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The Mazarrón 1 Shipwreck: an iron-age boat with unique features from the Iberian Peninsula

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Two iron-age shipwrecks, associated with Phoenician ceramics, were discovered at the Playa de la Isla in Mazarrón, Spain. This preliminary report describes hitherto unknown boatbuilding features of the Mazarrón 1 hull remains. The vessel presents hybrid boatbuilding techniques using both pegged mortise-and-tenon plank-edge fasteners and sewn seams employing longitudinal continuous stitching, and a unique keel scarf. It is an important source of information for the development of shipbuilding in the western Mediterranean during the Iron Age.

Key words: Mazarrón 1 shipwreck, shipbuilding, naval architecture, T-shaped scarf, longitudinal continuous stitching (whipstitch), Phoenicians.

Of the 117 wreck-sites found along the shores of the Mediterranean dated earlier than *c.* 300 BC catalogued by Parker (1992: 10–12), only 11 had preserved hull remains (McGrail, 2001: 145). Thus, ancient shipwrecks found in the western Mediterranean that provide us with information about shipbuilding and its development before the Roman era are relatively scarce. Since Parker's publication less than a dozen shipwrecks of this period with preserved hull remains have been reported. Among them, two iron-age shipwrecks associated with abundant ceramics of Phoenician origin were discovered at the *Playa de la Isla* in Mazarrón, Spain (Fig. 1). This article discusses the presence of mixed shipbuilding techniques and hitherto unknown boatbuilding features documented on the Mazarrón 1 hull remains. Through comparative study of analogous wrecks, it is argued that the Mazarrón 1 shipwreck represents an important source of information for our understanding of ancient shipbuilding and its development during the Iron Age.

The hull remains of Mazarrón 1, currently on display at the National Museum of Underwater Archaeology (ARQVA), Cartagena, Spain, reveal a number of shipbuilding features that, despite their being unique, have barely been mentioned in previous publications of the wreck, which partly inspired this detailed, though forcibly partial study and reconstruction of the vessel to be undertaken.

The Mazarrón 1 hull was not archaeologically recorded or documented following the excavation of the timber remains in 1995 as they immediately underwent a lengthy conservation treatment that lasted until 2007. This project therefore is the first and only officially approved post excavation study of the Mazarrón 1 timber remains, other than the original excavators' site reports.[1] This study was completed in different phases from 2006 to 2009, which included a one-day direct inspection of the hull remains conducted in 2008 (Cabrera Tejedor, 2017: 190–193).

This article aims to supplement previous publications that described but sketchily a number of unique shipbuilding features of Mazarrón 1; it provides a concise but complete summary of all previously published data about the Mazarrón 1 shipwreck and, indirectly, some of the Mazarrón 2 features used here as *comparanda*. The results of a preliminary reconstruction of the Mazarrón 1 hull are also briefly presented (see also Cabrera Tejedor, forthcoming; 2017). The results of this preliminary study of the Mazarrón 1 remains are used to re-examine previous interpretations that suggested the vessel was of Phoenician origin, and to propose new hypotheses regarding the nature, function, and origin of the construction techniques documented in the hull.

The excavation of Mazarrón 1

The underwater site of *Playa de la Isla* was discovered in 1988 during a series of coastal surveys by a team from the *Museo Nacional de Arqueología Marítima y Centro Nacional de Investigaciones Arqueológicas Submarinas* (*MNAM-CNIAS*). The ongoing project has been overseen by a series of museum directors: Víctor Antona del Val, Paloma Cabrera, and Ivan Negueruela,

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Figure 1. Location of Mazarrón in the Iberian Peninsula (red rectangle). 1: Playa de la Isla underwater site where the Mazarrón 1 and 2 shipwrecks where discovered and 2: the location of the Punta Gavilanes archaeological site (©Author).

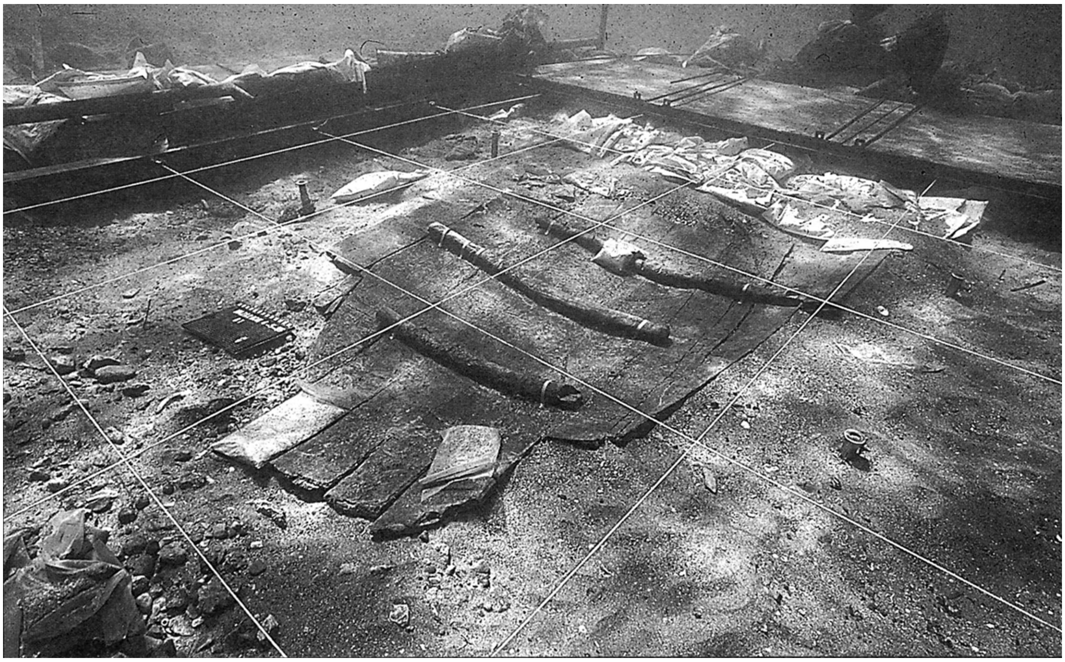

Figure 2. Mazarrón 1 *in situ* at the *Playa de la Isla* underwater archaeological site (Negueruela *et al.* 2000: photograph 5).

but from 1988 until 1995 all fieldwork at Playa de la Isla was directed by archaeologist and permit co-holder Juan Pinedo Reyes. The remains of a wooden boat (Fig. 2), designated Mazarrón 1, was found and protected *in situ* in July 1991 (Cabrera *et al.*, 1992: 38; 1997: 151; Barba *et al.*, 1999: 196; Negueruela *et al.*, 2000: 1671). From October 1993 to June 1995 a systematic survey of the area and documentation of the Mazarrón 1 wreck was initiated as part of the '*Nave Fenicia*' project (Arellano *et al.*, 1999; Barba *et al.*, 1999: 197; Negueruela *et al.*, 2000: 1671). In 1994 the remains of a second shipwreck were discovered and designated Mazarrón 2 (Arellano *et al.*, 1999: 221; Negueruela *et al.*, 2000: 1673–1674). The hull remains of Mazarrón 1 were raised in 1995 and transferred to the *MNAM-CNIAS* to begin conservation, while Mazarrón 2 remains *in situ* (Gómez-Gil and Sierra, 1996).

Structural elements of Mazarrón 1

The hull of the Mazarrón 1 shipwreck was found largely incomplete without any cargo, but the surviving timbers were relatively well preserved (Fig. 2). The hull timbers found consist of a complete keel, nine incomplete strakes of planking including one fragmented garboard, and four incomplete and fragmented frames (Fig. 3) (Negueruela, 2000a: 183; 2002: 167; 2004: 230; 2006: 24; 2014: 243; Negueruela *et al.*, 2000: 1673–1674).

When inspected in 2008, the timber remains were in two groups of articulated timbers: the first comprising keel, garboard, and second strake; the second comprising the preserved side of the hull from the third to the eighth strakes (Fig. 4); a third group of the disarticulated ninth strake and the frames was not examined. Both groups of assembled timbers were lying over supports made *ad hoc*, resting on the

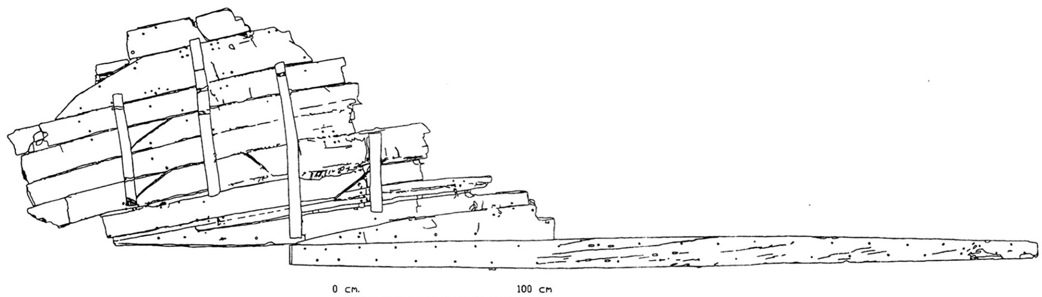

Figure 3. Site plan of Mazarrón 1 (scale bar 1m, with permission Negueruela *et al.* 2000: fig. 1).

Figure 4. Timber remains of Mazarrón 1 after the conservation process in summer 2008 (©Author).

outboard surface, which allowed the inspection of the internal surfaces only.

In previous publications of Mazarrón 1 and 2 (Cabrera *et al.*, 1992; 1997; Roldán *et al.* 1994; Arellano *et al.*, 1999; Barba *et al.*, 1999; Negueruela, 2000a; 2000b; 2002; 2004; 2006; 2014; Negueruela *et al.*, 1995; 1998; 2000; 2004; Miñano *et al.*, 2012; Miñano, 2014), Mazarrón 1 hull is reported to have 'the same construction method and fairly similar overall dimensions' as that of Mazarrón 2 (Negueruela, 2004: 230; 2006: 24; 2014: 243). The claim that both hulls were made using the same construction method can be disputed as, although both hulls have pegged mortise-and-tenons fasteners, other construction elements present in the hull of Mazarrón 1 have not been reported in the hull of Mazarrón 2, such as longitudinal continuous stitching. The following presents a brief summary of the main shipbuilding elements of the Mazarrón 1 boat, and this information is compared with some features of the Mazarrón 2 boat as published.

Keel

The keel of Mazarrón 1 has been preserved almost completely (Fig. 3). The aft end has some damage produced by biological attack (Cabrera *et al.*, 1997: 151–52; Negueruela *et al.*, 2000: 1672). The keel dimensions are 3.98m long, 170mm sided and 100mm moulded (Cabrera *et al.*, 1997: 151–52; Negueruela, 2002: 165 fig. 3 and 167; Negueruela *et al.*, 2000: 1675, fig. 1), although in 2008 the maximum keel width recorded was *c.*155mm. Elsewhere, it has been reported as 4.50m long (Negueruela, 2004: 230; 2006: 24; 2014: 243), yet this is not compatible with the evidence (Fig. 3). It has a rectangular cross-section amidships, presents no rabbets, and its bottom longitudinal edges are chamfered. Wood species identification of samples taken in 1997, determined that the keel is made of *Cupressus sempervirens L.* (Negueruela, 2004: 236–237; 2006: 25), commonly known as cypress, yet it has been mistakenly

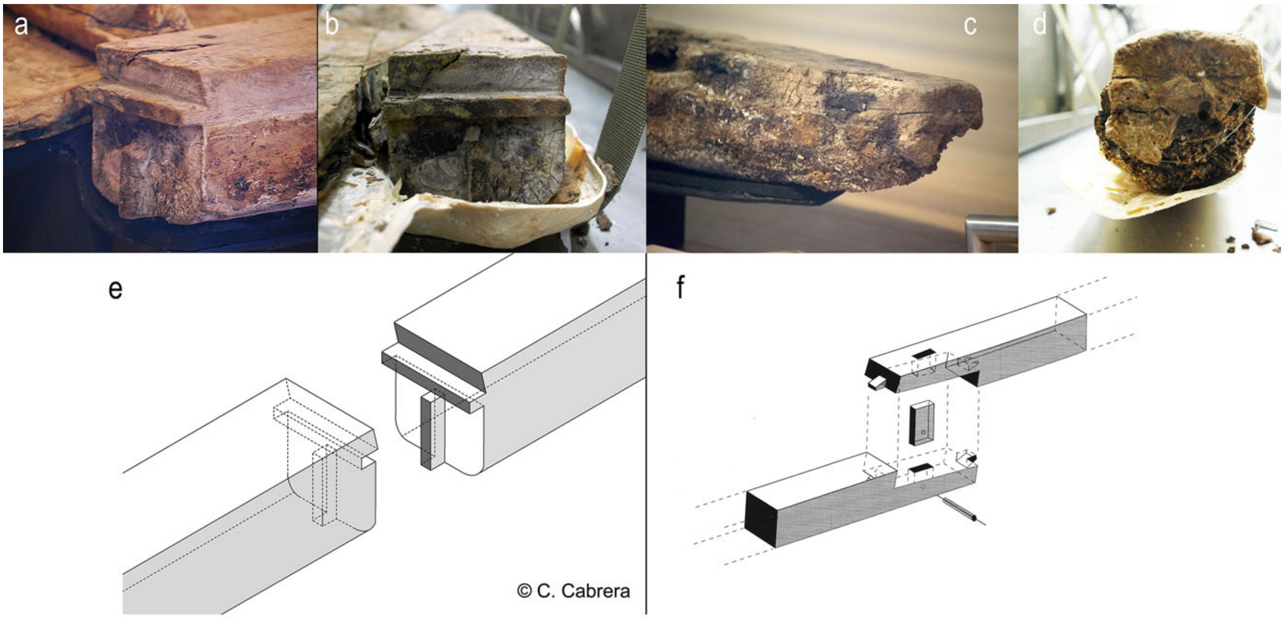

Figure 5. *a)* and *b)* Fore end of the Mazarrón 1 keel and the T-shaped scarf; aft end of the Mazarrón 1 keel: *c)* on display at the ARQVA Museum; *d)* after conservation treatment in 2008; *e)* axonometric reconstruction of the T-shaped scarf of Mazarrón 1 (all ©Author); *f)* axonometric reconstruction of the *trait de Jupiter* from 6th-century-BC Jules-Verne 9 (Drawing M. Rival, with permission Pomey, 2012: fig. 20).

described as cedar (Negueruela, 2004: 237; Miñano, 2014: 6).

The fore end of the Mazarrón 1 keel presents a unique type of scarf, that was mentioned by Negueruela *et al.* (1995: 196; 2000: 1673; Negueruela 2002; 167), but only recently fully published (Cabrera Tejedor, 2017: 210–213) (Fig. 5a, b and e). The scarf between the keel and the stem has two perpendicular tenons, one positioned above, though not touching, the other. The top tenon is horizontal and the lower one vertical, creating a T-shaped scarf. The vertical tenon is slightly damaged at its upper end. Additionally, the uppermost edge of the scarf was carved to create an inverted oblique angle of approximately 70°; this feature would have helped to secure the joint between keel and stem under vertical stress. The stem of Mazarrón 1 was not preserved, so matching mortises can only be hypothesized.

The aft end of the keel appears to have had the same type of scarf (Fig. 5c, d), although it is not so clearly recognizable due to damage. This hypothesis cannot be confirmed without further analysis of the timber.

Planking and mortise-and-tenon joints

Nine incomplete strakes of planking, including one fragmented garboard plank, were found. In 2008, it was observed that the width of the planks ranges from *c.*130mm to *c.*140mm, except for the eighth strake that is wider, at *c.*210–220mm. It was observed that plank thickness is *c.*36mm. The third, fourth, sixth, and eighth strakes have diagonal scarfs (Fig. 3), which do not present pegged mortise-and-tenon joints on their edges, except that in the eighth strake. The eighth strake is wider and reported to be thicker than the rest of the planking; it also has mortises that do not match the adjacent strakes and, consequently, it has been interpreted as a reused plank from a different hull (Negueruela *et al.*, 2000: 1673), perhaps used in the Mazarrón 1 hull as a repair (Negueruela, 2002: 167).

One fastening system used to assemble the hull of Mazarrón 1 was pegged mortise-and-tenon joints (Basch, 1972: 15). This type of fastener was used for shipbuilding in the Mediterranean at least since the Late Bronze Age as it is archaeologically documented in the Uluburun shipwreck, dated *c.*1320 BC (Pulak, 1998; 2005; 2008), where only fragments of the keel and planking survived. Half of a tenon survived from the hull of the Cape Gelidonya shipwreck dated to *c.*1200 BC (Bass, 1967; Pulak, 1998); however, the directors believe that its construction method was similar to the Uluburun vessel (Pulak, 1998: 210). The two boats found in Mazarrón are the next earliest-known archaeological examples using pegged mortise-and-tenon joints (Negueruela, 2002: 167; 2004: 246; 2006: 27; 2014: 243; Negueruela *et al.*, 1995: 195; 2000: 1673; Negueruela *et al.*, 2004: 480). Cato the Elder, writing in *c.*160 BC, described the use of pegged mortise-and-tenon joinery (*De Agri*, XVIII, 9) called them 'Punic joints' (*punicanis coagmentis*) (Sleeswyk, 1980: 243). Pegged mortise-and-tenon joinery was widely used for shipbuilding in the Roman period (Steffy, 1994: 43, 46, 77–78, 83–84; Casson, 1995: 203).

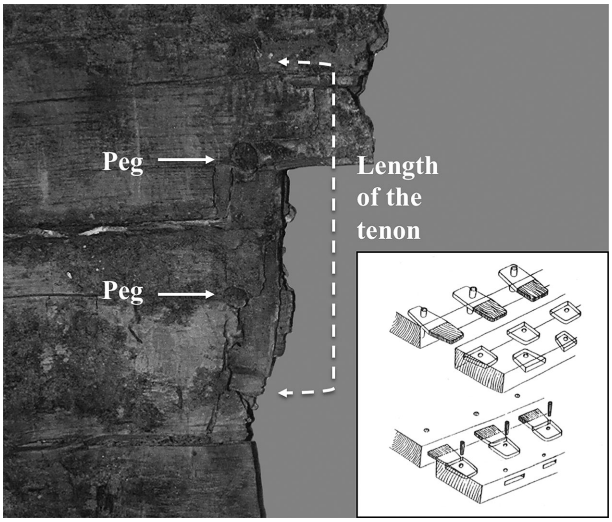

Figure 6. Partially exposed tenon *in situ*, at the aft end of the third and fourth strakes of the Mazarrón 1 hull remains (©Author). Schematic reconstruction for joining planks with pegged mortise-and-tenon fastenings (inset) (with permission Pomey, 1997: 94).

In 2008, it was observed that mortises in the Mazarrón 1 hull are on average 30–36mm wide, 8–10mm thick, and 60–80mm deep. Tenons fit their mortises tightly both in thickness and width. Pegs are cylindrical in section with diameters of 7–10mm, although the majority are 8mm (Fig. 6). The spacing between pegs was rather difficult to document in some strakes since a layer of pine tar covers large areas of the hull planking (Gómez-Gil and Sierra, 1996: 219) (Fig. 2). However, when pegs were covered by the tar, their approximate position was documented by locating them in the open seams of the strakes. The spacing of those pegs documented varies substantially depending on the strake (Fig. 7), and two distinct zones with different arrangements were identified. First, on the keel, garboard, and second strake spacing between pegs varies from 110–240mm (195mm on average) and pegs are more closely spaced towards the ends of each timber. In contrast, a second zone was observed from the seam of the third and fourth strakes up to the ninth, where pegs are more widely spaced, varying from 280–520mm (400mm on average). It was also observed that tenons seem to be slightly larger in this second zone than in the lower part of the hull.

Wood species identification of samples taken in 1997 determined that the planking is made of pine (*Pinus sp.*), whereas tenons and pegs are made of olive (*Olea europea L.*) (Negueruela, 2004: 236–237; 2006: 25).

Stitching of the planking

It was reported that at the seams the planks have chamfered edges and that thin ropes were placed in the resulting grooves to serve as waterproofing material, held in place with simple running stitching (Negueruela, 2000a: 196; 2002: 167; Negueruela *et al.*, 2000: 1673). The initial hypothesis was that the stitching served to strengthen the union between planks and that the waterproofing ropes made the plank seams watertight (Negueruela *et al.*, 2000: 1673); although in later publications only the waterproofing function was maintained (Gómez-Gil and Sierra, 1996: 219; Negueruela, 2002: 167). The rope and stitching are visible in the only *in situ* detailed photograph published to date (Fig. 8b). The position of the stitching is shown schematically in one drawing (NAVIS, nd), and

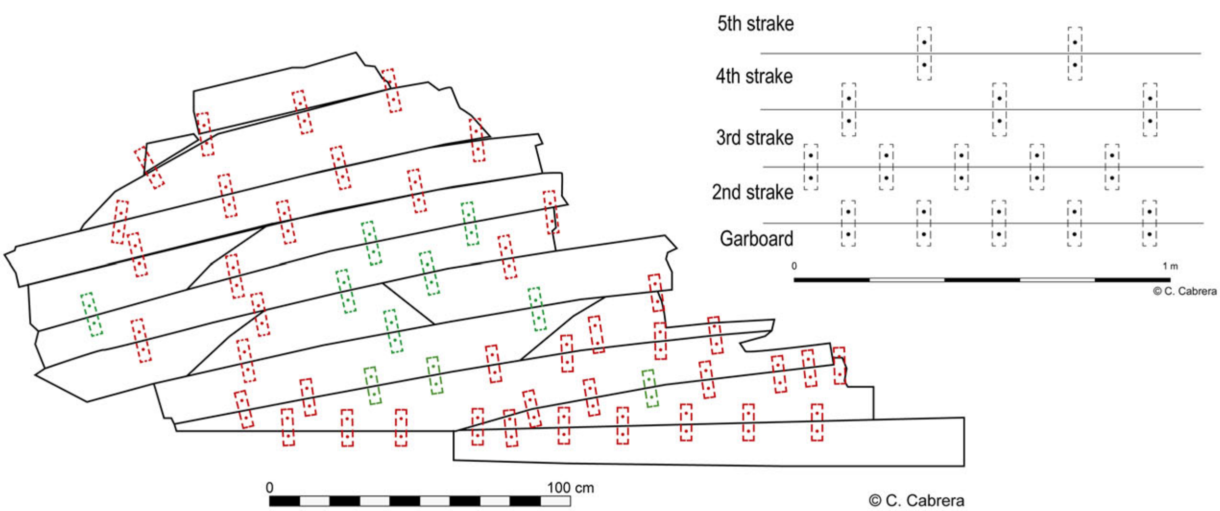

Figure 7. Reconstructed position of the mortise-and-tenon joints of the Mazarrón 1 hull: clearly documented (red) and hypothesized (green), frames are not represented for clarity (scale bar 1m, ©Author); inset: schematic reconstruction of the distribution of tenons: two zones with different arrangements could be identified (scale bar 1m, ©Author).

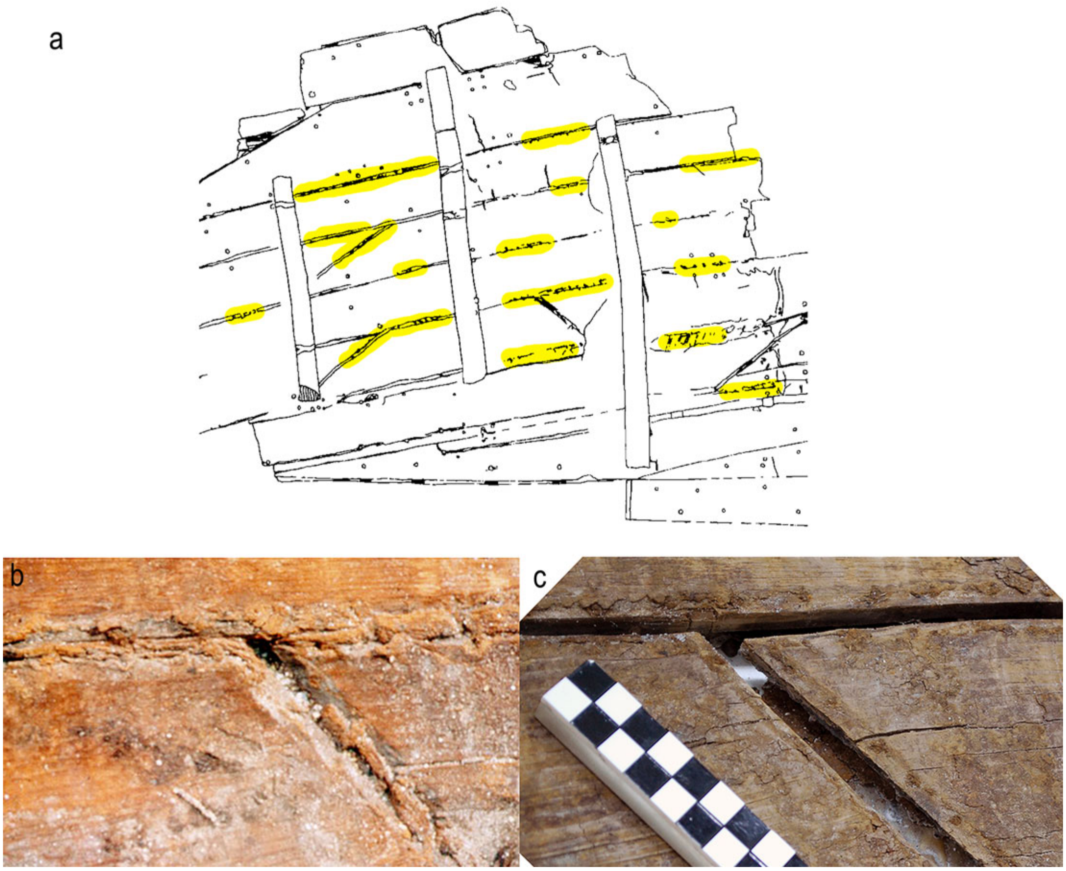

Figure 8. *a)* Detail of the only *in situ* archaeological drawing from the excavation published, the stitches were documented to be present and visible in several areas along the seams of the planking (highlighted in yellow)(after Negueruela *et al.*, 1995: fig. 11); *b)* underwater photograph of the longitudinal continuous stitching (©ARQVA Museum archives, Ministerio de Cultura); *c)* the same seam in 2008 after the conservation process (note that both waterproofing ropes and stitching are missing) (scale bar shows cm, ©Author).

one published site drawing (Negueruela *et al.*, 1995: fig. 11) marked as diagonal parallel lines along the seams (Fig. 8a). Unfortunately, only scant remains of the waterproofing ropes and the original stitching have survived the extraction/conservation processes, since they were not readily apparent after conservation in 2008 (Fig. 8c). Consequently, the longitudinal continuous stitching is now only attested by the chamfered plank edges, the pre-drilled sewing holes and imprints of the stitches left on the protective coating of pine tar that was applied to the hull.

Chamfered edges, waterproofing rope, and stitching were reported for the seams between the second and third strakes up to the seams of the ninth strakes (Negueruela *et al.*, 2000: 1673). In 2008, however, no chamfered edges or sewing holes were seen along the keel-garboards seams or garboard/second strake seam. From the outer edge of the second strake upwards these features were seen in the remaining strake seams and scarfs up to the seam between the seventh and eighth strakes (Fig. 9) but not between the eighth and ninth strakes (cf. Negueruela *et al.*, 2000: 1673), neither are chamfered plank edges and sewing holes found only in two small areas within the surviving part of the hull as reported elsewhere (De Juan, 2017a: fig. 8). The only preserved end of any of the surviving strakes of the Mazarrón 1 hull is the fore end of the second strake (Fig. 3). This end was originally fastened to the stem with pegged mortise-and-tenon joints alone as it presents neither chamfered edges nor sewing holes to accommodate stitching (Fig. 10). This limited evidence suggests that the stem and hood-ends were not sewn.

Each plank edge is chamfered at an angle of *c.*45° starting about *c.*5mm from the edge of the plank, penetrating about *c.*5mm into the plank thickness (*c.*36mm); the chamfered edges of two adjacent strakes create a V-shaped groove in their seam. The sewing holes were also made at about *c.*5mm from the edge of the plank and they sit just within the groove along the chamfered edges (Fig. 11). It was noted that the sewing holes on adjacent planks were disposed diagonally to one another and not in opposing pairs (Fig. 12). They

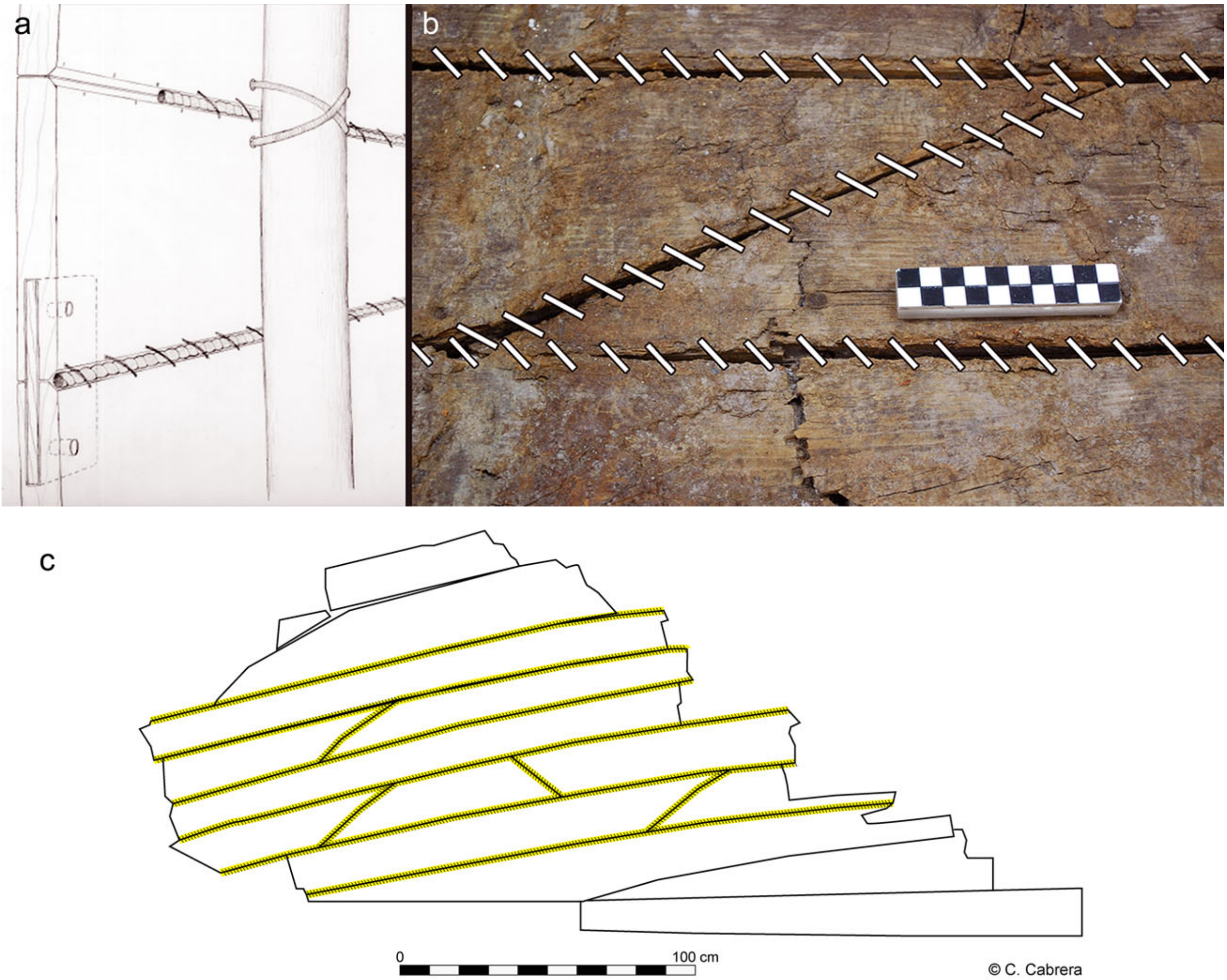

Figure 9. *a)* Schematic reconstruction of the different fastening systems used in Mazarrón 1 (©ARQVA Museum archives, Ministerio de Cultura); *b)* approximate reconstruction of the pattern created by the longitudinal continuous stitching along the seams of Mazarrón 1 (scale bar 10cm, ©Author); *c)* planking plan with sewn plank seams and scarf seams (that is with chamfered edges and sewing holes) highlighted in yellow (scale bar 1m, ©Author).

have an approximate diameter of *c.*2mm and are fairly regularly spaced *c.*20–25mm apart. The holes appear to be drilled through the plank at an approximately 90° angle—perpendicular to the plank's face and parallel to its edge—through the entire thickness of the plank, but this could not be confirmed since the external surfaces of the hull were not available for inspection. However, this hypothesis is supported by the following observations: first, given the proximity of the perforations to the edge of each strake (*c.*5mm), there is little space for the perforation to traverse the plank at a significantly oblique angle. Moreover, the edge surfaces of some planks were visible but no exit holes could be seen (Fig. 12b, c). Second, in the edges of some the planks cracks were documented that appear related to the perforations; these may have resulted from stresses sustained by the planking cracking the small wood interstice between the perforation and the edge of the plank. The few documented cracks are perpendicular to the face of the plank (Fig. 12c). Third, one plank fragment apparently recovered from Mazarrón 2 has perpendicular perforations traversing the thickness of the plank and also has a perpendicular crack (*vide infra*, Fig. 19). For all of the above, the sewing holes seem to traverse the strake thickness completely and are perpendicular to the face of the plank.

The scant surviving evidence suggests that the sewing string fitted tightly in the sewing holes; accordingly, it would have had an approximate thickness of *c.*2mm. On careful observation of the published photograph, it could be tentatively estimated that the waterproofing ropes had an approximate diameter of *c.*6–8mm (Fig. 8). The balance of evidence suggests that the waterproofing ropes were placed in the inboard planking seams only; in the only schematic drawing of the stitching published by the excavators (Fig. 9a) it is represented inboard only. Nonetheless, this cannot be confirmed since the external surfaces of the hull were not available for inspection.

It was reported that the waterproofing ropes were formed of a number of strands (Negueruela *et al.*, 2000: 1673). Careful observation of the published photograph (Fig. 8b) suggests that both waterproofing ropes, and the string for the stitching, were formed of a number of strands; the waterproofing rope depicted seems to have been formed by two strands (Fig. 11). Fibre identification of a rope sample taken in 1997 revealed that it was made of esparto grass (*Stipa tenacissima L.*) (Negueruela, 2004: 236–237).

Figure 10. Fore end of the second strake; note that it does not have sewing holes for the longitudinal continuous stitching where it was connected to the stem. Its upper edge (left) is fractured and not the original, thus it also lacks sewing holes (©Author).

Because the external surface of the hull planking was not available for inspection, the characteristics of the stitching on the outboard surface can only be hypothesized. However, as J.F. Coates rightly noted (1985: 15) 'if wadding were semi-circular in section and fitted on both sides of the seam, the stitching would lose all capacity to pull the planks together and much of any resistance to sliding it would otherwise have had'. Therefore, the arrangement proposed in Figure 11 shows the simplest solution: the string, after exiting a sewing hole, enters the next one located diagonally on the opposite plank, creating a pattern of short, parallel, diagonal stitches. More complex solutions could have been used as documented in different sewn-plank boats around the world (McGrail and Kentley, 1985; McGrail, 2001; McCarthy, 2005: 10–21), but, until inspection of the external surface of the hull planking of Mazarrón 1 is permitted, it remains conjectural.

Cylindrical frames

Four fragmented frames were found (Figs 2 and 3). These were described as lightly worked branches (Negueruela, 2004: 237; 2014: 244). They were not available for inspection in 2008 but are reported to be cylindrical in section and 60–65mm (Gómez-Gil and Sierra, 1996: 219) or 70–80mm in diameter (Cabrera *et al.*, 1997: 152), with room and space of *c.*0.45m (centre to centre). Wood species identification

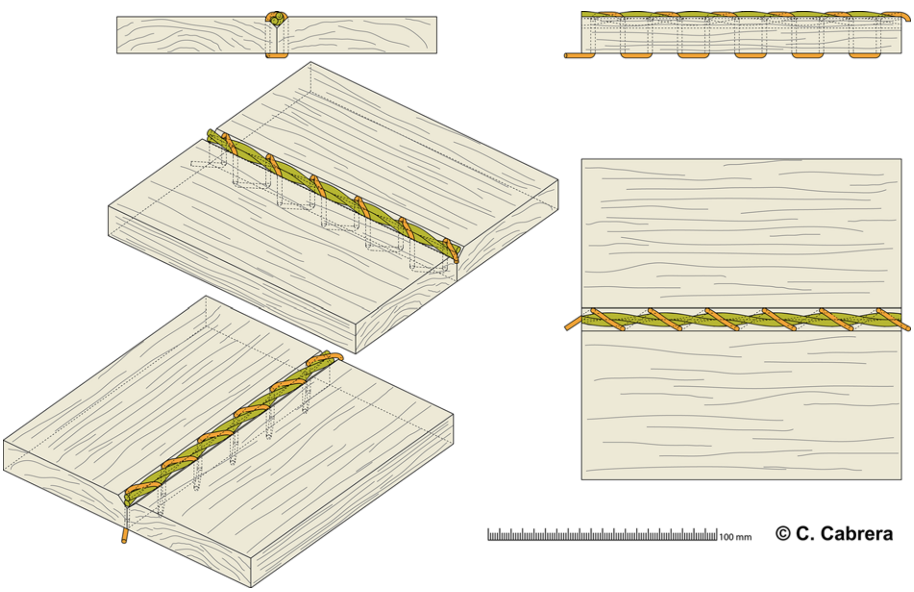

Figure 11. Front, side, and top views (inboard), and two isometric views of the Mazarrón 1 longitudinal continuous stitching arrangement. A waterproofing rope perceived to be formed of two strands (green) and the string that secures the rope and fastens the planks creating a pattern of short, parallel, diagonal stitches (orange)(Scale bar 100mm, ©Author).

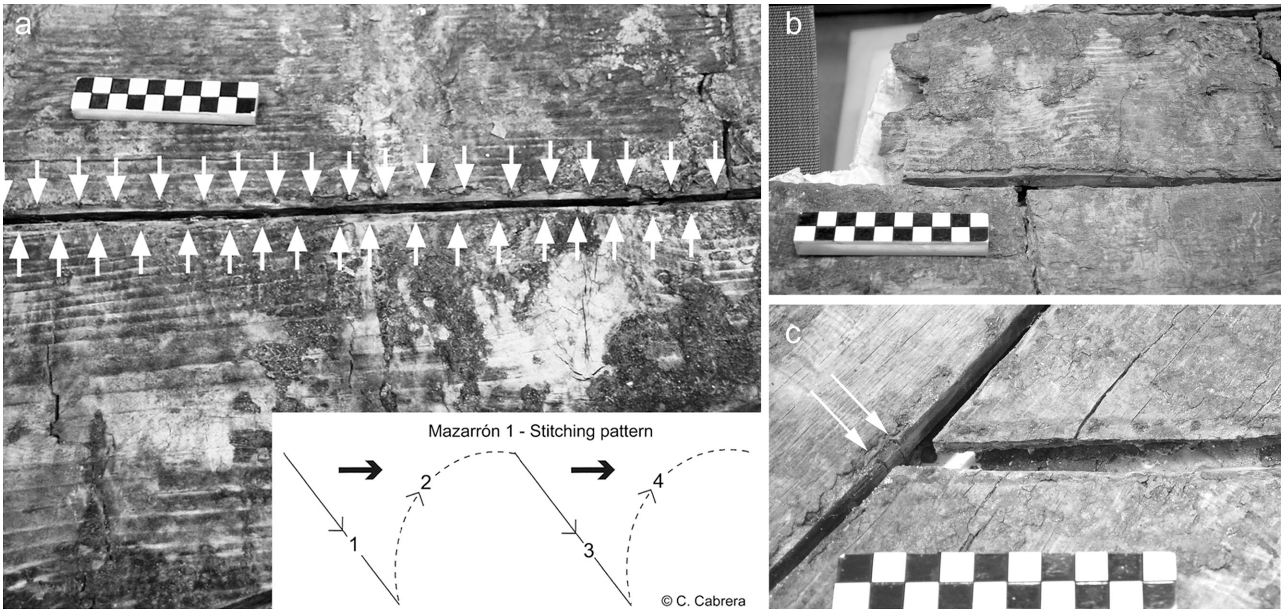

Figure 12. a) Sewing holes (marked by arrows) disposed diagonally to one another on adjacent planks; *inset* Mazarrón 1 stitching pattern (scale bar 10cm, ©Author); *b)* inner edge of the seventh strake, note the absence of exit holes (scale bar 10cm, ©Author); *c)* detail of the upper end of a diagonal scarf at the fourth strake showing its chamfered edges, sewing holes and imprints of the stitches left on the protective coating of pine tar. Arrows indicate cracks in the inner edge of the fifth strake that are perpendicular to the face of the plank, note also the absence of exit holes (scale bar 10cm, ©Author).

of samples taken in 1997 determined that the frames are made of fig wood (*Ficus carica L.*) (Negueruela, 2004: 236–237; 2006: 25, 29).

The frames of Mazarrón 2 are reported to be cylindrical in section also, 40mm in diameter, with room and space ranging 0.40–0.50m (Negueruela, 2004: 249; 2006: 29; 2014: 244). They lay over the keel but were not fastened to it (Negueruela, 2004: 249–250; 2006: 29–30). According to wood species identification conducted in 2010, they are made of wood from the genus *Juniperus* (Miñano, 2014: 9).

In the case of Mazarrón 1, the frames were lashed to the planking and some of the lashing cords were preserved *in situ* (Negueruela *et al.*, 2000: 1673); when examined in 2008, only lashing points survived (Fig. 13). The holes were drilled in two pairs on either side of each frame so that the ligatures crossed over the top of the frame forming an X shape (Negueruela, 2004: 249; 2006: 29; 2014: 244). The sets of paired lashing points were positioned with two holes on each side of a strake seam (Negueruela, 2004: 245, 249–250; 2006: 29–30; 2014: 244; Miñano, 2014: 10). The lashing points of Mazarrón 1 are *c.*6mm in diameter and *c.*40 mm apart (Fig. 13). It was not possible to document the angle at which the lashing points were bored. After drilling, several individual lashings were tied to fasten each frame to the hull. De Juan (2014: 29; 2017b: fig. 7) offers a hypothetical reconstruction of how the Mazarrón 2 individual lashings were tied.

This type of cylindrical frames may have an archaeological parallel in the tentatively dated 7th- or 6th-century-BC Golo wreck found off the island of Corsica, France (Pomey, 2012: 26, 28). Additionally, the type of lashing used to fasten the frames to the hull according to the excavators may have an archaeological parallel in the 4th-century-BC Benissafúller wreck found off the island of Menorca, Balearic Islands, Spain (De Juan *et al.*, 2010: 65). The frames of this wreck, however, are trapezoidal in section, not cylindrical (De Juan *et al.*, 2010: 66).

Mast-step timber

In the Mazarrón 1 shipwreck no mast-step timber was found but its existence is suggested by the presence of six mortises on the upper side of the keel to which it could have been secured (Fig. 14). The mortises are all longitudinally orientated: four are located towards the bow in an approximately square arrangement; the remaining two are aligned aft of the other mortises. If the four fore mortises echo the position of the step in the mast-step timber, a similar position for the mast is seen, slightly towards the bow and at the fore end of its mast-step timber, as in the *c.*400 BC Ma'agan Mikhael shipwreck (Linder, 1992; Linder and Rosloff, 1995; Linder *et al.*, 2003). If correct, additional information regarding the Mazarrón 1 hull can then be deduced: the position of the missing mast allows us to identify the bow and the stern of the ship and thus the preserved strakes correspond to the starboard side of the original vessel (Fig. 14). Study of the Ma'agan Mikhael shipwreck proved the need of a through-beam acting as mast-partner to secure the mast in conjunction

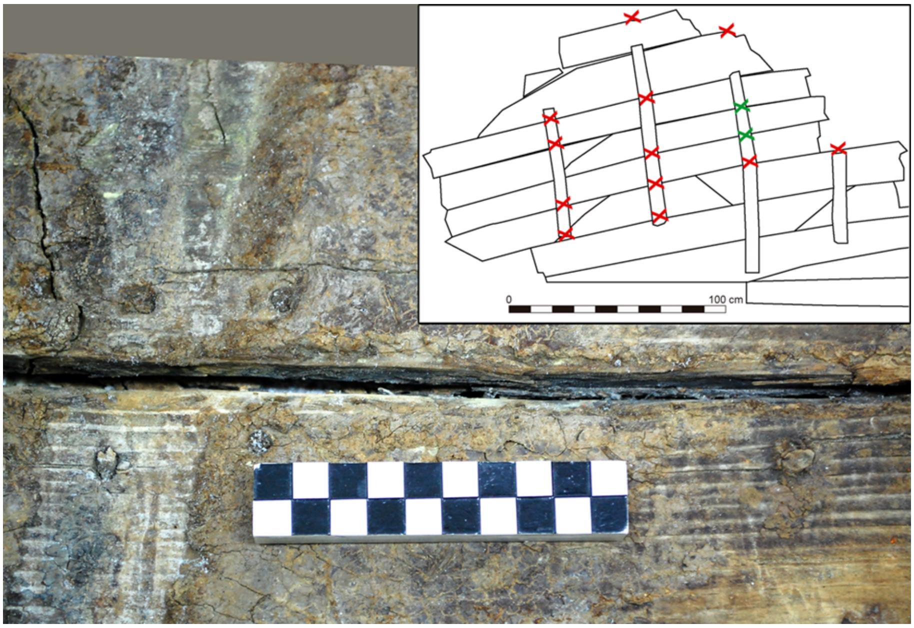

Figure 13. Remains of four lashing points. Note that the sewing holes on the seams are present underneath the frame (scale 10cm); *inset* reconstructed position of the lashing points of the Mazarrón 1 hull: clearly documented (red X) and hypothesized (green X) (top right, scale bar 1m) (©Author).

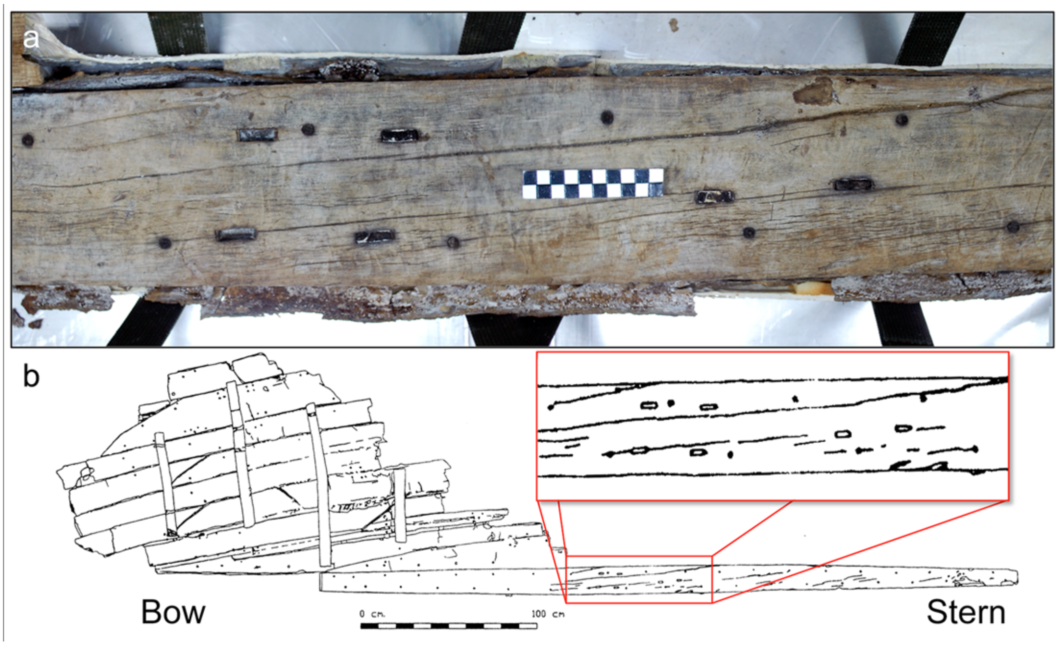

Figure 14. *a)* Upper face of the Mazarrón 1 keel (scale bar 10cm)(©Author), six longitudinal mortises are noticeable where the now lost mast-step was located; *b)* drawing and detail (scale bar 1m)(after Negueruela *et al.* 2000: fig. 1).

with the mast-step (Steffy, 1994: 40–41; Linder *et al.*, 2003: 105; Kahanov and Pomey, 2004: 7–8). For that reason, a preliminary reconstruction of the Mazarrón 1 shipwreck (Cabrera Tejedor, 2017) included through-beams.

In Mazarrón 2 a 0.98m-long mast-step timber was reported (Negueruela, 2004: 241; 2006: 26), whereas Miñano (2014: 7), has stated that the mast-step timber is 1.04m long, 0.10m wide, and 0.06m deep. It is fastened to the keel with five mortise-and-tenon joints: four longitudinally arranged in a straight line, with the fifth, aft, orientated perpendicular to the others (Negueruela, 2004: 241; Miñano, 2014: 7). The mast-step timber is in direct contact with the keel and

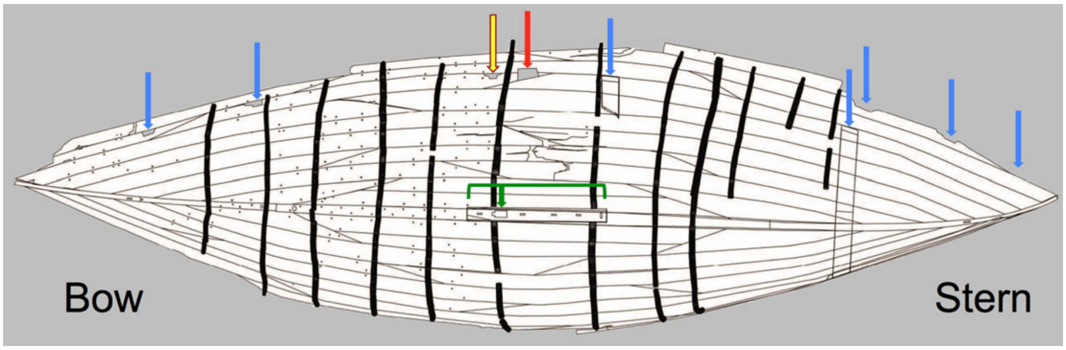

Figure 15. Plan of the Mazarrón 2 shipwreck: blue arrows: position of the through-beams, or their notches, reported by excavators; red arrow: rectangular hole made by the excavators to extract a wood sample for C14 analysis (Negueruela, 2004: 267 fig. 12); yellow arrow: notch of a through-beam not previously reported located next to the mast, which originally served as mast-partner; green arrow: mast-step, allowing us to identify the bow and the stern of the boat (Author, after Miñano, 2014: fig. 2).

is notched over two of the cylindrical frames with transverse approximately rectangular slots made *ad hoc* on its base (Miñano, 2014: 7, fig. 5). This data has also been used to identify the bow and the stern of the boat (Fig. 15).

Through-beams

In the case of Mazarrón 1 no through-beams were reported, and the uppermost parts of the hull were lost (Figs 2 and 3). In contrast, in the Mazarrón 2 shipwreck seven through-beams were reported: four astern, one amidships (*c.*1m abaft the mast), and two more at the bow (Negueruela, 2004: 241–244; 2006: 24–26; 2014: 243). However, this description seems incomplete since an eighth through-beam is attested by notches in the top of the eighth strakes visible on published photos (Negueruela, 2004: figs. 12, 14, 25; 2006: figs. 13, 15, 20; Miñano *et al.*, 2012: fig. 10). The starboard notch is close to a rectangular hole cut by the excavators to take a sample for radiocarbon analysis (Negueruela, 2004: 267 fig. 12)(Fig. 15).

Judging by its position next to the mast-step, this through-beam may have served as mast-partner (Cabrera Tejedor, forthcoming), as seen in the *c.*400 BC Ma'agan Mikhael shipwreck (Steffy, 1994: 40–1; Linder *et al.*, 2003: 105; Kahanov and Pomey, 2004: 7–8), although this mast-partner was placed aft of the mast. This through-beam and mast-partner is not mentioned in any published reports of the Mazarrón 2 shipwreck. In the only published reconstruction of Mazarrón 2 (Negueruela, 2006: figs. 6, 19, 30, 31), this through-beam fore of the mast-step is not included. Miñano (2014: 8), however, reports that 'it is currently possible to detect the presence of more (through-beams)' without additional detail.

The through-beams in the Mazarrón 2 shipwreck were secured to the hull with dovetail ends fitted into *ad hoc* notches made in the upper edge of the eighth strakes (Negueruela, 2004: 241, 250–251; 2006: 26, 31–32; 2014: 244). The ends of the through-beams protruded outside the hull (Fig. 16) and were locked in place by the row of strakes inserted above them (Negueruela, 2004: 242, 272 figs. 21, 22; 2006: 40 fig. 26; 2014: 244).

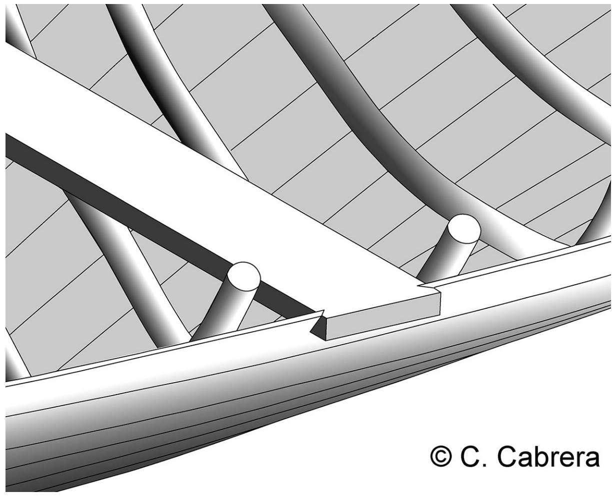

Figure 16. Isometric drawing of a dovetail end of one of the through-beams documented in the Mazarón 2 shipwreck and used in the preliminary reconstruction of the Mazarrón 1 boat (©Author).

On the preserved parts of the eighth and ninth strakes of Mazarrón 1, there are two features that could be partial remains of dovetailed notches: on the upper aft edge of each strake, there is an angular feature in which a through-beam could have been fitted (Fig. 17).

In Mazarrón 2, the through-beams were fitted on the eighth strakes (Negueruela, 2004: 241, 250–251; 2006: 26, 31–32; 2014: 244). The eighth strake of Mazarrón 1 is wider, reported to be thicker than the others, and a reused timber from another ship (Negueruela *et al.*, 2000: 1674; Negueruela, 2002: 25). Marlier has suggested it is a wale (2005: 138). Together these observations support the suggestion that the eighth strake of Mazarrón 1 carried through-beams.

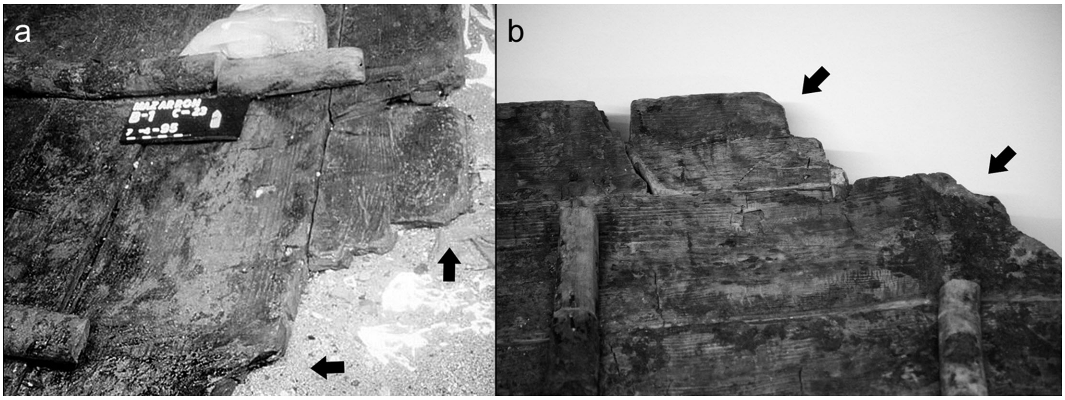

Figure 17. Eighth and ninth strakes of Mazarrón 1 *a) in situ* (with permission Negueruela *et al.* 1995: fig. 12) and *b)* on display: arrows point at the potential remains of notches where the ends of through-beams could have been fitted (©Author).

Unfortunately, the aft broken fragment of the ninth plank of Mazarrón 1 was not present during the examination of the hull remains in 2008 (Fig. 4), and it has been impossible to inspect the Mazarrón 1 timber remains in detail since. Observation from outside the museum cabinet does not allow these hypotheses to be confirmed or dismissed.

Nevertheless, there seems to be indirect and analogous evidence to suggest that through-beams were used in the construction of the Mazarrón 1 hull. Consequently, for the preliminary reconstruction of Mazarrón 1 (Cabrera Tejedor, 2017), a minimum solution construction was adopted resulting in six through-beams: two at the stern, two amidships, and two at the bow all fitted on the eighth strakes (see Fig. 24).

Waterproofing

The final step in the construction process consisted of waterproofing the hull with a protective coating of resinous material. Abundant remains of a protective coating can be seen on the hull remains of Mazarrón 1 (Negueruela, 2002: 167) (Fig. 4). A preliminary chemical analysis of samples taken in 1997 stated that the coating material was copal resin, which led to some preliminary erroneous interpretations of the boat (Negueruela, 2004: 255; 2006: 25). Further analyses conducted in 2002 concluded that the coating was pine tar, made from heating pine resin (Negueruela, 2004: 235–236; 2006: 25). A waterproof coating of pine tar was applied both internally and externally (Negueruela, 2002: 167), as also seen on Mazarrón 2 (Negueruela *et al.*, 2000: 167; Negueruela, 2004: 251–252, Negueruela *et al.*, 2000: 1674).

Discussion of the hull features

T-shape keel scarf

The distinctive T-shape scarf from the keel of Mazarrón 1 is contemporary with the *trait de Jupiter* scarf in use at least from the 6th century BC as documented archaeologically in the Jules-Verne 7 and 9 shipwrecks discovered in the ancient port of Marseilles (Pomey, 1999; 2001; 2003). The Jules-Verne 9 vessel was *c.*9m long and *c.*1.60m in the beam (Pomey, 1999: 148) and thus similar in size to Mazarrón 1; its *trait de Jupiter* scarf is the closest archaeological parallel to the Mazarrón 1 T-shape scarf in form, geographically, and chronologically (Fig. 5).

The Mazarrón 1 T-shape scarf differs from the '*trait de Jupiter*' in that it does not have a self-locking mechanism by means of a pegged tenon (Fig. 5). The T-shape scarf was locked by the garboards and the second strakes being fastened to the keel and stem respectively with pegged mortise-and-tenon joinery (Figs 3 and 7).

The design of the Mazarrón 1 T-shape scarf would withstand stress from pressures derived from hogging and sagging of the hull and the keel of the ship caused by the imbalance of weight and buoyancy along the length of the hull (McGrail, 2001: 147). Its design would prevent the separation of the keel and stem despite stresses in the vertical and transverse axes or through torsional forces in the longitudinal axis. In contrast to the *trait de Jupiter* scarf, however, it would not be able to contain tensile stress in the longitudinal axis because of the absence of a self-locking feature. This tensile stress would have been sustained instead by the pegged mortise-and-tenon joinery of the garboards and the second strakes. Consequently, the distinctive T-shape scarf from the keel of Mazarrón 1, is a less sophisticated joint than the *trait de Jupiter* scarf.

Cylindrical frames

It has been suggested that the wood used for the frames of Mazarrón 1 and 2 was flexible, thus providing no structural stiffness to the hull (Negueruela, 2004: 250; 2006: 31; 2014: 244; Polzer, 2011: 363): this can be questioned. Despite their simplicity and small diameter cylindrical frames were used in both Mazarrón 1 and 2, and perhaps in the Golo wreck (Pomey, 2012: 26), and they must have had a function. The fact that each frame was made from a lightly worked single piece (branch of a tree or the trunk of a sapling), and so retained the natural configuration of the wood fibres, would have given them strength and flexibility. If they were bent to shape using force during the construction process, the natural tendency of the wood would be to recover their initial shape, thus pushing the hull sides outwards, consequently providing some transversal reinforcement.

In Mazarrón 2 they were used along the entire length of the hull at fairly regular intervals. Elsewhere, it has been proposed that these frames served to protect the hull from the cargo, functioning as a kind of permanent dunnage (Polzer, 2011: 363). This hypothesis, however, does not explain why frames were installed at the ends of the hull where cargo was unlikely to be stowed.

Despite their small diameter, these simple pieces of wood seem to have had a structural role in strengthening the hull transversally and hence acted as frames (Cabrera Tejedor, 2017: 209–210). Guerrero Ayuso also discussed the Mazarrón 1 and 2 frames (2008: 57–60), proposing the hypothesis that they are a remnant or a distinctive boatbuilding feature of an indigenous local shipbuilding tradition.

Longitudinal continuous stitching

As we have seen, only scant remains of the waterproofing ropes and the stitching have survived the extraction/conservation process (Fig. 8c). The loss of the waterproofing ropes and the stitching might have been the result of the use of a silicone mould for raising the timber remains from the underwater site (Gómez-Gil and Sierra, 1996: 220), or as a result of the freeze-drying conservation they underwent (Sierra, 2009). Regardless, the stitching of Mazarrón 1 is attested by the chamfered edges and the pre-drilled sewing holes along some of the plank edges (Figs 8, 9, 11, 12).

This simple longitudinal stitching from Mazarrón 1 is defined as continuous because the evidence suggests that a single string was used creating overcast stitches without interruption (whipstitch) along the seams between planks (Figs 8a, 11). J.F. Coates produced an essential engineering analysis of the use of stitches as a fastening method for assembling planking, including different arrangements and their features (Coates, 1985). The stitching observed on Mazarrón 1 corresponds to the Type B proposed by Coates (1985, fig. 2.5) in a helical pattern, going from the inside to the outside of the hull. Whipstitch creates a pattern of parallel, diagonal stitches along each of the seams of the planks (Fig. 11). Since the sewing holes traverse the planks at an approximate 90° angle, the pattern of parallel, diagonal stitches could have been present on both sides of the hull, but this could not be verified.

Evidence documented during the inspection of the hull suggests that the stitching overlaps the pegged mortise-and-tenon joints (Fig. 18). This would indicate that, *a priori*, both the sewing holes as well as the stitching were completed after fastening the planks edge-to-edge using pegged mortise-and-tenon joints. Additionally, it was observed that the stitching is present underneath the frames (Fig. 13), which shows that the frames were inserted after the stitching was completed.

Figure 18. Remains of the longitudinal continuous stitching (chamfered edges, sewing holes and imprints of the stitches left on the protective coating of pine tar) over one pegged mortise-and-tenon joint that connects the fifth and sixth strakes. Arrows point to the two pegs fixing the tenon in place (scale bar 10cm, ©Author).

In addition, there is evidence to suggest that repairs in Mazarrón 2 were made with the same longitudinal continuous stitching. At the ARQVA Museum, the remains of the Mazarrón 1 hull are displayed mixed with some timbers from Mazarrón 2 in a rather confusing manner. For example, at the fore end of the Mazarrón 1 third strake, a foreign timber has been placed (Fig. 19). This is the end of a plank with a diagonal scarf and has a triangular shape. The two longest edges of the piece are chamfered; the remains of sewing holes are visible and appear to be similar in diameter and arrangement to those documented in the seams of Mazarrón 1. It is not in its rightful place because it simply does not fit the fore end of the third strake (Fig. 19); moreover, it was not recorded in the Mazarrón 1 site plan (Fig. 3). It seems that the timber on display is part of the Mazarrón 2 hull remains. According to the on-line database of the ARQVA Museum collection this timber has the reference number MZ-24-1/B2 (CERES, nd). The description on its data sheet states that, because of the presence of sewing holes, the timber seems to be a sewn repair from the hull remains. Regrettably, the data sheet does not indicate to which of the two Mazarrón boats the piece belongs. However, on the accompanying photograph, the piece is labelled MZ-24-1/B2. It is reported that MZ-24-1 stands for ‘Mazarrón’, ‘year 2004’, ‘inventory number 1’; and B2 indicates ‘Boat 2’ (Negueruela, 2004: 232). If the MZ-24-1/B2 timber is indeed a repair from Mazarrón 2—reported to be built with pegged mortise-and-tenon fastenings—the Jules-Verne 7 would be an archaeological parallel;

Figure 19. a) Timber MZ-24-1/B2 possibly from the Mazarrón 2 shipwreck currently placed at the fore end of the Mazarrón 1 third strake (©Author).

Jules-Verne 7 was built with pegged mortise-and-tenon fastenings but repairs were sewn in place (Pomey, 1999: 151–153; Kahanov and Pomey, 2004: 16; Pomey *et al.* 2012: 293).

There are other documented archaeological examples of sewn-plank boats with simple longitudinal continuous stitching (whipstitch) of the Types A and B proposed by Coates (1985, fig. 2.5), similar to that of the Mazarrón 1 hull. In the central Mediterranean, the use of longitudinal continuous whipstitch is well-attested, represented by several wrecks in the eastern Adriatic. In northern Dalmatia, three wrecks from Zaton, were discovered at the port of Nin (ancient *Aenona*). These are small boats suitable for coastal navigation dated to the first half of the 1st century AD (Brusić 1968; Brusić and Domjan 1985; Gluščević 2004). Caska 1 (1st–2nd century AD) has remains that are 8m long and 1.7m wide (Radić and Boetto 2010; Boetto and Radić, 2014). In Istria, the sewn Zambratija wreck is a unique extended logboat, the timber remains of which are 6.7m long and 1.6m wide, dated by radiocarbon analysis between the 12th to the 10th centuries BC (Boetto *et al.*, 2014: 23–24; Koncani *et al.,* 2017: 36, 42). In the British Isles, the Brigg 'raft' (McGrail, 1981; 1985: 165–194; 2001: 187–188, 2014), a riverine flat-bottomed boat, radiocarbon dated to *c.*820–790 BC, had planks fastened by simple longitudinal continuous stitching (whipstitch) described by McGrail as continuous zig-zag stitching.

In the Nin wrecks and Caska 1, the stitching was sewn over longitudinal wads or strips of vegetal fibres (Brusić and Domjan 1985: 77; Boetto and Radić, 2014: 55)(Fig. 20). In the Zambratija wreck the stitching was sewn over wadding and longitudinal fir laths (Boetto *et al.*, 2014: 24; Koncani *et al.* 2017: 60). The use of laths, held in place by the stitching, was also documented in the Brigg 'raft', but here laths were made of hazel and they trapped moss as the caulking material (McGrail, 1985: 183; 2001: 187)(Fig. 20). In contrast, the stitching of the Mazarrón 1 hull secured thin ropes of esparto grass (*Stipa tenacissima L.*) (Negueruala 204: 236–237). Despite the difference in materials, the stitching pattern and waterproofing technique used for Mazarrón 1 is similar in some respects to that documented in some Adriatic wrecks and the Brigg 'raft' (Table 1). However, pegs were used to block the stitches in the Nin wrecks (Brusić and Domjan 1985: 77)(Fig. 20), the Caska 1 (Boetto and Radić, 2014: 55), and the Zambratija wreck (Boetto *et al.*, 2014: 24; Koncani, *et al.* 2017: 40), which Coates deemed a necessity with helical sewing (Coates, 1985: 17). No stitch pegs were found inboard the Mazarrón 1 hull (Fig. 13) or the Brigg 'raft' (McGrail, 1985: 183)(Fig. 20).

Function

In the preserved timber remains of the Mazarrón 1 hull two zones with different arrangements of tenons were identified. Two observations need to be emphasized: first, average spacing between tenons doubles from one zone to the other. Second, the zone with widely spaced tenons coincides with those strakes where seams are sewn with a longitudinal continuous stitching (Fig. 21).

It has been shown that the Mazarrón 1 boat planking was fastened with pegged mortise-and-tenon joinery and plank seams were also sewn with an overlapping stitching. It has been proposed that

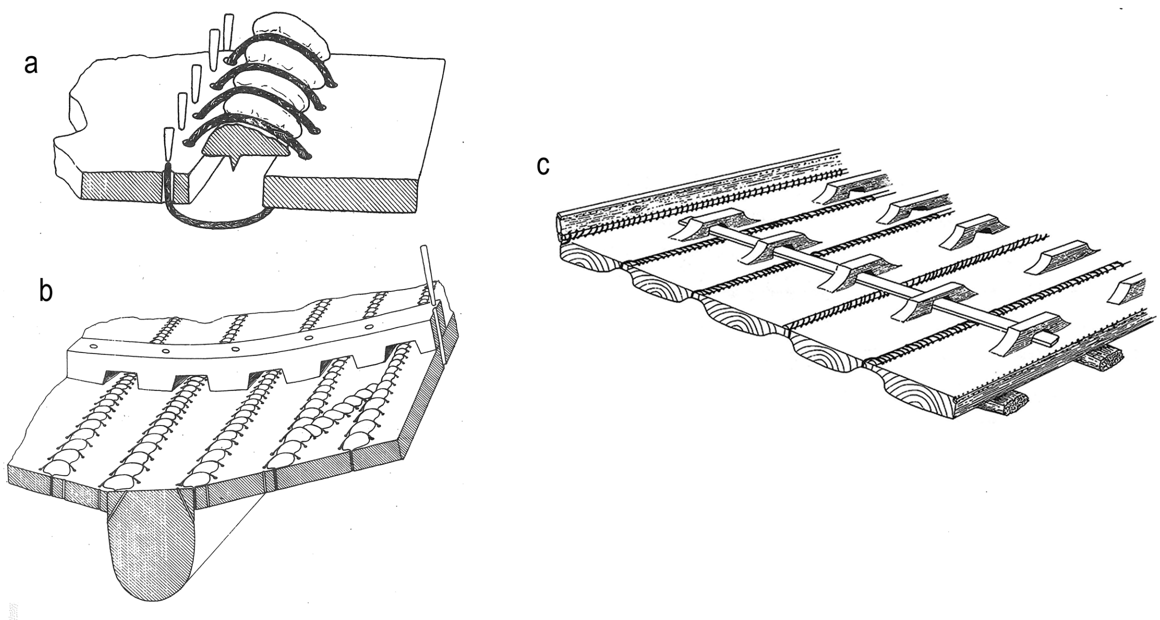

Figure 20. *a)* and *b)* Method of fastening the planking on the Nin boats. The stitching is wedged in the sewing holes by pegs (after Brusić and Domjan, 1985: 75; fig. 6.5); *c)* method of fastening the planking on the Brigg 'raft' with a 'zig-zag' stitching (after McGrail, 2001: 187, fig. 5.19).

Table 1. *Archaeological examples of sewn-plank boats with simple longitudinal continuous stitching (whipstitch) (* dimensions not stated in the consulted publications but observed in published images with metric scale bar)*

Wreck	Brigg 'raft'	Mazarrón 1	Zambratija	Nin wrecks	Caska 1
Location	British Isles	Western Mediterranean	Adriatic Sea	Adriatic Sea	Adriatic Sea
Chronology	*c.*820–790 BC	*c.*650–600 BC	12th–10th century BC	1st century AD	1st–2nd century AD
Type of navigation	Riverine	Maritime-Riverine	Coastal	Coastal-Maritime	Coastal-Maritime
Stitch pattern Type A (Coates 1985, fig. 2.5)	////////	—	—	—	////////
Stitch pattern Type B (Coates 1985, fig. 2.5)	\\\\\\\\	\\\\\\\\	\\\\\\\\	\\\\\\\\	—
Waterproofing material	Hazel laths trapping moss	Esparto ropes	Fir laths	Vegetal wads	Vegetal strips
Angle of the perforations	Perpendicular to the face of the plank	Perpendicular to the face of the plank	Oblique to the face of the plank	Perpendicular to the face of the plank	?
Diameter of sewing holes	*c.*9mm*	*c.*2mm	8–15mm	3–4mm	*c.*5mm*
Equidistant sewing holes	*c.*35–55mm	*c.*20–25mm	*c.*25–55mm*	*c.*20–25mm	*c.*25mm*
Use of pegs to wedge the stitches	No	No	Yes	Yes	Yes
References	McGrail, 1981; 1985; 2001	Cabrera Tejedor, 2017	Boetto *et al.*, 2014; Koncani *et al.,* 2017	Brusić 1968; Brusić and Domjan, 1985; Gluščević, 2004	Radić and Boetto, 2010; Boetto and Radić, 2014

the construction of hulls using pegged mortise-and-tenon joinery is generally thought to be largely incompatible with driven caulking (Steffy, 1982: 72; Basch, 1986: 187). Consequently, hulls are made watertight by carving a smooth union between the planks, yet this requires skilled craftsmanship (Basch, 1986: 188). It has been previously proposed that the stitching on Mazarrón 1 served to make the plank seams watertight (Gómez-Gil and Sierra, 1996: 219; Negueruela, 2002: 167). Yet, pegged mortise-and-tenon joinery and closely fitting planks can provide a watertight hull if properly executed (Basch, 1986: 188).

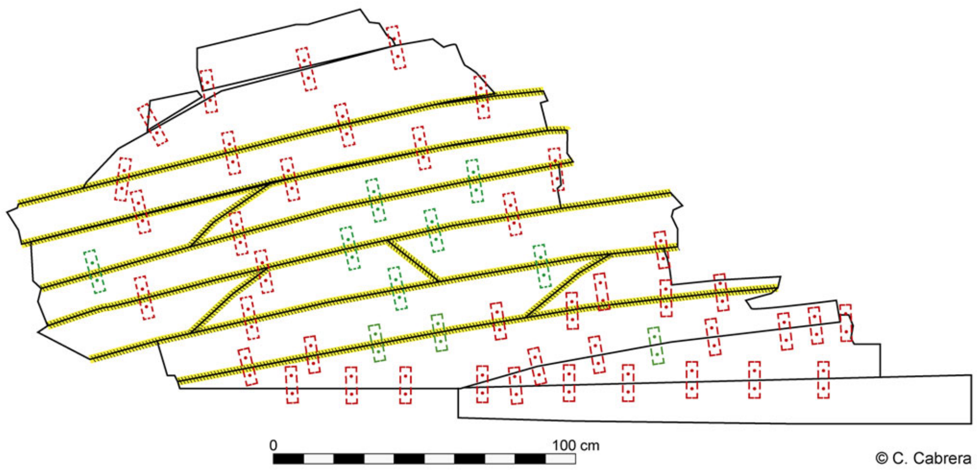

Figure 21. Reconstructed position of the mortise-and-tenon joints of the Mazarrón 1 hull clearly documented (red) and hypothesized (green), with sewn planking and scarf seams (highlighted in yellow), frames are not represented for clarity (scale bar 1m, ©Author).

Consequently, the stitching overlapping the mortise-and-tenon joinery could be seen as superfluous. An important question then arises: why did the shipwright of Mazarrón 1 employ countless hours of painstaking effort drilling the estimated 7500–8500 holes required for the installation of the stitching? The conservative nature of ancient shipwrights could offer a possible justification.

Mark (2005) suggested that ancient shipwrights operated rather conservatively since any slight variation in their shipbuilding traditions, deviation in the hull design, the use of inferior materials, or lazy craftsmanship could lead to the loss of a cargo, a ship, and possibly the crew. Therefore, the professional prestige of ancient shipwrights, their economic wellbeing as well as the life and commercial ventures of others, depended on duplicating as closely as possible successful models with techniques that the shipwright knew from experience and were unlikely to result in failure (Mark, 2005: 61). It is possible, then, to suggest two general hypotheses to explain the use of pegged mortise-and-tenon joints and stitching in the planking of the Mazarrón 1 hull: the stitching could be a structural reinforcement or repair of the original hull; or, the stitching could be an original feature and an integral part of the planking system.

In the first hypothesis, either the shipwright adopted a ‘conservative’ strategy during the construction of Mazarrón 1 and used stitching overlapping the pegged mortise-and-tenon joints as an additional measure to ensure that plank seams were watertight, for peace of mind. Or the stitching was added later in the life of the hull as a structural repair as a consequence of either a faulty initial construction or wear of the planking seams.

In the second hypothesis, the shipwright integrated two shipbuilding methods for fastening the hull planking from the start. Pegged mortise-and-tenon joints (spaced 195mm on average) were used as the only plank fastenings in the keel, garboards and the second strakes. From the third up to the ninth strakes, half the number of tenons were used per strake and were more widely spaced (spacing 400 mm on average). The longitudinal continuous stitching in this precise zone was also essential to fasten the planks, especially in the scarfs of the strakes (Fig. 21). This second hypothesis explains two features simultaneously: the combination of pegged mortise-and-tenon joints and longitudinal stitching; and the existence of two zones with clearly differentiated arrangements of tenons.

This suggests that the stitching of Mazarrón 1 had a double function: first, it served to fasten the planking aiding to pull the planks together (Coates, 1985: 15), alongside the widely spaced tenons. Second, it held the rope in the plank-edge groove ensuring that plank seams were watertight. The seams of the uppermost strakes of the hull above the possible wale (between the ninth and tenth strakes) did not have stitching, because those timbers had less need to be watertight as they were above the waterline. The suggested double function of the stitching aligns with the excavators' original hypothesis (Negueruela *et al.*, 2000: 1673).

The hypothesis that the sewing technique documented in the Mazarrón 1 boat was considered a viable method for fastening planks by the boatbuilder is supported not only by the existence of two zones with clearly differentiated tenon distributions, but also by the presence or absence of the stitching in the diagonal scarfs of the strakes. The scarfs on the third, fourth, and sixth strakes do not have pegged mortises-and-tenons joints (Fig. 21). Leaving those scarfs without any fastening method would have seriously compromised the impermeability of the hull, therefore the stitching is the only fastener used to join the scarfs and make

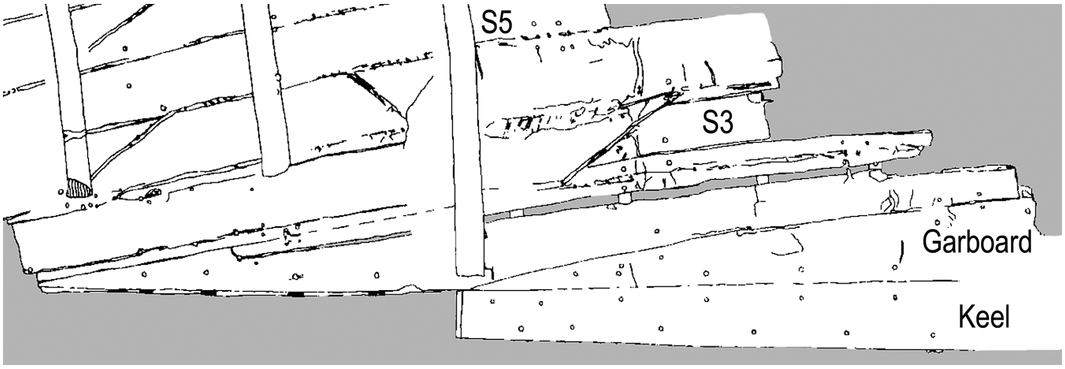

Figure 22. Detail of the only published *in situ* archaeological drawing, a long longitudinal fracture in visible between the second and third strake (after Negueruela *et al.*, 1995: fig. 11).

them watertight. In contrast, the diagonal scarf of the eighth strake does not present stitching but does have a pegged mortise-and-tenon joint (Fig. 21).

Moreover, despite the small size of the holes and stitches, and lack of pegs locking the stitches, the system was able to withstand stress from pressures derived from hogging and sagging of the hull, as evidenced by the remains that survived prior to being lifted. The timber remains of Mazarrón 1 were unearthed severely flattened as a result of the weight of the sediment that covered the wreck for more than two and a half millennia (Fig. 2). The hull had lost most of its original curvature, especially in the areas where curvature was originally more pronounced: the fore ends of the strakes, where they connected to the stem, and the lower part of the hull. As a result, the seams had opened in the fore ends of the strakes (Fig. 2) and the second and third strake had been entirely separated by a longitudinal fracture in the second strake (Gómez-Gil and Sierra, 1996: 221) (Fig. 22). The fracture occurred along the wood grain, splitting the second strake plank along the line of pegs locking the tenons, rather than along the sewn seam (Figs 4 and 22). That suggests that the stitching was more resistant than the planking itself. This observation could be investigated further using experimental archaeology.

Evidence discussed above suggests the stitching method present in the Mazarrón 1 boat (Fig. 11) should be considered as structural, similar to that documented in the Nin wrecks and the Brigg 'raft' (Fig. 20). The stitching does not seem to be a repair or reinforcement of the hull planking added after the original construction.

This hypothesis implies that the shipwright was confident that stitching could be used as a plank fastening method and had mastered and trusted the sewing technique. It can, therefore be suggested that the Mazarrón 1 shipwright used this intricate system because stitching was an important part of a probably local shipbuilding tradition. This would align with Guerrero Ayuso's thesis that the frames of Mazarrón 1 and 2 are a remnant of an indigenous local shipbuilding tradition (2008: 59–60).

Preliminary reconstruction of Mazarrón 1

An initial report of the preliminary reconstruction of the Mazarrón 1 hull can be found elsewhere (Cabrera Tejedor, 2017, forthcoming). The rather incomplete published information regarding Mazarrón 1 and the fragmentary hull remains (keel and nine partial strakes of planking) made attempting a reconstruction a challenge: however, the 'Steffy method' (Steffy, 1994) provided the means to undertake the task (Cabrera Tejedor, 2017: 193–203). The Mazarrón 1 hull is reported as having similar, yet not identical, structural elements, overall dimensions and general shape as Mazarrón 2 (Negueruela, 2004: 230; 2006: 24; 2014: 243). Therefore, the limited data available for Mazarrón 1 was supplemented by construction details drawn from Mazarrón 2.

A graphic and a three-dimensional reconstruction were completed by the current author (Steffy, 1994: 214–215). A lines plan at 1:10 was produced (Fig. 23) in which the original profile and size of the Mazarrón 1 hull were reconstructed, resulting in estimated dimensions of *c.*8.20m overall length, a *c.*2.20m beam, and a depth of *c.*1m amidships (Table 2 and Fig. 23). This information was used to create a 3D virtual model with Rhinoceros® 4.0 software (Fig. 24). It was analysed using Delftship® naval architecture software to evaluate its hydrostatic and performance characteristics (Table 2). It must be stressed that the hydrostatic calculations are illustrative values aimed to provide a general idea of the capabilities of Mazarrón 1 as this preliminary reconstruction is an approximation based on partial remains.

Construction sequence

The evidence discussed above and the preliminary reconstruction of the Mazarrón 1 hull (Cabrera Tejedor, 2017; forthcoming) suggest that the Mazarrón 1 boat was constructed with what has been described as a longitudinal concept (Pomey, 1998: 54, 57; Steffy, 1998: 169), following the principle of shell-first construction (Casson, 1963; 1964; 1971; Hasslöf, 1963; 1972; Basch, 1972; Pomey, 1988; 1994;

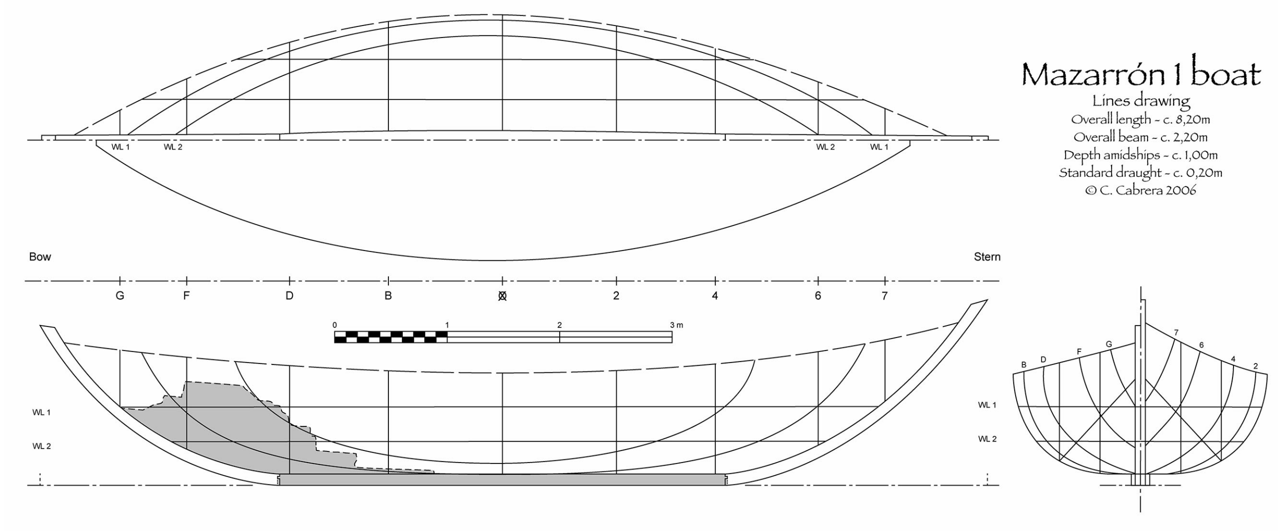

Figure 23. Lines drawing of the preliminary reconstruction of the Mazarrón 1 hull; the grey area represents the hull timber remains (scale bar 3m, ©Author).

Table 2. *Reconstructed measurements, calculations and hydrostatic coefficients of the Mazarrón 1 hull (©Author)*

Reconstructed dimensions and calculations of Mazarrón 1

Depth amidships	Overall length	Overall beam	Standard draught	Standard displacement	Length-to-beam ratio
*c.*1.00m	*c.*8.20m	*c.*2.20m	*c.*0.20m	*c.*0.500tn.	*c.*3.7:1

Different draughts and their correspondent dimensions, calculations and coefficients of the hull

Draught depth	Length on waterline	Beam on waterline	Hull volume	Displacement (saltwater)	Block coefficient	Prismatic coefficient	Waterplane coefficient
0.65m	7.127m	2.191m	4.813m^3	4.933tn.	0.474	0.580	0.659
0.60m	7.018m	2.166m	4.305m^3	**4.412tn.**	0.471	0.582	0.658
0.45m	6.655m	2.053m	2.878m^3	2.950tn.	0.468	0.585	0.656
0.30m	6.220m	1.862m	1.636m^3	**1.676tn.**	0.470	0.589	0.650
0.15m	5.689m	1.523m	1.636m^3	0.667tn.	0.500	0.591	0.630

1998; 2004; Steffy, 1995; Hocker, 2004; Pomey and Rieth, 2005), the common shipbuilding technique used in the ancient Mediterranean. The construction sequence of the Mazarrón 1 hull could be briefly summarized as follows:

1) The keel was laid, then the stem and sternpost were aligned.
2) The garboards were secured to the keel, stem and sternpost and the second strakes were fastened using pegged mortise-and-tenons spaced on average 195mm apart.
3) Consecutive strakes were added up to the ninth strake, also fastened with pegged mortise-and-tenon joints but widely spaced at 400mm on average. Diagonal scarfs in the third to seventh strakes are not fastened with mortise and tenons. Before the final fitting of these planks, their interior edges were chamfered, *c.*5mm in at an approximate 45° angle.
4) Stitch holes were drilled on both planks from the seam between the second and third strakes up to the seam between the seventh and eighth strakes, and along the scarfs.
5) Thin rope, used as waterproofing material, was placed into the V-shape grooves resulting from two adjacent chamfered edges of the planks on the interior of the hull.
6) The waterproofing ropes were held in place by simple longitudinal continuous stitching (whipstitch) that also fastened the planks in addition to the widely spaced mortise and tenons.
7) Frames, made of a single piece, were then added and fastened to the hull with several individual lashing points per frame.

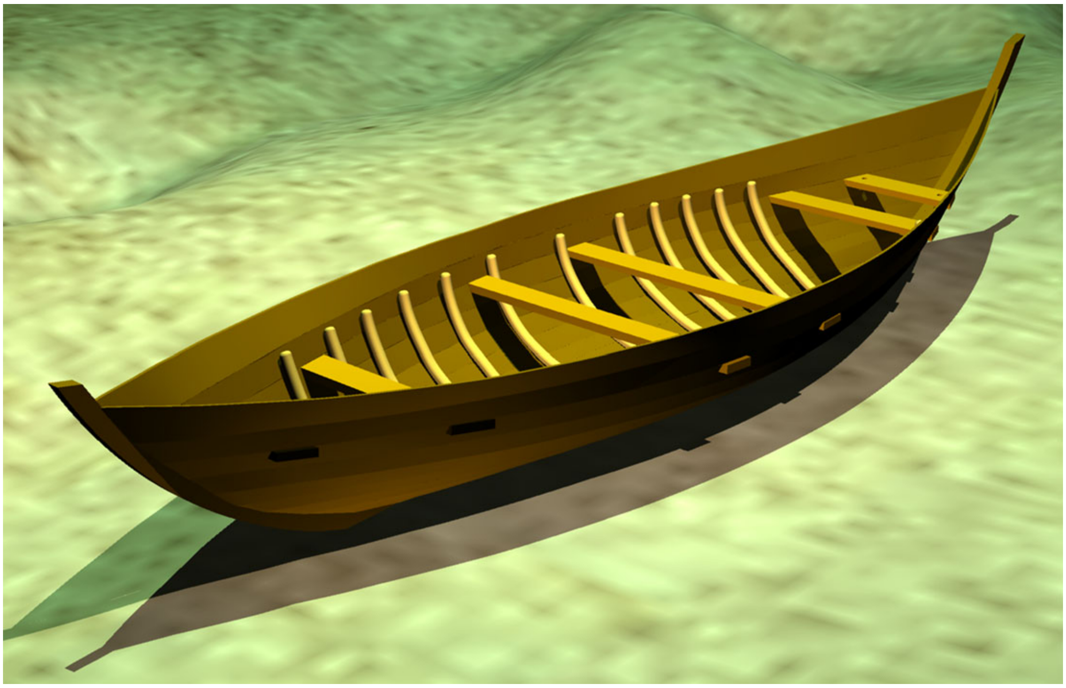

Figure 24. Computer-based three-dimensional preliminary reconstruction of the Mazarrón 1 hull completed with RhinocerosR 4.0 software (©Author).

8) A mast-step timber was then laid directly over the keel and the two frames amidships and fixed in place with mortise-and-tenon joinery.
9) It is possible that on the upper edge of the eighth (and potentially ninth) strakes, dovetailed notches were cut for fitting through-beams.
10) Analogous evidence suggests that transversal through-beams were then fitted in the dovetailed notches (Fig. 16) and these were locked in place by the strakes inserted immediately afterwards.
11) Waterproofing the internal and external surfaces of the hull with pine tar completed the construction of the hull.

Design and operational environment

The data obtained from the minimum solution reconstruction and subsequent study of the hull remains (Cabrera Tejedor, 2017) allows the following observations about the Mazarrón 1 boat. Because of its modest length (*c.*8.20m), shallow depth (*c.*1m), perceived lack of deck and, above all, its proposed limited freeboard when loaded (*c.*300–400mm), the Mazarrón 1 boat would not have been suitable for high-seas or seagoing navigation; this suggests that it was built and operated on the shores of the Iberian Peninsula. The characteristics of the proposed reconstructed hull of Mazarrón 1 would have made it very suitable for mixed, coastal, fluvial and wetlands navigation. Guerrero Ayuso (2008: 54, 55, pers. comm.) reached similar conclusions based on his examination of the published photographs of Mazarrón 2.

The proposed shape, dimensions, and length-to-beam ratio (*c.*3.7:1) of the hull would have provided the Mazarrón 1 boat with good sailing qualities, being light, swift and manageable. In addition, its small size and shallow draught (*c.*200mm in standard displacement) allowed it to navigate in shallow-water environments such as close to beaches, lagoons, rivers, inlets, wetlands, and so on. The paleo-geographical reconstruction of the Playa de la Isla archaeological site seems to indicate that the area where the Mazarrón boats sank would have been a shallow-water, marine environment during the 1st millennium BC, which gradually became saltwater lagoons around the Roman period (Roldán *et al.* 1994: 505–506).

Despite its modest dimensions, the Mazarrón 1 boat would have had a large load capacity in relation to its size. The hydrostatic calculations obtained from the reconstruction of the Mazarrón 1 hull (Table 2) indicate that it would have been able to carry, without excessively compromising safety, a maximum load of about 4000kg of cargo. These calculations refute a previous hypothesis that the Mazarrón 2 boat (very similar in size to Mazarrón 1), loaded with 2800kg of mineral lead ore (Negueruela, 2004: 235; 2006: 25; Miñano, 2014: 10), sank because of overloading (Negueruela *et al.*, 2004: 480).

This light vessel had a main mast probably fitted with a single broad square sail, the standard sail used in antiquity (Casson, 1995: 38, 70, 239), as suggested by the presence of mortises on the keel to accommodate a mast-step timber. There is no direct evidence of the use of oars on the Mazarrón 1 wreck, but it can be inferred from the size and hull shape of the vessel as well as the coastal, fluvial and riverine environments in which this boat seems to have operated. On the Mazarrón 2, however, there might be indirect evidence of the use of oars. It is reported that on the starboard side of Mazarrón 2 a considerable portion of the caprail is preserved (Negueruela, 2004: 235, 242; 2006: 25; 2014: 243; Miñano, 2014: 8), yet the presence of fulcrums for rowing, such as tholepins, has not been reported. Nonetheless, a through-beam at the bow of Mazarrón 2 is reinforced with a stanchion fitted over the stem (Negueruela, 2004: 244, figs 17, 18; 2006: 26), and two other through-beams amidships could have had similar stanchions fitted in mortises in the ends of the mast-step timber (Miñano, 2014: 8). These through-beams reinforced with stanchions might have supported the weight of crewmembers using them as rowing thwarts. The proposed position of these reinforced through-beams or thwarts, one at the bow and two amidships (Fig. 15), supports this hypothesis.

Dating the Mazarrón boats

During the surveys at the Playa de la Isla site more than 7300 pottery sherds were recovered; approximately 70% were identified as Phoenician, although in ceramics collected from the immediate surroundings of the Mazarrón 1 shipwreck the percentage increased to *c.*80% (Arellano, *et al.* 1999: 221; Barba, *et al.*, 1999: 199; Negueruela *et al.*, 2000: 1671). All the Phoenician pottery sherds found had a homogenous chronology dating to the second half of the 7th century BC (Arellano *et al.* 1999: 221; Negueruela *et al.*, 2000: 1672; Negueruela, 2004: 238). No Phoenician pottery sherds were found which definitely belonged to either the 6th or 8th century BC (Barba *et al.*, 1999: 199; Negueruela *et al.*, 1995: 191, 192; 2000: 1671). This led the excavators to assign the Mazarrón boats to the second half of the 7th century BC (Negueruela *et al.*, 1995: 189; 2000: 1672; Negueruela, 2000a: 182; 2004: 238; 2006: 22–23). Dating obtained from radiocarbon analyses conducted on wood samples from Mazarrón 2 timbers, roughly matches the chronological dates of the pottery (Negueruela, 2004: 238; 2006: 24, 25; Negueruela *et al.*, 2000: 1674).

The date of the Mazarrón 2 has been recently reviewed by De Juan (2014: 30; 2017a: 70) and Miñano (2014: 11), based on the dating of the only amphora found on board (Type Trayamar-1), considered part of the crew's equipment for storing fresh water (Negueruela, 2004: 235; 2006: 25). The former proposes a date of 625–570 BC, while the latter proposes a slightly later date of the first third of the 6th century BC.

Cultural affiliations and purpose

The excavators of the Mazarrón 1 considered the whole material assemblage found in the vicinity of the wreck when attributing a cultural affiliation to the vessel. Mazarrón 1 shipwreck was found only partially preserved (Fig. 2) and without any cargo; however, as indicated above, during surveys of the Playa de la Isla site thousands of Phoenician pottery sherds were recovered, many of them in the immediate surroundings of the Mazarrón 1 shipwreck (Arellano *et al.,* 1999: 221; Barba, *et al.*, 1999: 199; Negueruela *et al.*, 2000: 1671). Additionally, given the context within which the boats were found (Cabrera *et al.*, 1992; Roldán *et al.*, 1994), the excavators believed that Mazarrón 1 transported the Phoenician ceramics found at the site as cargo. They also associated the wreckage with the nearby Punta Gavilanes site (Cabrera *et al.*, 1992: 42; 1997: 156), which has been identified as a long-standing mining settlement with silver smelting furnaces processing ores from the nearby Sierra de Cartagena (Ros Sala *et al.*, 2003)(Fig. 1).

In the case of Mazarrón 2, the vessel was discovered carrying a cargo of 2800kg of litharge (lead oxide) cake ingots along with one Phoenician amphora (Type Trayamar-1) (Negueruela, 2004: 235; 2006: 25). Prior to the discovery of Mazarrón 2, Maria Eugenia Aubet had provided an explanation for a vessel to be carrying a cargo of a lead ingots cargo in the 7th century BC despite the industrial or large-scale use of lead not being seen until the Roman period: the lead might have been used to extract silver from complex ores through the cupellation process (Cabrera Tejedor, forthcoming). Aubet explained that the Phoenician colonies of the Iberian Peninsula possessed an exceptional knowledge of metallurgy since they knew and employed the cupellation process (1993: 236–241).

Renzi *et al.* (2009) later supported this hypothesis having conducted isotopic analysis of samples from the litharge cake ingots from the Mazarrón 2 boat (Negueruela, 2004: 235; 2006: 25) and samples from the Phoenician settlement of La Foneta. Their study showed that the Mazarrón 2 ingots match the isotopic signature of fragments of litharge found on the La Foneta site concluding that both come from the mining area of the Sierra de Cartagena (Renzi *et al.*, 2009: 2592). They suggested that litharge from Sierra de Cartagena may have been transported by sea to La Fonteta and co-smelted with galena to recover the silver trapped in the lead oxide, making the overall processing more efficient and profitable (Renzi *et al.*, 2009: 2594). Mazarrón 2 would, therefore, attest to the long-distance transportation of litharge by sea. This hypothesis was later supported by the Bajo de la Campaña shipwreck, which, among an extremely diverse cargo, transported more than one tonne of galena ore (Pinedo Reyes, 2013: 22; Polzer, 2014: 234, 240).

Based on the material culture found at the Playa de la Isla site, Negueruela has and continues to describe the Mazarrón boats as Phoenician (Negueruela, 2000a: 179, 182; 2000b: 114; 2004: 227, 230; 2006: 22–24; 2014: 243; Negueruela *et al.*, 1995: 189; 2000: 1671; 2004: 453). Guerrero Ayuso proposed that the Mazarrón boats were transport vessels of a commercial enterprise supervised by a Phoenician colony in the Iberian Peninsula, such as Cádiz or Malaga (Guerrero Ayuso, 2008: 57); however, he pointed out that a commercial cargo is not necessarily culturally related to the vessel that transported it. Consequently, he attributed a cultural affiliation to the wrecks on the basis of the construction details of the vessels rather than the material assemblage, proposing that 'aboriginal' peoples of the Iberian Peninsula influenced by Phoenician-Punic shipbuilding techniques, built and were in charge of the Mazarrón boats (Guerrero Ayuso, 2008: 59, 60).

It is difficult to define the Mazarrón boats as either Phoenician or indigenous since they are dated to the second half of the 7th century BC; that is more than two centuries after the initial establishment of the first Phoenician colonies in the Iberian Peninsula (Aubet, 1993). The societies living in those long-established colonies of the Iberian Peninsula were the result of a complex cultural hybridization process that lasted centuries and was permanently changing (Aranegui and Vives-Ferrándiz, 2006; Vives-Ferrándiz, 2006; Álvarez Martí-Aguilar, 2009; 2013; Álvarez Martí-Aguilar and Ferrer Albelda, 2009). For these reasons, perhaps the best way to refer to the Mazarrón boats is that proposed by Guerrero Ayuso (2008: 59–60) with a small nuance, that is, the Mazarrón boats were built by local people, operated locally as transport vessels within a large and complex commercial 'Phoenician' enterprise, since large-scale commerce was supervised by the aristocratic elites of the colonies and, ultimately, by state of Tyre in the eastern Mediterranean (Aubet, 1993).

An Iberian tradition of sewn-plank boats?

The existence of local indigenous shipbuilding traditions, prior to the Phoenician colonization of the Iberian Peninsula, is attested to by iconography (Guerrero Ayuso, 2008; 2009; Rey Da Silva, 2009). On the other hand, the hypothesis that Mazarrón 1 is evidence of an indigenous sewn-plank-boat tradition in the Iberian Peninsula, is not proven due to limited evidence.

Evidence of the local construction of Mazarrón 1 is, however, provided by the smallest construction detail within the boat: the stitching. It was proposed that the location of a vessel's shipyard (geographically broadly speaking) could be pinpointed by identifying the species of the fibres used for its caulking (Black, 1999: 55, 56). Fibre identification analysis conducted on a Mazarrón 1 sample concluded that the ropes, and probably the string used for the stitching were made of esparto grass (*Stipa tenacissima L.*) (Negueruela, 2004: 236–237). *S. tenacissima* is an endemic plant of the western Mediterranean region, more precisely from the south-east of the Iberian Peninsula (that is Cartagena, Spain) and the north-west of Africa (Barreña *et al.* 2006: 5). Calibrated radiocarbon analyses of archaeological remains from the *Cueva de los Murcielagos* (Albuñol, Granada, Spain), attest to the use of *S. tenacissima* for the manufacture of extremely elaborate basketry and clothing in the Iberian Peninsula from the 6th millennium BC (Lillo Carpio, 2007: 372). In fact, 700 years later, in the 1st century AD, Pliny (*Natural History,* XIX, 7–10) described esparto grass as a valuable product of the south-eastern Iberian Peninsula, which was exclusive to this part of the Mediterranean Region. Esparto fibres are extremely resistant to rotting in seawater and esparto ropes and cordage excellent for rigging and shipbuilding. According to Pliny, the most suitable esparto plants were confined to a small area near Cartago Nova (Cartagena, Spain), whereas the variety from north-west Africa was of bad quality and useless.

The esparto used for the structural stitching present in the Mazarrón 1 boat, along with the possible existence of sewn repairs in the Mazarrón 2 hull, could be interpreted as a feature of this proposed local shipbuilding tradition on the Mediterranean shores of the Iberian Peninsula before the introduction of pegged mortise-and-tenon joints by the Phoenicians.

Conclusions

In this article the results of the preliminary study of the Mazarrón 1 boat have been presented. The direct, indirect and analogous evidence is used to formulate a hypothetical and preliminary reconstruction of the Mazarrón 1 boat. Although there is some uncertainty about the precise form of the ends and the uppermost parts of the hull, the minimum solution reconstruction of the boat and other hypotheses proposed here are firmly based on the surviving evidence.

Mazarrón 1 would have been a small boat approximately 8.20m long, 2.2m in the beam and 1m deep amidships probably with a mixed propulsion system of mast and square sail, and oars. If the sides are of a similar height to those of Mazarrón 2, it would not have been suitable for high-seas or open-sea voyaging but, rather, for mixed, coastal, fluvial, and wetlands navigation. This, among other factors, suggests that this boat was built and operated on the shores of the Iberian Peninsula. Thanks to the shape of its hull it would have had great sailing qualities, being light, fast, manoeuvrable and with a shallow draught that allowed Mazarrón 1 access to shallow environments such as beaches, lagoons, rivers, inlets, and wetlands. Despite its small size, it had a relatively large load capacity, being able to transport a maximum cargo of about 4000kg.

The Mazarrón boats have generally been termed as Phoenician and it is evident that, given the context in which these vessels were found (Cabrera *et al.*, 1992; Roldán *et al.*, 1994) and the associated material remains found in the site, they were part of a commercial enterprise likely driven by a Phoenician colony of the Iberian Peninsula (Guerrero Ayuso, 2008: 60). There is evidence, however, to suggest that a local shipwright from the Iberian Peninsula built the Mazarrón 1 boat. Although the boatbuilder had knowledge of fastening methods likely to have been originated in the eastern Mediterranean and introduced in the Iberian Peninsula by the Phoenicians (pegged mortise-and-tenon joints), other shipbuilding features, thought to be indigenous (Pomey and Rieth, 2005: 159; Guerrero Ayuso, 2008: 59), were used and retained in the construction of the hull.

The Mazarrón 1 boat presents pegged mortise-and-tenon joints in two different arrays where average spacing between tenons doubles from one zone to the other. Closely spaced tenons (195mm on average) were used as the only plank fastenings in the keel, garboards and the second strakes. For the remaining strakes, half the number of tenons per strake were employed (spacing 400 mm on average) in combination and integrated with seams sewn with longitudinal continuous stitching (Fig. 21) that pulled the planks together (Coates, 1985: 15) made of esparto grass. Sewn seams have chamfered plank edges on the interior of the hull resulting in a V-shaped grooves. Thin ropes were placed into the grooves (Figs 8, 11) that acted as waterproofing material. This arrangement shows a thorough understanding of the mechanical properties of both systems. The Mazarrón 1 hull also presents lashed cylindrical frames and unusual keel/post T-shaped scarfs.

This paper has shown that the hull of Mazarrón 1 presents a mix of shipbuilding techniques, some that likely originated in the eastern Mediterranean, and others only recorded in this wreck. If we accept the longitudinal continuous stitching served to fasten the hull planking, and was a local method it would be the first evidence of a sewn-plank boat tradition in the Iberian Peninsula. In this scenario, the Mazarrón 1 boat would represent the confluence of two different shipbuilding technologies in a unique hybrid construction. The hull of the Mazarrón 1 wreck represents an important source of information for our understanding of ancient shipbuilding and its development during the Iron Age.

Pegged mortise-and-tenon joinery became widely employed in shipbuilding during the Roman period (Steffy, 1994: 43, 46, 77–78, 83–84; Casson, 1995: 203) and the progressive assimilation of this technology in the Mediterranean by other shipbuilding traditions for fastening hull planking has been proposed (Kahanov and Pomey, 2004). Two questions could be then posed: Was there a technological transition from a pre-existing tradition of sewn-plank boats in the Iberian Peninsula with the assimilation of eastern Mediterranean technology of pegged mortise-and-tenon joinery? Was the Mazarrón 1 boat an oddity of its time, or was it an ingenious boatbuilding solution representing an intermediate stage of this technological transition? The limited examples that we have do not allow us to answer this. When further evidence for iron-age boatbuilding in the western Mediterranean is obtained, it may well be necessary to reassess the hypotheses proposed in this paper. We can look forward to future work on this topic.

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Notes

1. The official permit was granted on June 2008 (*Nº Ref. CCJD/DGBABC/SME, Nº Expte. 34/08*) and access to the materials at the ARQVA Museum was granted on August 2008 (*Nº Rº de salida, 568/2008–Museo ARQVA*) to both the Mazarrón 1 timber remains and the archive collections (i.e. photographs).

References

Álvarez Martí-Aguilar 2013, Definiendo Tarteso: indígenas y fenicios, in J.M. Campos Carrasco and J. Alvar Ezquerra (eds), *Tarteso. El emporio del metal*, 223–246. Córdoba.

Álvarez Martí-Aguilar, M. and Ferrer Albelda, E., 2009, Identidad e identidades entre los fenicios de la Península Ibérica en el período colonial, in F. Wulff and M. Álvarez Martí-Aguilar (eds), *Identidades, culturas y territorios en la Andalucía prerromana*, 165–204. Málaga-Sevilla.

Álvarez Martí-Aguilar, M., 2009, Identidad y etnia en Tartesos. *Arqueología Espacial* **27**, 79–112.

Aranegui, C. and Vives-Ferrándiz, J., 2006, Encuentros coloniales, respuestas plurales: los ibéricos antiguos en la fachada mediterránea central, in *De les comunitats locals als estats arcaics: la formació de les societats complexes a la costa del Mediterrani occidental, Homenatge a Miquel Cura*, 89–107. Arqueo Mediterrània 9/2006. Barcelona.

Arellano, I., Santos J., Gómez, M., Miñano, A., Negueruela, I. and Pinedo, J., 1999, Proyecto Nave Fenicia: 2ª campaña, in *Memorias de Arqueología 9 (1994)*, 220–222. Murcia.

Aubet, M. E., 1993, *The Phoenicians and the West: Politics, Colonies and Trade*. Cambridge.

Barba, J., Negueruela, I., Perera, J., Pinedo, J., and Roldán, B., 1999, El pecio de la Playa de la Isla. Puerto de Mazarrón (Murcia), in *Memorias de Arqueología 8 (1993)*, 196–199. Murcia.

Barreña, J.A., Rivera, D., Alcaraz, F., and Obón, C., 2006, The esparto grass question: A systematic approach for a long–lasting problem in *Stipa L.*(*Gramineae*). *Novon* **16**, 5–16.

Basch, L., 1972, Ancient Wrecks and the Archaeology of Ships. *IJNA* **1**, 1–58.

Basch, L., 1986, Note sur le calfatage: la chose et le mot. *Archaeonautica* **6**, 13–22.

Bass, G.F., 1967, Cape Gelidonya: A Bronze Age Shipwreck. *Transactions of the American Philosophical Society* NS **57**, 8.

Black, E., 1999, Fibers and textiles used in the construction of the ship's hulls, in H. Tzalas (ed.), *TROPIS V, Proceedings of the 5th International Symposium on Ship Construction in Antiquity, Nauplia 1993*, 53–64. Athens.

Boetto, G., Koncani Uhač, I., Uhač, M., 2014, Navires de l'âge du Bronze à l'époque romaine en Istrie. *Dossiers d'Archeologie* **364**, 22–25.

Boetto, G., Radić Rossi, I., 2014, Au large de la Damatie. Nouvelles recherches d'archéologie navale. *Dossiers d'Archeologie* **364**, 52–55.

Brusić, Z. and Domjan, M., 1985, Liburnian boats—their construction and form, in S. McGrail, E. Kentley, *Sewn Plank Boats, Archaeological and Ethnographical papers based on those presented to a conference at Greenwich in November 1984*, 67–85. Oxford: National Maritime Museum, Greenwich, Archaeological Series 10, BAR International Series 276.

Brusić, Z., 1968, Istrazivanje anticke luke kod Nina. *Diadora* **4**, 203–210.

Cabrera Tejedor, C., forthcoming, Technology Behind the Mazarrón Boats: a Virtual 3D Approximation, in H. Tzalas (ed.), *TROPIS X, Proceedings of the 10th International Symposium on Ship Construction in Antiquity, Hydra 2008*.

Cabrera Tejedor, C., 2017, Apuntes sobre el barco de Mazarrón 1: estimación de dimensiones, reconstrucción preliminar del casco, cálculos hidrostáticos, función y origen de la nave, in M. Martínez Alcalde, J.M. García Cano, J. Blánquez Pérez and Á. Iniesta Sanmartín (eds), *Mazarrón II. Contexto arqueológico, viabilidad científica y perspectiva patrimonial del barco B-2 de la bahía de Mazarrón (Murcia). En homenaje a Julio Mas García*, 187–227. Madrid: Universidad Autónoma de Madrid.

Cabrera, P., Pinedo, J., Roldán, B., Barba, J.S., and Perera, J., 1992, Campaña de cubrición del yacimiento subacuático de la Playa de la Isla (Mazarrón-Murcia), in *II Jornadas de Arqueología Subacuática en Asturias (Gijón 1991)*, 10–21. Oviedo.

Cabrera, P., Pinedo, J., Roldán, B., Santos, J., and Perera, J., 1997, Campaña de cubrición del yacimiento subacuático de la Playa de la Isla (Mazarrón-Murcia), in *Memorias de Arqueología 6 (1991)*, 150–156. Murcia.

Casson, L., 1963, Ancient Shipbuilding: New Light on an Old Source. *Transactions of the American Philological Association* **44**, 28–33.

Casson, L., 1964, New Light on Ancient Rigging and Boatbuilding. *American Neptune* **24**, 81–94.

Casson, L., 1971, *Ships and Seamanship in the Ancient World*. Priceton.

Casson, L., 1995, *Ships and Seamanship in the Ancient World*. Baltimore and London.

CERES, nd, Database of the Ministerio de Educación, Cultura y Deporte, http://ceres.mcu.es/pages/Viewer?accion=4&AMuseo=ARQUA&Museo=ARQUA&Ninv=MZ-24-1 (accessed 9/06/2018).

Coates, J. F., 1985, Some structural models for sewn boats, in S. McGrail, E. Kentley, *Sewn Plank Boats, Archaeological and Ethnographical papers based on those presented to a conference at Greenwich in November 1984*, 9–18. National Maritime Museum, Greenwich, Archaeological Series 10, BAR International Series 276, Oxford.

De Juan, C., 2014, Les épaves de Mazarrón et de Binissafúller. La tradition ibérique d'influence punico-phénicienne. *Dossiers d'Archeologie* **364**, 26–33.

De Juan, C., 2017a, Técnicas de arquitectura naval de la cultura fenicia. *SPAL* **26**, 59–85.

De Juan, C., 2017b, Los pecios de Mazarrón y la *familia arquitectónica ibérica*. Los ejemplos más antiguos de la arquitectura naval indígena en la Península Ibérica, in M. Martínez Alcalde, J.M. García Cano, J. Blánquez Pérez and Á. Iniesta Sanmartín (eds), *Mazarrón II. Contexto arqueológico, viabilidad científica y perspectiva patrimonial del barco B-2 de la bahía de Mazarrón (Murcia). En homenaje a Julio Mas García*, 229–251. Madrid: Universidad Autónoma de Madrid.

De Juan, C., Aguelo, X., Palomo, A. and Pons, O., 2010, La construcción naval del pecio di Binissafúller (Menorca-Islas Baleares). Análisis de los restos de casco conservados, in P. Pomey (ed.), *Transferts technologiques en architecture navale méditerranéenne de l'Antiquité aux temps modernes: identité technique et identité culturelle. Actes de la Table Ronde Internationale d'Istanbul, 19–21 mai 2007*, 59–73. Varia Anatolica **XXX**, Istanbul.

Glušćević, S., 2004, Hydroarchaeological excavation and the discovery of the third sewn Liburnian ship -*seriliae*–in the Roman port of Zaton near Zadar. *Archaeologia Marítima Mediterránea* **1**, 41–52.

Gómez-Gil, C. and Sierra, J.L., 1996, Extracción y tratamientos del barco fenicio (barco 1) de la Playa de la Isla (Puerto de Mazarrón, Mazarrón). *Cuadernos de Arqueología Marítima* **4**, 217–225.

Guerrero Ayuso, V.M., 2008, Barcos aborígenes en el estrecho de Gibraltar, in *VIII Jornadas de Historia de Ceuta. Barcos, puertos y navegación en la historia de Ceuta*, 33–65. Ceuta: Instituto de Estudios Ceutíes.

Guerrero Ayuso, V.M., 2009, *Prehistoria de la navegación. Origen y desarrollo de la arquitectura naval primigenia*. Oxford: BAR International Series 1952, Archaeopress.

Hasslöf, O., 1963, Wrecks, Archives and Living Tradition. Topical Problems in Marine-Historical Research. *Mariner's Mirror* **49**, 162–177.

Hasslöf, O., 1972, Main Principles in the Technology of Shipbuilding, in O. Hasslöf, H. Henningsen and A.E. Christiansen (eds), *Ships, Shipyards, Sailors, and Fishermen. Introduction to Maritime Ethnology*, 27–72. Copenhagen.

Hocker, F.M., 2004, Shipbuilding: Philosophy, Practice, and Research, in F.M. Hocker and C.A. Ward (eds), *The Philosophy of Shipbuilding*, 1–11. College Station TX.
Kahanov, Y. and Pomey, P., 2004, The Greek Sewn Shipbuilding Tradition and the Ma'agan Mikhael Ship: A Comparison with Mediterranean Parallels from the Sixth to the Fourth centuries BC. *Mariner's Mirror* **90.**1, 6–28.
Koncani Uhač, I., Boetto, G. and Uhač, M., 2017, *Zambratija: Prapovijesni šivani brod–Prehistoric sewn boat–Una barca cucita preistorica–Un bateau cousu préhistorique*. Pula: Arheološki muzej Istre / Archaeological Museum of Istria.
Lillo Carpio, P.A., 2007, *Pedro A. Lillo Carpio y la cultura ibérica–Materiales Arqueológicos*, *Vol. 1*. Murcia.
Linder, E., 1992, Excavating an Ancient Merchantman. *Biblical Archaeology Review* **18.**6, 24–35.
Linder, E. and Rosloff, J., 1995, The Ma'agan Michael Shipwreck, in H. Tzalas (ed.), *Tropis III, Proceedings of the 3rd International Symposium on Ship Construction in Antiquity, Athens 1989*, 275–281. Athens.
Linder, E., Kahanov, Y., and Black, E., 2003, *The Ma'agan Mikhael ship: The recovery of a 2400-year-old merchantman*. Israel Exploration Society, University of Haifa, Jerusalem.
Mark, S., 2005, *Homeric Seafaring*. College Station TX.
Marlier, S., 2005, Systèmes et techniques d'assemblage par ligatures dans la construction navale antique méditerranéenne. Doctoral Thesis, Université Aix-Marseille I, Aix-en-Provence, 3 vols.
McCarthy, M., 2005, *Ships' Fastenings: From Sewn Boat to Steamship*. College Station TX.
McGrail, S., 1981, *Brigg 'Raft' and Her Prehistoric Environment*. Oxford: BAR 89.
McGrail, S., 1985, Brigg 'raft': Reconstruction problems, in S. McGrail, E. Kentley, *Sewn Plank Boats, Archaeological and Ethnographical papers based on those presented to a conference at Greenwich in November 1984*, 165–194. National Maritime Museum, Greenwich, Archaeological Series 10, BAR International Series 276, Oxford.
McGrail, S., 2001, *Boats of the World: From the Stone Age to Medieval Times*. Oxford.
McGrail, S., 2014, The Late Bronze Age Brigg 'Raft' Displayed. *IJNA* **43.**1, 174–179.
Miñano Domínguez, A., 2014, El barco 2 de Mazarrón (electronically published paper) http://www.mecd.gob.es/fragatamercedes/dms/museos/fragatamercedes/patrimonio-cultural-subacuatico/pecios/mazarron/Barco-Mazarron-2.pdf
Miñano Domínguez, A., Fernández Matallana, F., and Casabán Banaclocha, J.L., 2012, Métodos de documentación arqueológica aplicados en arqueología subacuática: el modelo fotogramétrico y el fotomosaico del pecio fenicio Mazarrón 2 (Puerto de Mazarrón, Murcia). *SAGVNTUM* **44**, 99–109.
Moity M., Rudel M., and Wurst, A.X., 2003, Mazarron 1 and 2, in *Master Seafarers. The Phoenician and the Greeks. Encyclopedia of Underwater Archaeology*, *Volume 2*, 41–49. London: Periplus.
NAVIS, nd, NAVIS II database, Mazarrón 1 shipwreck webpage: http://www2.rgzm.de/Navis/Ships/Ship058/Ship058Engl.htm (Accessed: 01-12-2017)
Negueruela, I., 2000a, Managing the maritime heritage. The National Maritime Archaeological Museum and National Centre for Underwater Research, Cartagena, Spain'. *IJNA* **29**, 179–198.
Negueruela, I., 2000b, Protection of Shipwrecks: the experience of the Spanish National Maritime Archaeological Museum, in M.H. Mostafa, N. Grimal, and D. Nakashima (eds), *Underwater Archaeology and Coastal Management. Focus on Alexandría (Alexandría, 1997)*, 111–116. UNESCO, Paris.
Negueruela, I., 2002, Excavaciones arqueológicas subacuáticas realizadas por el Centro Nacional de Investigaciones Arqueológicas Submarinas en el yacimiento de Playa de la Isla (Mazarrón). Memoria de la campaña de 1995, in *Memorias de Arqueología 10 (1995)*, 161–180. Murcia.
Negueruela, I., 2004, Hacia la comprensión de la construcción naval fenicia según el barco Mazarrón 2 del siglo VII a.C., in V. Pena, A. Mederos Carlos and G. Wagner (eds), *La navegación Fenicia. Tecnología naval y derroteros, Encuentro entre marinos, arqueólogos e historiadores*, 227–278. Madrid: Universidad Complutense.
Negueruela, I., 2006, Coagmenta punicana e bagli. La costruzione navale a fasciame portante tra i Fenici del VIIe s. a.C., in B. M. Giannattasio, C. Canepa, L. Grasso and E. Piccardi (eds), *Aequora, pontos, jam, mare… Mare, uomini e merci nel Mediterráneo antico. Atti del Convegno internazionale, Genova, 9–10 dicembre 2004*, 22–41. Florence: All'Insegna del Giglio.
Negueruela, I., 2014, The Phoenician Ships of Mazarrón, in J. Aruz, S. B. Graff and Y. Rakic (eds), *Assyria to Iberia: At the Dawn of the Classical Age*. New Haven and London: Metropolitan Museum of Art.
Negueruela, I., González Galero, R., San Claudio, M., Méndez Sanmartín, Á., Presa, M., and Marín, C., 2004, Mazarrón-2: el barco fenicio del s. VII a.C. Campaña de noviembre-1999/marzo 2000, in G. Matilla, A. Egea, and A. González (coords.), *El mundo púnico: religión, antropología y cultura material: actas II Congreso Internacional del Mundo Púnico, Cartagena, 6–9 de abril de 2000*, 453–483. Murcia: Universidad de Murcia.
Negueruela, I., Moya, A., Marín, C., Correa, C., and Pérez M.A., 1998, El yacimiento fenicio de Playa de la Isla (Mazarrón). Campaña de 1997, in *IX Jornadas de Arqueología Regional, Murcia, mayo 1998*, 27–28. Murcia.
Negueruela, I., Moya, A., Marín, C., Correa, C., and Pérez M.A., 2004, El yacimiento fenicio de Playa de la Isla (Mazarrón). Campaña de 1997, in *Memorias de Arqueología 12 (1997)*, 273–290. Murcia.
Negueruela, I., Pinedo, J., Gómez, M., Miñano, A., Arellano, I. and Barba, J. S., 1995, Seventh-century BC Phoenician vessel discovered at Playa de la Isla, Mazarrón, Spain. *IJNA* **24.**3, 189–97.
Negueruela, I., Pinedo, J., Gómez, M., Miñano, A., Arellano, I. and Barba, J. S., 2000, Descubrimiento de dos barcos fenicios en Mazarrón (Murcia), in M. Barthélemy, M. E. Aubet Semmler (eds), *Actas del IV Congreso Internacional de Estudios Fenicios y Púnicos: Cádiz, 2 al 6 de octubre de 1995*, 1671–1680. Cádiz: Universidad de Cádiz.
Parker, A. J., 1992, *Ancient Shipwrecks of the Mediterranean and the Roman Provinces*. Oxford: BAR 580.

Pinedo Reyes, J., 2013, Investigaciones arqueológicas subacuáticas en el Bajo de la Campaña 2007–2011. San Javier (Murcia), in X. Nieto, A. Ramírez and P. Recio (eds), *I Congreso de Arqueología Náutica y Subacuática Española. Cartagena, 14, 15 y 16 de marzo de 2013*, 16–25. Madrid: Ministerio de Educación, Cultura y Deporte.
Polzer, M.E., 2011, Early Shipbuilding in the Eastern Mediterranean, in A. Catsambis, B. Ford and D. L. Hamilton (eds), *Oxford Handbook of Maritime Archaeology*, 349–78. New York.
Polzer, M.E., 2014, The Bajo de la Campaña shipwreck and colonial trade in Phoenician Spain, in J. Aruz, S. B. Graff and Y. Rakic (eds), *Assyria to Iberia: At the Dawn of the Classical Age*, 230–242. New Haven and London: Metropolitan Museum of Art.
Pomey, P., 1988, Principes et méthodes de construction en architecture navale antique, in *Navires et commerces de la Méditerranée antique, Hommage à Jean Rougé, Cahiers d'Histoire* **XXXIII.**3–4, 397–412.
Pomey, P., 1994, Shell Conception and Skeleton Process in Ancient Mediterranean Shipbuilding, in C. Westerdahl (ed.), *Crossroads in Ancient Shipbuilding. Proceedings of the Sixth International Symposium on Boat and Ship Archaeology, Roskilde 1991*, 125–30. Oxford.
Pomey, P., (ed.), 1997, *La Navigation dans l'Antiquité*. Aix-en-Provence: Édisud.
Pomey, P., 1998, Conception et réalisation des navires dans l'Antiquité méditerranéenne, in E. Rieth (ed.), *Concevoir et construire les navires. De la trière au picoteux (Technologie, Idéologies, Pratique, Revue d'anthropologie des connaissances* **XIII**.1), 49–72. Ramonville Saint-Agne.
Pomey, P., 1999, Les épaves grecques du VIe siècle av. J-C. de la place Jules-Verne à Marseille, in P. Pomey and E. Rieth (ed.), *Construction navale maritime et fluviale. Approches archéologique, historique et ethnologique, Actes du 7e Colloque International d'Archéologie Navale—7th International Symposium on Boat and Ship Archaeology, île Tatihou, 1994, Archaeonautica* **14**, 147–154. Paris.
Pomey, P., 2001, Les épaves grecques archaïques du VIe s. av. J-C. de Marseille: épaves Jules-Verne 7 et 9 et César 1, in H. Tzalas (ed.), *Tropis VI. Proceedings of the 6th International Symposium on Ship Construction in Antiquity, Lamia, 1996*, 425–437. Athens.
Pomey, P., 2003, Reconstruction of Marseilles 6th century BCE. Greek ships, in C. Beltrame (ed.), *Boats, ships and shipyards: proceedings of the Ninth International Symposium on Boat and Ship Archaeology, Venice 2000*, 57–65. Oxford.
Pomey, P., 2004, Principles and Methods of Construction in Ancient Naval Architecture, in F. M. Hocker and C. A. Ward (eds), *The Philosophy of Shipbuilding*, 25–36. College Station, TX.
Pomey, P., 2012, Le dossier de l'épave du Golo (Mariana, Haute-Corse). Nouvelles considérations sur l'interprétation et l'origine de l'épave. *Archaeonautica* **17**, 11–30.
Pomey, P. and Rieth, E., 2005, *L'archéologie navale*. Paris.
Pomey, P., Kahanov, K., and Rieth, E., 2012, Transition from Shell to Skeleton in Ancient Mediterranean Ship-Construction: analysis, problems, and future research. *IJNA* **41**, 235–314.
Pulak, C., 1998, The Uluburun Shipwreck: An Overview. *IJNA* **27**, 188–224.
Pulak, C., 2005, Discovering a Royal Ship from the Age of King Tut: Uluburun, Turkey, in G.F. Bass (ed.), *Beneath the Seven Seas*, 34–47. Thames & Hudson.
Pulak, C., 2008, The Uluburun shipwreck and Late Bronze Age trade, in J. Aruz, K. Benzel and J. M. Evans (eds), *Beyond Babylon. Art, Trade, and Diplomacy in the Second Millennium BC*, 289–310. New Haven and London: Metropolitan Museum of Art.
Radić Rossi, I., and Boetto, G., 2010, Arheologija broda i plovidbe – Šivani brod u uvali Caski na Pagu, Istraživačka kampanja 2009. *Histria Antiqua* **19**, 299–307.
Renzi, M., Montero-Ruiz, I., and Bode, M., 2009, Non-ferrous metallurgy from the Phoenician site of La Fonteta (Alicante, Spain): a study of provenance. *Journal of Archaeological Science* **36.**11, 2584–2596.
Rey Da Silva, A., 2009. *Iconografía Náutica de la Península Ibérica en la Protohistoria*. Oxford: BAR International Series 1982, Archaeopress.
Roldán Bernal, B., Perera Rodríguez, J., Santos, J., Frutos, B. and Pinedo Reyes, J., 1994, El fondeadero de la Playa de la Isla. Avance preliminar, en J.L. Cunchillos and M. Molina (eds). *El Mundo Púnico. Historia, sociedad y cultura. (Cartagena, 17–19 de noviembre de 1990)*, 503–516. Murcia.
Ros Sala, M.M., Arana Castillo, R., and Antolinos, J.A, 2003, The Metallurgical Furnaces from c. IV-III B.C. of Punta de Los Gavilanes (Mazarrón Port, Murcia, Spain): An Aproximation to the Cupellation Process in the West Mediterranean, in *Proceedings to the International Conference Archaeometallurgy in Europe*, *vol. I*, 315–325.
Sierra, J.L. 2009, Tratamiento de materiales orgánicos arqueológicos empapados en agua. *Revista Museos* **14**, 55–68.
Sleeswyk, A.W., 1980, Phoenician joints, '*coagmenta punicana*'. *IJNA* **9.**3, 243–244.
Steffy, J.R., 1982, Reconstructing the Hull, in G. F. Bass and F. H. van Doorninck Jr., *Yassi Ada Volume 1. A Seventh-Century Byzantine Shipwreck*, 65–86. College Station, TX.
Steffy, J.R., 1994, *Wooden Ship Building and the Interpretation of Shipwrecks*. College Station, TX.
Steffy, J.R., 1995, Ancient Scantlings: The Projection and Control of Mediterranean hull-shapes, in H. Tzalas (ed.), *Tropis III, Proceedings of the 3rd International Symposium on Ship Construction in Antiquity, Athens 1989*, 417–428. Athens.
Steffy, J.R., 1998, Seldom discussed features of ancient and medieval ship construction. *Archaeonautica* **14**, 165–169.
Vives-Ferrándiz Sánchez, J., 2006, *Negociando encuentros: situaciones coloniales e intercambios en la costa oriental de la península ibérica (ss. VIII–VI a.C.)*. Barcelona.

