow, and they are different: one more and the other less: that of the stern more, and of the bow less (Y) The after scale usually rises one twelfth part of the length which, with eighteen pairs, gives us one "pair and a half": and the one for the bow rises one half or one third less, resulting in almost a single "pair"* (p. 96 and 175; a "pair" (*par*) is the measure of one room-and-space).

The value of each of the 18 bow and stern *graminhos* was calculated with the *besta* method, considering for the *par* value the average of the room-and-space in the preserved frames, which is 46,2 cm. The results are presented in Table VI below. Even though the results obtained in this preliminary and still initial stage of the analysis showed great interest, they should be noted with great reserve.

TABLE VI

Graminhos after Oliveira – Measures for *compartidas* of 1 *par* and 1 $^1/_2$ *pares*

Frame	Besta –1 par (cm)	Besta – 1 $^1/_2$ pares (cm)	*N.ª S.ª Mártires (cm)*
I	25,84	25,93	–
II	26,37	26,72	31
III	27,24	28,03	25
IIII	28,45	29,85	27
V	30,00	32,16	36
VI	31,86	34,95	31
VII	34,02	38,20	35
VIII	36,48	41,88	37
VIIII	39,20	45,96	39
X	42,17	50,42	42
XI	45,37	55,22	46
XII	48,77	60,32	–
XIII	52,34	65,68	–
XIIII	56,07	71,27	–
XV	59,91	77,03	–
XVI	63,84	82,93	–
XVII	67,84	88,93	–
XVIII	71,87	94,97	

These values are graphically presented in Fig. 6. Based on the remarkable coincidence between the theoretic values for the bow *graminho* and the values obtained *in situ*, it seems possible to consider the hypothesis that the fragment of the hull under study is a part of the zone immediately forward of the master frames. We note, however, that this hypothesis remains to be carefully verified in a later phase of the project.

About 30 years after Oliveira, João Baptista Lavanha described a much simpler way of designing the floor of a ship of 17 $^1/_2$ *rumos*, according to which only five floor timbers were pre-designed on each side of a single main frame that was, in this case, not flat, but slightly

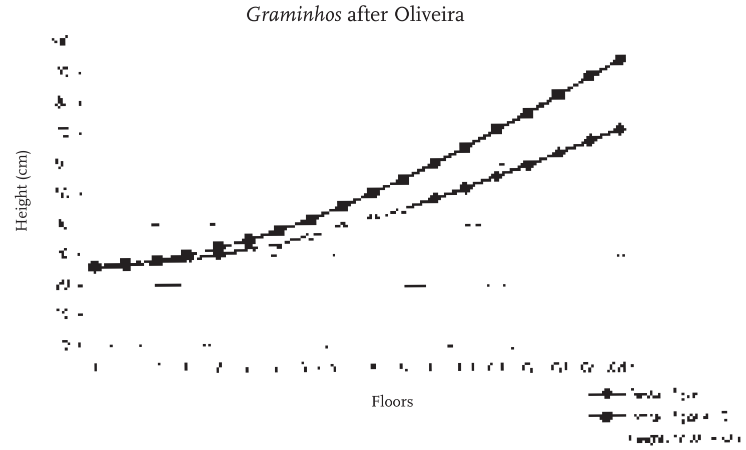

FIG. 6 – Theoretic molded dimensions for the bow and stern pre-designed floors for a nau of 18 *rumos* of keel after Oliveira and correspondent heights measured *in situ*.

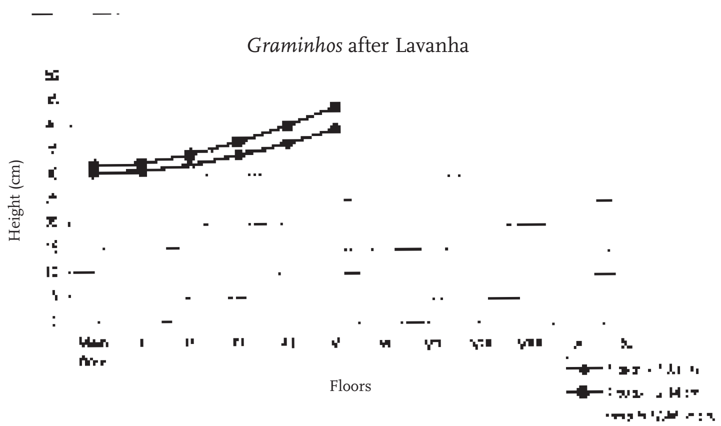

FIG. 7 – *Graminhos* after Lavanha. Measures for a main floor *pé* of 2 *dedos* and *compartidas* of 5 *dedos* (bow and stern) [cm].

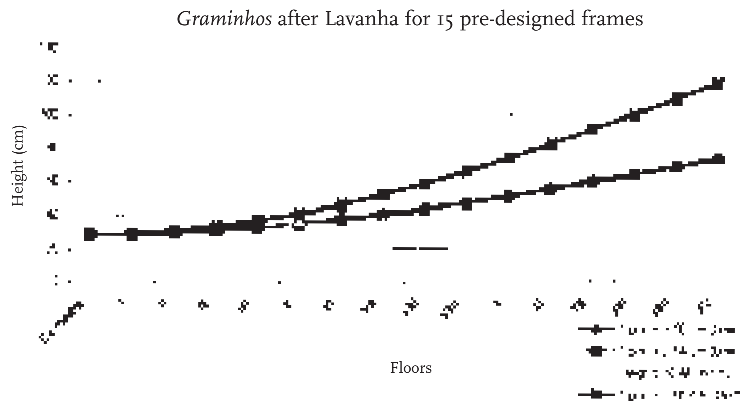

FIG. 8 – *Graminhos* for 15 pre-designed frames (after Lavanha). Measures for a main floor *pé* of 1 *polegada*, and *compartidas* of 2 *palmos de vara* (bow) and 3 *palmos de goa* (stern) [cm].

V-shaped. Lavanha also described a mould used to produce a hull with fifteen pre-designed floor timbers on each side of the master frame, apparently no longer in use at the time he wrote[16].

In the first case the main floor timber had a foot (*pé*) of 2 ¹/₂ *dedos*, and a *compartida* of 5 *dedos*. In the second case, the *pé* was 1 *polegada* (although it is not specified whether it was a *polegada de vara* or a *polegada de goa*) and the *compartida*, 2 *palmos de vara* for the bow and 3 ¹/₂ *palmos de goa* for the stern.

The values obtained by these two methods are given in Tables VII and VIII, and graphically presented in Figs. 7 and 8 (as mentioned, we have considered one *polegada* as 3,6 cm, and one *dedo* as 2,4 cm) Even when other than these values were tested, the curves obtained are always much steeper than that curve obtained from the values measured *in situ*.

TABLE VII

Graminhos after Lavanha – Measures for a main floor *pé* of 2 *dedos* and *compartidas* of 5 *dedos* (bow and stern) [measures in cm]

Pre-designed floor timbers	*Graminhos* 1 dedo = 1,38 cm	*Graminhos* 1 dedo = 1,83 cm	*Graminhos* 1 dedo = 2,44 cm	Heights (*in situ*)
Main floor	29,7	30,2	31,7	–
I	29,4	30,6	32,3	–
II	30,4	31,9	34,0	31
III	31,9	33,9	36,7	25
IIII	33,8	36,5	40,1	27
V	36,0	39,3	43,9	36
				31
				35
				37
				39
				42
				46

TABLE VIII

Graminhos for 15 pre-designed frames (after Lavanha) – Measures for a main floor timber *pé* of 1 polegada, and *compartidas* of 2 *palmos de vara* (bow) and 3 *palmos de goa* (stern) [measures in cm]

Pre-designed floor timbers	*Graminhos* (bow) 1 pol. = 3,66 cm	*Graminhos* (bow) 1 pol. = 2,75 cm	*Graminhos* (stern) 1 pol. = 3,66 cm	*Graminhos* (stern) 1 pol. = 2,75 cm	Alturas NSM (*in situ*)
Main floor	29,3	28,4	29,3	28,4	
I	29,5	28,6	29,8	28,8	
II	30,2	29,3	31,2	30,3	31
III	31,4	30,5	33,6	32,7	25
IIII	33,1	32,2	37,0	36,1	27
V	35,2	34,2	41,3	40,4	36
VI	37,7	36,8	46,4	45,5	31
VII	40,6	39,7	52,3	51,4	35
VIII	43,8	42,9	58,9	58,0	37
VIIII	47,4	46,5	66,2	65,3	39
X	51,3	50,4	74,1	73,2	42
XI	55,4	54,5	82,4	81,5	46
XII	59,7	58,8	91,2	90,3	
XIII	64,1	63,2	100,2	99,3	
XIIII	68,7	67,8	109,5	108,6	
XV	73,3	72,4	118,9	118,0	

2.4. *Planking*

The hull planking was 11 cm thick, one of the highest values found for Iberian ships from the early modern period (see Table IX), being surpassed only by the value of 12,5 cm shown in the scantlings illustrated by Manoel Fernandez in his *Livro das Traças de Carpintaria* for the bottom planking of an Indiaman.

TABLE IX

Planking. Thickness in Iberian ships[17]

Ship	Capacity or overall length (estimated)	Plank thickness	Date
Western Ledge Reef wreck	= 20 m	3,5 cm	Late 16th C.
Corpo Santo ship	=12,32 (8 rumos?)	4 cm	Late 14th C.
Ria de Aveiro A wreck	=12,32 (8 rumos)	5 cm	Middle 15th C.
Molasses Reef wreck	= 20 m	4,5 cm	Early 16th C.
Fuxa wreck (*N.ª S.ª del Rosario*)	= 26 m (300 t.)	5 cm	Early 17th C.
Emanuel Point wreck	= 30 m (?)	5/8 cm	presum. 1559
Angra D wreck	= 40 m	5/8 cm	Late 16th C.
Highborn Cay wreck	= 20 m (?)	6 cm	1st half 16th C.
Studland Bay wreck	= 33 m (150-200 t.)	6 cm*	Early 16th C.
San Juan	= 22 m	6 cm	1565
Cattewater wreck	= 30 m (?)	6/7 cm	1st half 16th C.
San Diego	= 40 m	6,5/7 cm	1600
Cais do Sodré ship	= 40 m (18 rumos?)	7 cm	Late 15th C.
Rye A ship	= 200-300 t.	7,6 cm	Middle 16th C.
Green Cabin Wreck (*San Martin*)	= 200 t.	8,5/9 cm**	1618
Seychelles wreck***	= 30 m (?)	9 cm	Late 16th C.
San Esteban	= 20 / 21 m	10 cm	1554
Nuestra Senora de Atocha	= 550 t.	10 cm**	1622
N.ª S.ª Mártires	= 40 m (18 rumos?)	11 cm	1606

* Pers. comm. Mikkel H. Thomsen.
** Pers. comm. David Moore.
*** The Portuguese wreck of the Seychelles may be the nau *S.^{to} António*, lost in 1589 on its way to India, as was recently pointed out to us by Patrick Lizé.

Both Oliveira and Lavanha recommend thick or double planking for these vessels, mentioning that the vessels for the India route had usually double hulls. However, we do not know of any archaeological evidence of double planking in an Iberian ship, whether excavated or salvaged. Oliveira supported the practice of placing a second layer of planking over the first, in alluding to galagala, a caulking paste made of oil and chalk and recommended that the hull planks of warships and vessels destined for intercontinental trips should be thicker than four "*dedos* (9,8 cm): *This side or planking must also have a thickness in accordance with the size of the ship and the work it must do, and the voyages it must make: and for large ships and those that must voyage far in rough seas, and those that are to serve in war, there must be sides of heavy planking, doubled if necessary. I say doubled, as it has become usual in ships on the India run, over the galagala anti-*

fouling" (p. 117, 198). As to the thickness of a single planking, Oliveira states: *"The thickness of the side planking itself will, in large and strong ships, not be less than four* dedos*, especially if the wood is soft and light, like pine, cedar or larch: for wood like* angelim *and other hard and heavy woods can be made less thick: but not less than three* dedos*"* (p. 118, 198).

The planking is generally fixed to each floor timber with two square-shanked nails, whose 1,8 to 2,0 cm section is similar to those fastening the floor timbers to the futtocks, and the frames to the keel. At the ends of the planks, square nails about 2,5 cm in section were sometimes used, although no clear distributional pattern for the use of these nails has yet been observed.

2.5 Fastenings

All the fasteners are made of iron, as advised by Lavanha and Oliveira for ships of this size. Similarly, all timbers had nail holes of various dimensions, the majority square in section. Head impressions, visible in the countersinks, were squarish with rounded corners.

As mentioned, some of the floor timbers also had round holes, presumably where bolts had linked the keel to the keelson. These round holes were also found in the presumed apron timber. While no distributional pattern for these bolts has been found, it is possible to state that:

a) they do not occur in all the frame timbers;

b) they do not occur in floor timbers situated at a keel scarf;

c) they always occur in the floor timbers situated before and abaft each keel scarf.

From the analysis of the fastening holes it seems, on one hand, that were all previously bored with an auger and, on the other hand, that the spikes had a thicker section close to their heads.

TABLE X

Fastenings – Types of spikes and bolts found

Links	Sections	Heads	Counter sinks
Planking to frames	□ = 1,6 a 1,8 cm	□ = 4,0 cm, w/ round corners	Ø = 5 cm 1,2 cm deep
	□ = 2,0 a 2,5 cm	□ = 5,0 cm, w/ round corners	Ø = 7,5 cm 2,0 cm deep
Floors to futtocks	□ = 2,0 cm	□ = 3,5 a 4,0 cm, w/ round corners	Ø = 6 cm 2,0 cm deep
Floor to keel	□ = 1,8 a 2,0 cm	?	?
Keel to keelson (?)	Ø = 4,0 cm	?	?
Apron to Keelson (?)	Ø = 3,5 / 4,0 cm	?	?

These values will be verified after the excavation season of the year 2000.

On the absence of wooden fasteners, Oliveira does not categorically advise against their use, stating simply that *"(...) although they are not as unyielding as iron, they last just as long as any other wood they are hammered into and do not rot with dampness, nor do they create rust (...)"* (p. 73 and 151). However, he does indicated that they are more appropriate for small ships since for larger vessels, treenails are required in greater numbers and of larger dimensions: *"(...) they must be made of hard and proven wood that does not twist, such as well cured chestnut:*

and they must be thicker than iron nails, and more full: but not excessively so, in order that the wood might not be holed too much and weakened. Treenails are used more frequently in small vessels, because large ones have thick timbers that require long fastenings and the wooden pins cannot do so" (p. 73, 151).

Lavanha, however, clearly prefers iron nails: *"The fastening customary among us is iron (...)"* (p. 33, 146) (fl. 53 v°). In his opinion, wooden nails endanger a hull's water tightness, since teredo worms eat in the direction of the wooden grain, following the treenail: *"To remedy then the injury which this worm causes, it is fitting that the fastenings may not be of wood, but of iron, and well tempered strength, and well-made; because the teredo (*busano*) entering through the planking of the ship, and burrowing along the grain, will not meet wooden dowels, through which it may pass, but hard iron, which its teeth may not gnaw"* (p. 34 and 147) (fl. 54 v°).

2.6 The caulking

The caulking was performed with great care. Lead straps 5 to 9 mm thick were placed at the joints between hull planks during or after construction (including at the hood ends) and the joints were filled with a fibrous material such as oakum (hemp), inserted from the outside (Fig. 9). The seams were then protected with long and narrow lead sheets, generally nailed along their central axis with a single line of square iron tacks, 4 mm in section with round heads around 27 mm in diameter, and spaced at intervals of 4 to 8 cm. Lead sheets nailed on both sides of the seams were also found, mostly between the strakes near the keel. Repairs may also have been performed, for lead sheets of square or rectangular shape were found on the site, pierced along their perimeters with the same 4 mm square holes, spaced from 4 to 8 cm.

These lead straps (Fig. 10) and sheets (Fig. 11) are the most abundant type of remains in the whole wreck area. The square and rectangular sheets, less abundant, have very different dimensions, the smallest example measuring 12 by 13,5 cm and the largest 40,5 by 23 cm. The long, narrow sheets have widths varying between 2 and 8 cm (usually greater than 3,5 to 4 cm) and have lengths up to 1 m. All these sheets are between 1 and 2 mm thick.

Fernando Oliveira considers caulking a delicate operation, of great responsibility: *"(...) the caulkers are obliged to check all the seams and parts of the ship where water can penetrate or seep in, and must caulk them all with oakum and pay them with pitch, so that no humors can pass between them, neither less, nor more, (...). They must caulk once or twice, and as many times as are necessary until the seams can take no more, filling them with blows of a caulking hammer and clean oakum, not rotten stuff. They must also test the planks with a chisel to see whether they are rotten or not: and they shall have the bad ones removed and replaced (...)"* (p. 119, 199-200). He adds: *"After going over the whole hull, its surface is burnt, not more than what would soften the pitch, so that it does not escape and detach itself from the smooth planking: over this scorching a coat of pitch is given, (...). And the seams will immediately be tamped down once more with the caulking iron and light mallet, to see whether any are left to caulk, or fire has burnt the oakum excessively, any needs to have new caulking put in its place: then everything is tarred once more, completely."* (p. 119, 200). Finally he mentions the use of lead sheeting: *"Over the pitch and the oakum, and covering the seams or cracks of ships that make long voyages, it is customary to nail lead plates, to protect them from the beating of the sea"* (p. 119, 200).

Lavanha is very laconic on the subject of caulking, perhaps because his manuscript is incomplete. He alludes only to caulking materials, where he includes lead without, however, specifying whether straps or sheets are to be used: *"The other materials for shipbuilding are as we have said nails, linen, tow, tar, pitch, grease and lead (...)"* (p. 32, 146) (fl. 53 v°).

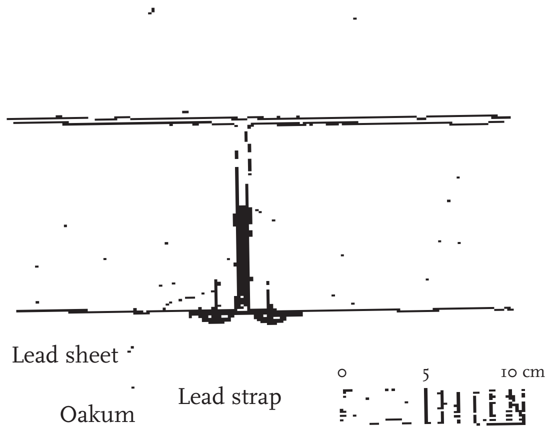

FIG. 9 – Section of the planking, showing the lead straps and oakum in the seams, and the lead sheets nailed over them.

FIG. 10 – The lead straps.

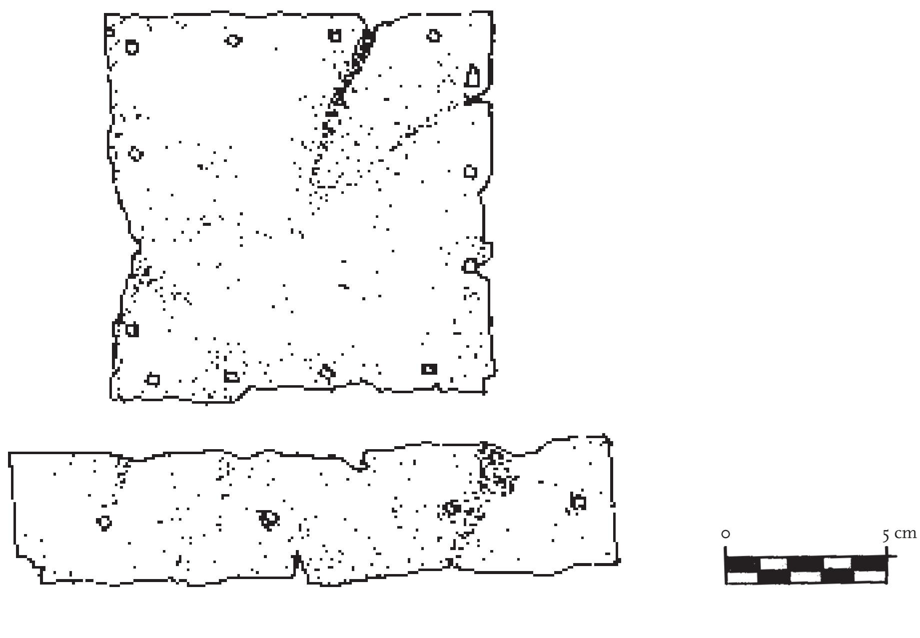

FIG. 11 – The lead sheets.

2.7 Wood species

The keel, apron(?) and frames were of cork oak (*Quercus suber*) and the planks of umbrella pine (*Pinus pinea*), just as Oliveira and Lavanha recommend. In their books they further elaborate on the virtues of these two species.

Oliveira writes: *"In this, our land, there are two kinds of woods that are appropriated for these two parts of ships, respectively: they are the woods of cork-oak and of pine. The cork-oak for the frames and the pine for the planking."* (p. 63, 140). Referring to the cork oak, he says: *"(...) the cork-oak is very hard and does not rot in water, but freshens, rather, and is revigorated: for its is naturally dry and is preserved by humidity. In addition to this, its branches are twisted and the crooks have forms that are suitably shaped for bow and stern timbers, and knees, and other parts of this assemblage, being of such shapes that they seem, without any alteration, to have been born for this."* (p. 63, 141). About pine wood: *"For planking, we use pine, because it is flexible and close grained, free of fissures and does not crack: furthermore, its sap is resinous and resists the humour of water, which does not penetrate it, And it is also contrary to the shipworm: which it does not create in itself, nor admits from the outside: Vitruvius says that this wood becomes bitter and will not consent the penetration of the shipworm, nor support it. The pine of which he speaks is the stone pine, which provides the seeds that we eat: and by this, we must understand that it is good for the planking of ships, contrary to the cluster pine, which has long cones without seeds of any use: because the wood of this cluster pine is dry and without the resin that resists the humour of the water: which penetrates it and causes it to rot: this why it is useless except for upper works which are situated above the water"* (p. 64).

Lavanha's text concurs almost point for point: *"(...) for the great naus of our long navigations (...) the Cork-Oak, for the skeleton, and (...) the Stone Pine (*pinho manso*) for the planking, The Cork-Oak is very hard, dry, on account of its density exterior humours do not enter it, it does not nurture dry rot (*caruncho*), nor rot in water, before it is conserved in that with dampness, and made green again, and besides all these qualities, so conformable to what is needed, it has another, no less important, which is the tortuosity of its branches, curved in such a way that it appears to have been created for this Art. (...) Stone Pine serves for that, whose timber is pliable, as such can be bent, and accommodate all the turns of the side of a nau, which the skeleton makes. And it has one more perfection, that its resin resists greatly the dampness of the water, and being bitter, the teredo (*bicho*) does not enter into it"* (p. 26-7 and 141) (fl. 48-48 v°).

2.8. Stone remains

No evidence of ballast was found on the site of the presumed *Nossa Senhora dos Mártires*. However, a group of stone pieces found close to the hull might be mentioned here, because of its weight and possible connection with the shipwreck under study:

a) a grinding stone with a diameter of 83 cm;

b) three long stones with roughly rectangular shapes, each about 10 cm thick but of varying width and length: 13 by 79 cm; 22 by 110 cm; 15 by 119 cm;

c) a stone that may be an anchor stock (reused or not) about 1,5 m long.

It must be mentioned that the hull remains lie on a thick layer of round shingle of small dimensions (about 5 to 15 cm), most of an Eocene basalt that is characteristic of the Lisbon region. This rock appears in the northern Tagus shore and has been used as ballast in other ships, although generally in larger sizes.[18]

2.9 Conclusion

After the first season of work on this site, many more questions than answers remain. Further excavations to be undertaken (a campaign is planned for the summer of 1999) in this area will certainly produce material of great interest for the study and understanding of construction techniques of the ships for the India route during the early modern period.

At this time, we can only state that this wreck, identified with reasonable certainty as the *Nossa Senhora dos Mártires*, contains a set of features that match the construction techniques described by Portuguese writers in the late 16th century. The paucity of archaeological information from this period makes this wreck a precious object for the understanding of the specific characteristics of Portuguese shipbuilding, of which so little is known and so much has been written.

NOTES

1 The preliminary report was published in 1998. See Alves et al., 1998.

2 These three works are available with transcriptions and translations into English.

3 Barata, 1989; Leitão and Lopes, 1990.

4 In fact, we see this dimensions increase drastically shortly after, as shown in the discussions over the qualities and disadvantages posed by the three and four decks ships, in the 1620s. See Barcelos, 1898-1899.

5 All the quotations from Oliveira and Lavanha follow the translations indicated in the bibliography with the page(s) of the Portuguese version followed by the page(s) of the English version. The other authors quoted have the only page of the Portuguese original text, since I have translated them myself.

6 The description of the *San Diego* keel is far from clear. L'Hour, 1994, p. 118-153.

7 See Casado Soto, 1988.

8 Macaulay, D., 1995.

9 In the original we read: *"(...) E em umas [*cavernas*] e em outros [*braços*] se fazem umas emmoçaduras com que se aJuntão"*. Therefore I think it is more correct to translate *"(...) and <u>in ones</u> [*the floors*], and <u>in others</u> [*the futtocks*], mortises are made, with which they are ajusted.* The original meaning of the phrase is that mortises are cut in all the pre-designed floors and their respective futtocks.

10 The wrongheads or *couvados* are the points in which the pre-designed frames join the circular arcs of the futtocks, being therefore vital for the elaboration of any model.

11 See Nieto Prieto et al., 1989; Rieth, 1996.

12 See Alves, 1998a.

13 See Rodrigues, 1998.

14 In the original we read: *"(...) que atrauesse quasi toda a madeyra: & em partes algUnas passe alem (...)"*. This would perhaps be better translated as *"(...) go right through the timber: and in any parts go beyond (...)"*.

15 As the Cais do Sodré and Ria de Aveiro A wrecks, for example.

16 This is the way in which the naos of Sebastião Themudo and Gonçalo Ruiz were designed in the late 1590s. See Barata, 1989.

17 The information in this table was taken from: Western Ledge Reef *wreck* - Watts (1993); Corpo Santo ship - Alves, 1998b; Ria de Aveiro A wreck - Alves, 1998a; Molasses Reef wreck - Oertling, 1989a; *Nuestra Señora del Rosario* - López Pérez and Alonso Sanson, 1993; Emanuel Point wreck - Smith et al., 1995; Angra D wreck - Garcia and Monteiro, 1998; Highborn Cay wreck - Oertling (1989b); Studland Bay wreck - Mikkel H. Thomsen personal communication; *San Juan* - Grenier, Lowen and Proulx, 1994; Cattewater wreck Redknap, 1984; *San Diego* – L'Hour, 1994; Cais do Sodré ship - Rodrigues, 1998; Rye A - Lovegrove, Capt. H., 1964; Green Cabin wreck - Moore and Muir, 1987; Seychelles wreck - Blake and Green (1986); *San Esteban* - Rosloff and Arnold III (1984); *Nuestra Señora de Atocha* - David M. personal communication; *Nossa Senhora dos Mártires* - Alves et al., 1998a.

18 See Lamb Keit and Judy, 1990.

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