EXHIBIT A-8

DR. SEAN A. KINGSLEY

PART 8

ANNEXES 13.4 TO 13.7

ANNEX 13 (Continued)

TO

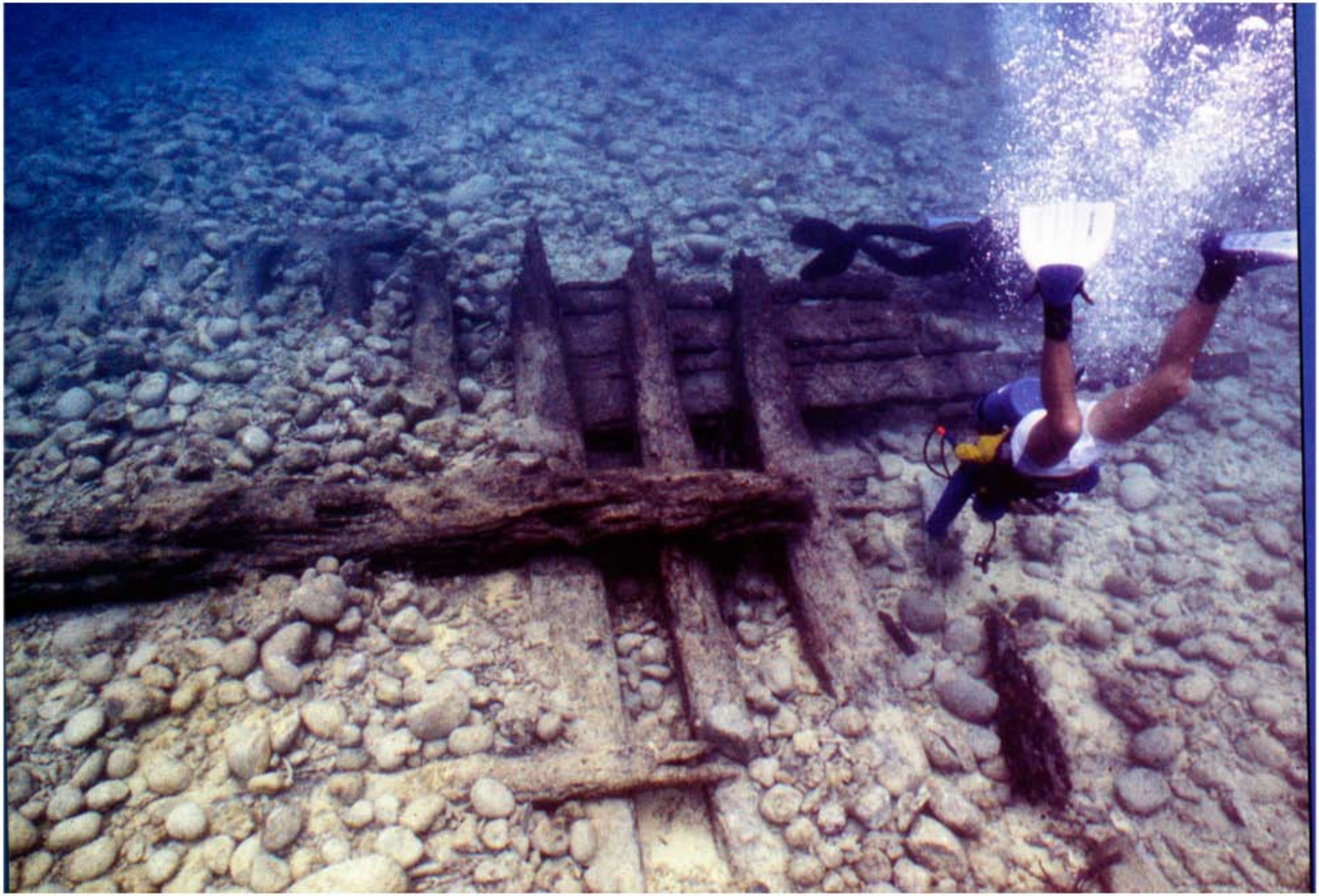
EXHIBIT A

13.4. Wooden hull remains of the *Nuestra Senora de Balvaneda*, Florida, 1733.

13.5. Wooden hull remains from the Spanish galleon off the Dry Tortugas wreck, Florida, 1622: Kingsley, S., 'Odyssey Marine Exploration and Deep-Sea Shipwreck Archaeology: the State of the Art', *Minerva* 14.3 (2003), figs. 12, 14.

13.6. Wooden hull remains from the Azores, Portugal, 15th-19th centuries: Alves, F.J.S., 'Underwater Cultural Heritage Management and Ship Archaeology – The Portuguese Experience'. In Satchell, J and Palma, P. (eds.), *Managing the Marine Cultural Heritage: Defining, Accessing and Managing the Resource* (CBA Research Report 153, 2007), 42, figs. 5.5, 5.6.

13.7. Wood report for the Arade 1 shipwreck, Portugal, 16th/17th century: Loureiro, V. and Gachet Alves, J.G., 'The Arade 1 Shipwreck: Preliminary Results of the 2004 and 2005 Field Seasons', *International Journal of Nautical Archaeology* 37.2 (2008).



Annex 13.4

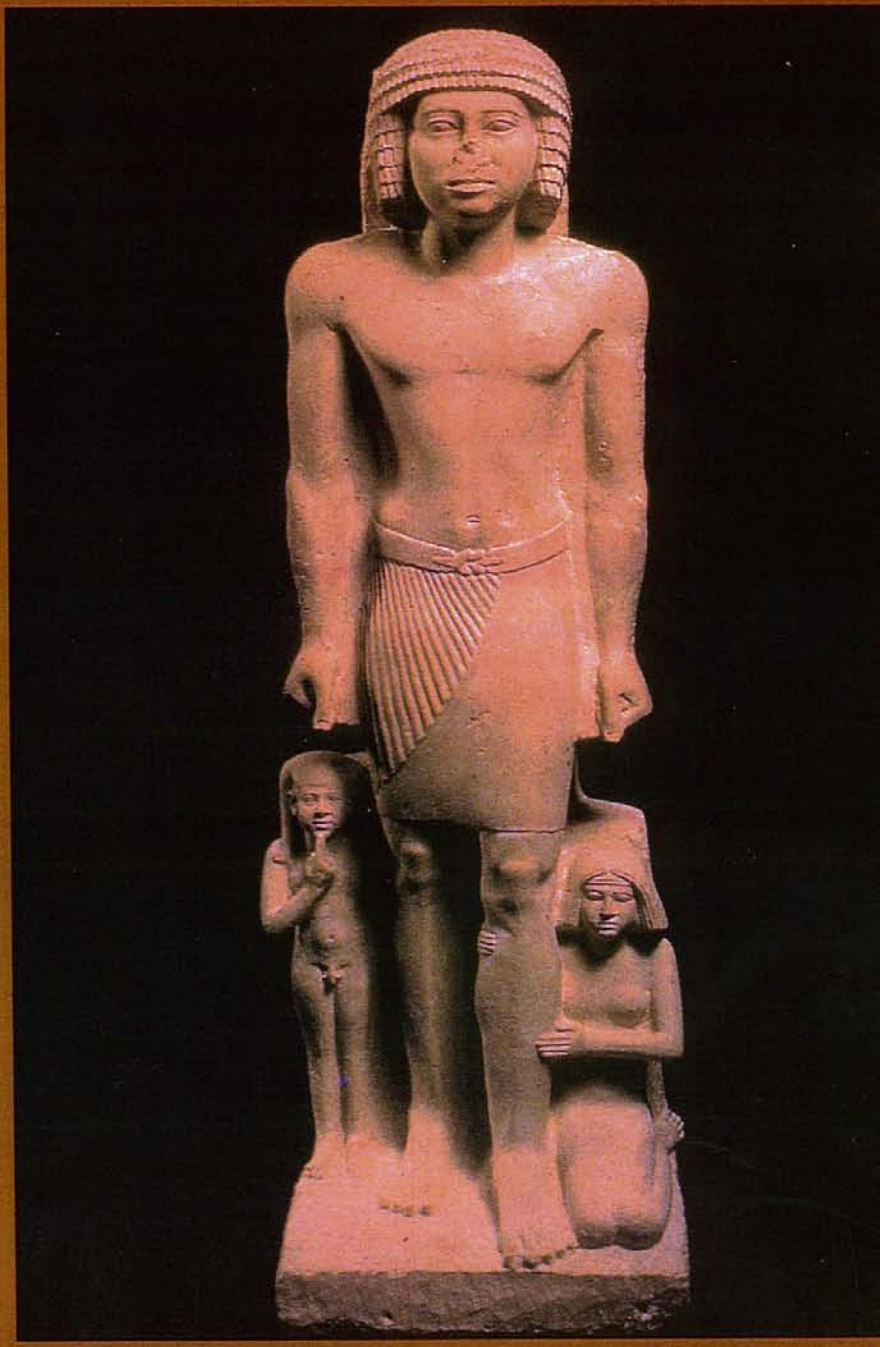
The International Review of Ancient Art & Archaeology

MINERVA

MAY/JUNE 2003 PUBLISHED IN GREAT BRITAIN £4.00/$7.99 USA VOLUME 14 NUMBER 3

A SPECIAL ISSUE ON ANCIENT EGYPT

INCLUDING A SPECIAL SECTION DEVOTED TO NUMISMATICS



Statue of a family group collected in Egypt by Dr Henry Abbott between 1839 and 1853. Limestone. C Kingdom, late 5th Dynasty - early 6th Dynasty, c. 2371-2298 BC. Said to be from Saqqara. H. 73.5 c 37.17E, Charles Edwin Wilbour Fund. On display in the new galleries of Brooklyn Museum, U

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Annex 13.5

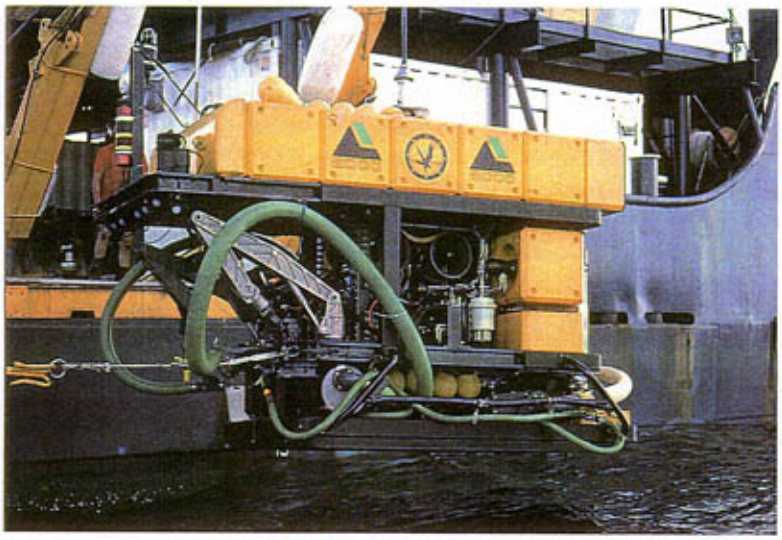


Fig 6 (left). Merlin, a 3.7m-long, 3-ton Ametek ROV equipped with six hydraulic powered positioning thrusters, titanium manipulator arms, video and still cameras, and various complex excavation tools (the tubing is attached to suction heads for air-lift excavation). This ROV was the mechanical brain behind the Tortugas excavation. © Odyssey Marine Exploration, Inc.

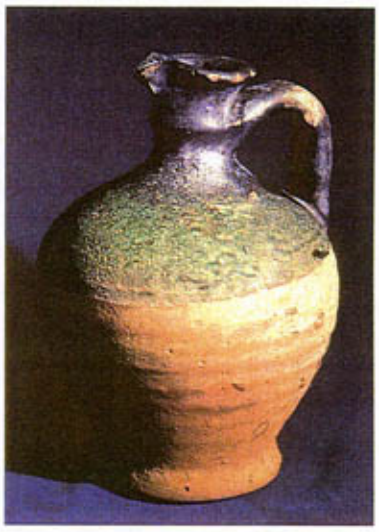


Fig 7 (above). A green-glazed coarse earthenware pitcher of Spanish provenance from the Tortugas shipwreck; AD 1622. H. 18.2 cm. Inv. 90-1A-0002864. © Odyssey Marine Exploration, Inc.

Fig 8 (below). Various artefacts excavated from the Tortugas wreck of 1622, including the ship's bell, two sizes of olive jars, astrolobes, an Andalucian polychrome juglet, and gold items. © Odyssey Marine Exploration.

Fig 9 (above). The seed assemblage from the Tortugas wreck included hazlenut and olives (top row) and plum and squash (bottom row). This material suggests that Spanish historical documentation of appalling living conditions at sea may have been exaggerated. © Odyssey Marine Exploration, Inc.

Fig 10 (below). One of several key innovations developed by Odyssey for the Tortugas shipwreck excavation included a suction limpet system. By automatically adjusting suction pressure, artefacts as varied as an olive jar or glass beaker could be successfully lifted. © Odyssey Marine Exploration, Inc.

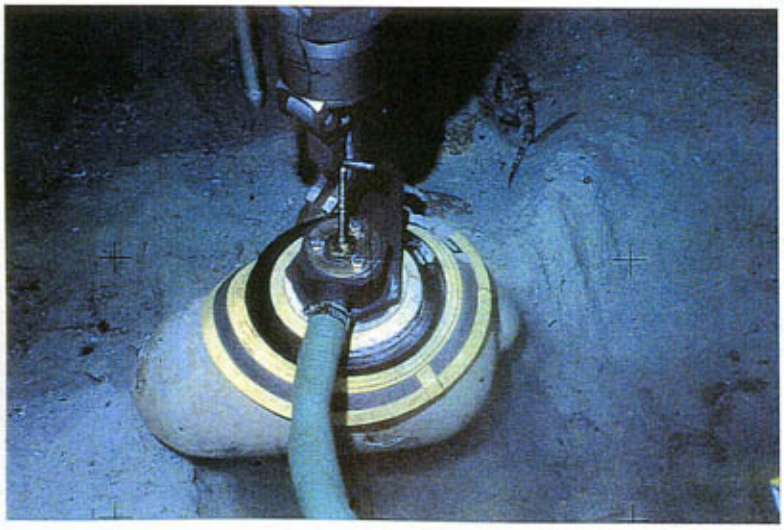


Fig 11 (below). Typical surface features of the Tortugas shipwreck, with dense layers of intact and fragmentary olive jars visible. © Odyssey Marine Exploration, Inc.

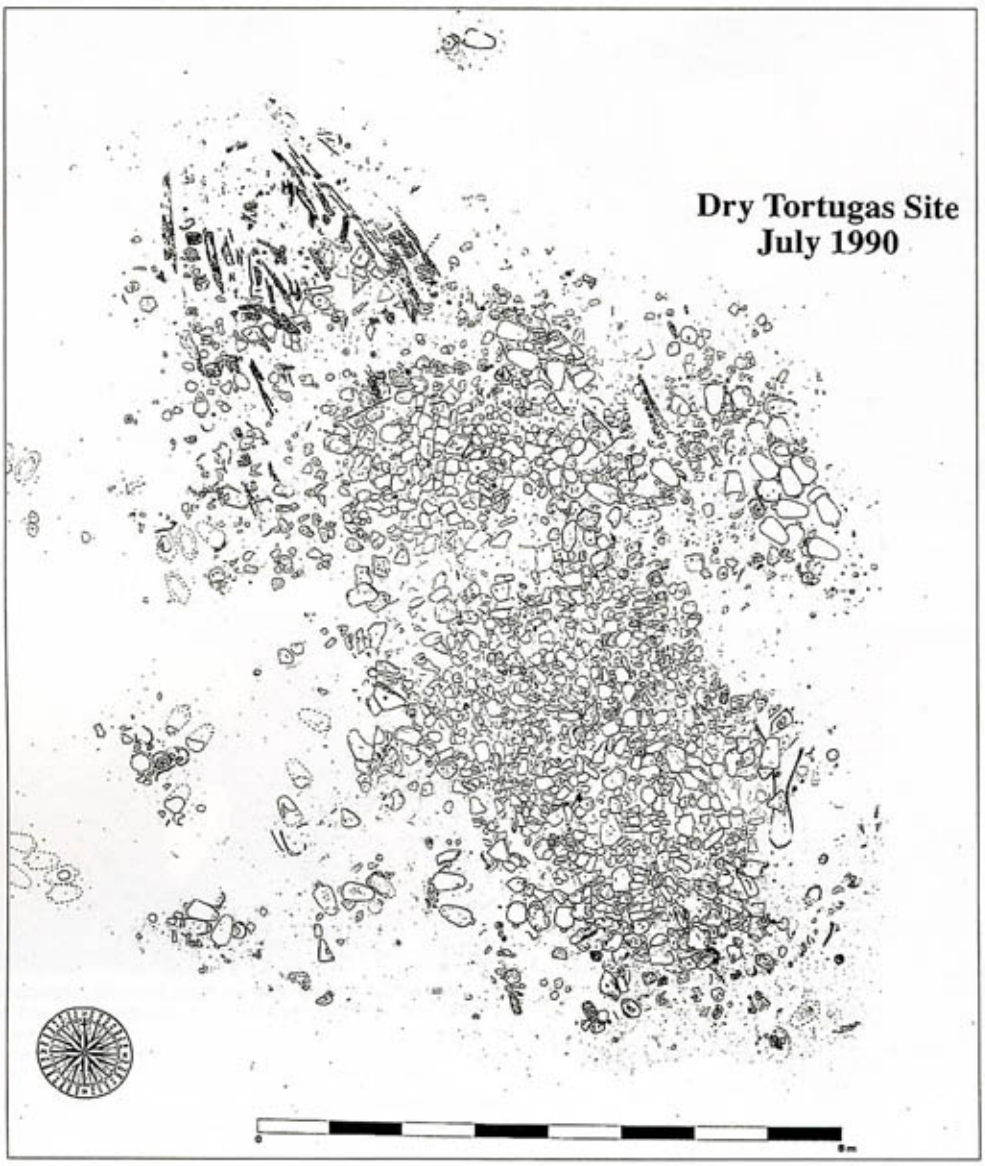


Fig 12. Site plan of the Tortugas shipwreck, a Spanish merchant vessel that foundered in the Florida Straits in 1622. All excavated material including ballast, fragmentary olive jars, and hull planking is featured. Lying in about 500m of water, this plan is the most detailed record of a deep-water wreck achieved to date. © Odyssey Marine Exploration, Inc.

Following the discovery of this shipwreck Odyssey approached the British Government and entered into a collaboration agreement to excavate *HMS Sussex* and its cargo. The portfolio of research objectives for the site's excavation - scheduled for summer 2003 - is multi-layered. A comprehensive pre-disturbance survey will produce a master site plan and include off-site sediment coring to determine the seabed's stratigraphic matrix. Just as on a shallow-water wreck excavation will proceed systematically, contextually recording all objects and wooden structures revealed to an accuracy of 5cm - quite remarkable given the site's location at such great depth. Personal belongings of the ship's crew will be sought and sediment from the wreck will be analysed for botanical materials that will help reconstruct the rigours of everyday life at sea at the close of the 17th century. In addition, the mass of modern contamination littering the wreck (fishing nets, beer cans, plastics, human waste) will be cleaned away. Study of the wreck's state of preservation will open a new chapter in the formative field of shipwreck site-formation analysis in the abyss. As in the best traditions of modern archaeology, the *Sussex* excavation will be multi-disciplinary, with all classes of artefacts, hull remains, and ecofacts studied and published by specialist scholars.

Some critics of this visionary collaboration between the British Government and a private-sector company have expressed serious reservations as to whether comprehensive excavation at such depth is feasible, arguing that appropriate technologies are a long way from being invented. However, not only is such meticulous shipwreck excavation possible, but Odyssey Marine Exploration founders Greg Stemm and John Morris have already achieved the impossible: in 1990 and 1991 this team, coupled with technical director John Astley and archaeologist David Moore, went down in history as the first group to completely excavate a deep-water shipwreck.

The Tortugas Wreck of 1622

Thirteen years ago, when Stemm and Morris initiated the excavation of a shipwreck at a depth of about 500m in the Florida Strait, 110km off Key West, no precedent existed for deep-water shipwreck studies. ROV's were untried as excavation tools and constant innovation was necessary during the project to overcome atmospheric pressure, total darkness, and to resolve methodological puzzles. A project so reliant on state-of-the-art technology required archaeologists to work closely with experts from the fields of robotics, mechanical engineering, computer technology, marine biology, and electronics.

The brain of the operation was a 3.7m-long 3-ton Ametek ROV called Merlin (Fig 8), equipped with titanium manipulator arms, video and still cameras, and various mechanical interfaces designed for complex excavation techniques. Six hydraulic powered positioning thrusters enabled Merlin to retain its position on site without stirring up sand or damaging the archaeology, even when lifting a 115kg object. Video camera fibre-optics relayed live images to monitors on the mother ship above the site, where Merlin's movements were directed automatically using joysticks.

The Tortugas shipwreck excavation witnessed a number of important innovations. Fixed acoustic transponders on the seabed constantly measured rates of sound-waves communicating between each other, enabling a transducer on Merlin to deduce its precise co-ordinates every five seconds and to thus record relative artefact positions contextually to an accuracy of 10cm. The team also utilized a 1m grid system that was incorporated into the computerised site database, enabling Merlin to excavate and record as on land within well-defined stratigraphic units. Suction heads attached to the ROV were operated automatically, offering greater sensitivity than is possible on shallow-water wrecks because air pressure could be changed immediately according to the condition and nature of artefact or structure being excavated. Rather than relying on ROV manipulator arms to lift artefacts (and possibly damage them), the team utilised a specialised suction limpet system capable of lifting objects as varied as a glass or a complete olive jar by changing suction pressure (Fig

10). Finally, an inertial filtering system was derived to enable all sediment excavated from the shipwreck to be screened for missed small finds.

The results proved astounding. Complete excavation revealed remains of a Spanish colonial Nao merchant vessel measuring 10 x 15m, with the wreck's surface characterised by wooden hull planking, 1664 stone ballast boulders, and olive jars (Fig 12). The high-level recording of the Tortugas wreck has produced some unique evidence for early 17th-century Spanish trade with the Americas. Alongside the gold (27 bars, 12 bits, seven jewellery stems, a 12m-long chain, gold and emerald ring), a diverse cargo was recovered (Fig 8). In addition to the 86 intact Spanish olive jars (height range: 27.5-34.0 cm and 43.5-56.5cm), the positions of thousands of pottery sherds were recorded and lifted, enabling the total consignment to be calculated at 209 jars (Figs 8, 11, 12). Subsequent study identified inscribed makers' marks; 2cm-thick corks imploded within jars, and remains of resin proved that vessels were sealed with pitch covering the cork and jar mouth. Chalky red stains coating the interior of some sherds suggest possible contents of red ochre, a scarlet dye derived from dried Coccus insects living on cacti.

Other cargo elements included 64 pieces of cut tortoise shell and some 400 beads of glass, crystal, wood (palm nut), and ceramic, each measuring less than 1cm in diameter. The 6639 pearls came in a bewildering array of shape and colour: round, pear, egg, drop, button, baroque, blister, white, cream, rose, silver, yellow, blue, and black (Fig 13). With diameters of 1-8mm their recovery is a reflection of the success of the sampling strategy formulated.

Finally, the archaeobotanical and faunal assemblages have revealed some unparalleled evidence for life at sea at the time. A pig tooth and tusk hint at the presence of live animals on-board. The 565 seeds sampled include peach, woody palm nut for carving beads, four intact coconuts, olives, hazelnut, a grape seed, almonds, and one melon seed (Fig 9). It is this kind of detail, alongside the inkwell and shaker excavated (indicative of a literate person on the ship), and the ability of the olive jars dated to 1622 to improve chronologies of this vessel type, that make the excavation of the Tortugas wreck scientifically significant.

Perhaps the most poignant find, however, were the rat bones excavated. These attest to part of the horror of this ship's final voyage: for 1622 is historically attested to have been a disaster year for Spanish shipping. Friar Antonio Vazquez de Espinosa was aboard one of the ships in the fleet of 1622, and wrote that the rats 'were all over the ship in great numbers, doing harm everywhere on deck, in the hold...in the pilot's chair, and although we watched for them, they ate the boxes of the soldiers and sailors and everything in them...They chewed off the tops of jars, entered and ate...' Further, some ships in this fleet are recorded as having been in particular bad repair, and the year was also plagued by fierce storms. Of the 28 ships that left Havana on 4 September 1622, the Tortugas wreck is probably one of the four merchant vessels sunk during a horrendous hurricane.

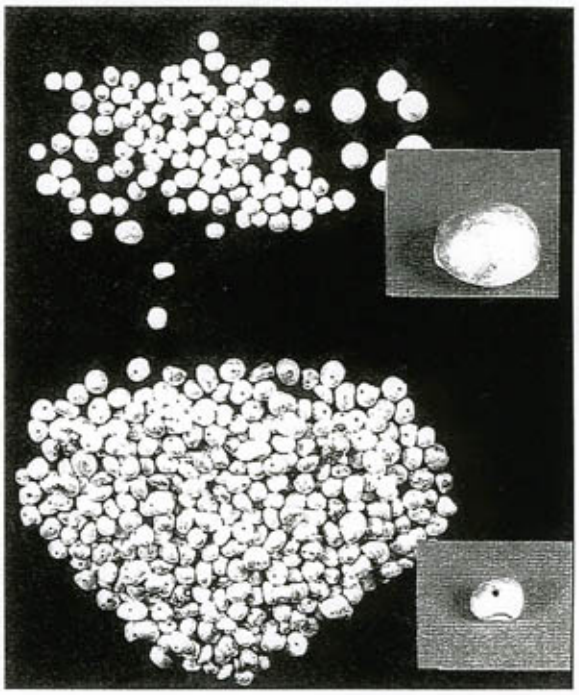


Fig 13. Excavation of the Tortugas shipwreck reovered 6639 pearls of 1-8mm diameter using an innovative inertial filtering system that enabled all sediment excavated to be screened and studied. © Odyssey Marine Exploration, Inc.

Fig 14. Section of wooden hull planking from the bow section of the Tortugas shipwreck. © Odyssey Marine Exploration, Inc.

For further information on Odyssey Marine Exploration's various projects, visit: www.shipwreck.net.

Conclusion

Just as the invention of SCUBA revolutionised mankind's knowledge of the world's seas, so current developments in deep-water archaeology will humble humanity with incredible discoveries. Historically, the aqualung has enabled divers to investigate vast stretches of unknown ancient sea-lanes, but 95% of the planet's seabeds lie at depths beyond the capabilities of this apparatus. As the impact of marine archaeologists 'driving' ROV's revolutionises the discipline, so the further endeavours of Odyssey Marine Exploration are creating new methods and standards for the future of deep-water excavation. In years to come we will hardly blink at sensational reports of unknown types of shipwrecks and cargoes found at depths formerly consigned to the imagination of the likes of Jules Verne. But for the moment it is exhilarating to be living during a watershed where the prospects of shipwreck archaeology are experiencing a quantum leap.

Managing the Marine Cultural Heritage

Defining, accessing and managing the resource

Annex 13.6

by J Satchell and P Palma

5

Underwater cultural heritage management and ship archaeology – the Portuguese experience

By Francisco J S Alves

Abstract

In the last ten years, three interrelated circumstances have completely changed the field of underwater cultural heritage in Portugal. The first was the progressive adoption of mitigation policies in waterfront works, following procedures established across many European Union countries. The second was the creation of an Underwater Cultural Heritage (UCH) specialist branch within the Portuguese Institute of Archaeology of the Ministry of Culture – the National Centre for Nautical and Underwater Archaeology (CNANS). The third was the discovery of shipwrecks every year, in foreshore, freshwater, and maritime environments. These discoveries have presented an enormous challenge for both management and research.

Introduction

Portugal is located in the extreme south-west of Europe. Its coastline stretches almost 1000km and is incised by rivers and lagoons that provide excellent harbour conditions (Fig 5.1). Some rivers like the Tagus have a wide estuary which can be navigated far upstream, these conditions have been recorded since antiquity (Strabo, *Geography*, 3.3.1). Founded as a kingdom in 1147 and geographically unified in the early 13th century Portugal had a continuous maritime tradition between the Mediterranean and the Atlantic.

There is a long tradition of maritime usage of Portugal's inland and coastal waters. Additionally, from the early 15th century, the islands of Madeira and the Azores formed part of the national territory. The geography and climate of these islands played a fundamental role in European expansion. Therefore, it is easy to imagine the huge potential for UCH in Portuguese waters.

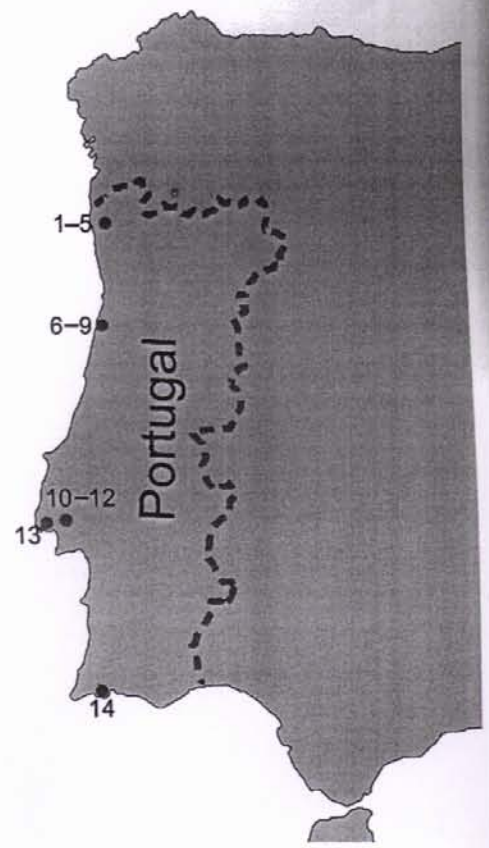


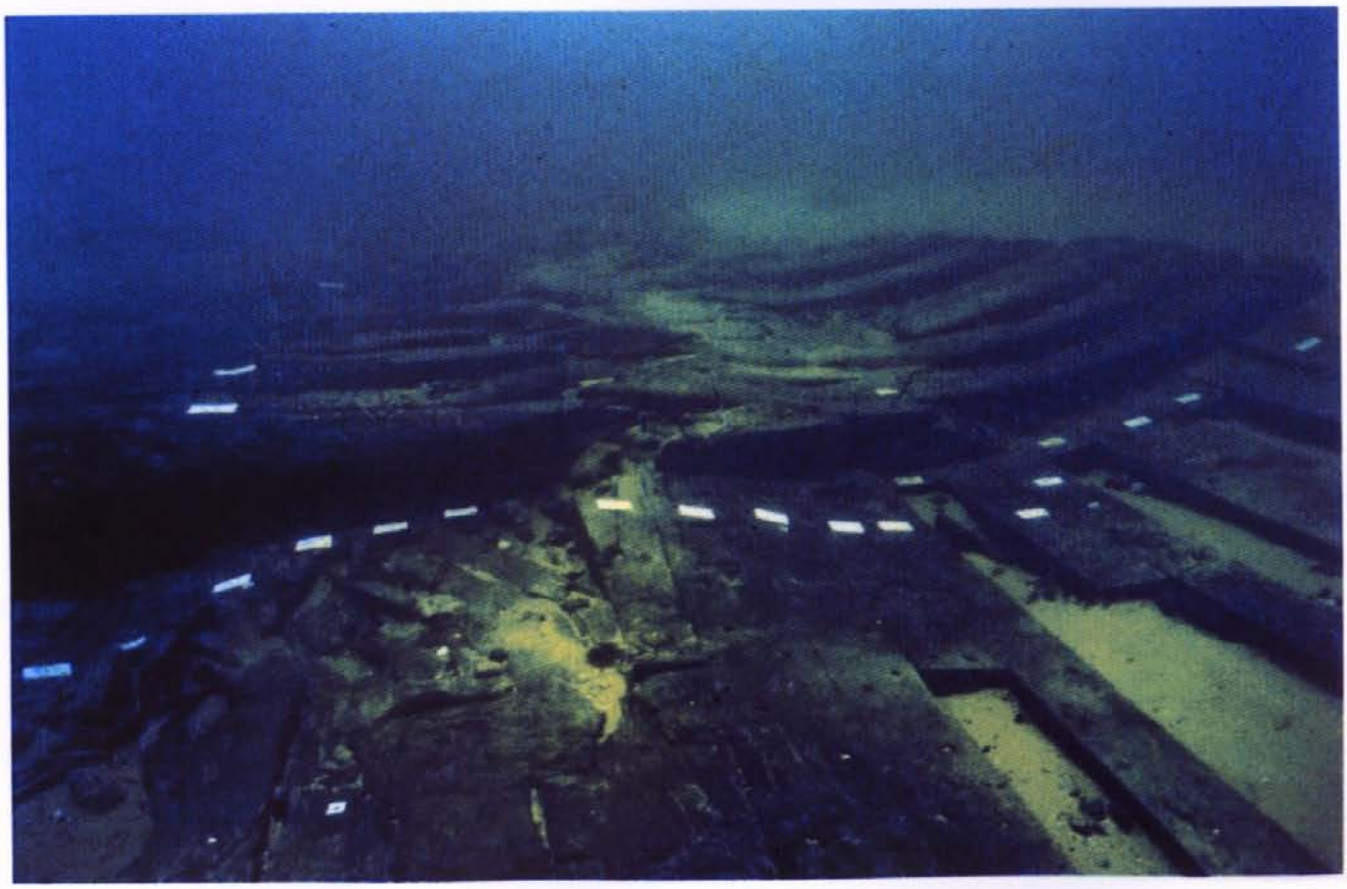
Figure 5.1 Map of Portugal. 1–5: Lima river dugouts 1 to 5; 6–9: Ria de Aveiro A, E, F and G shipwrecks; 10–12: Cais do Sodré and Corpo Santo shipwrecks, and Praça do Município Ribeira das Naus shipyard timbers (Lisbon); 13: *Nossa Senhora dos Mártires*

Figure 5.4 The Ria de Aveiro A shipwreck in 1999, at the moment of dismantling

Figure 5.5 The Angra C shipwreck, Angra bay, Terceira Island, Azores

Figure 5.6 The Angra D shipwreck, Angra bay, Terceira Island, Azores

Figure 5.7 The hull remains of the presumed Indiaman *nau Nossa Senhora dos Mártires* (The Pepper Wreck), lost in 1606 in the Tagus bar, off Lisbon



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The Arade 1 Shipwreck: Preliminary Results of the 2004 and 2005 Field Seasons

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Lost after partial destruction by dredging in 1970, Arade 1 was a priority for the Centro Nacional de Arqueologia Náutica e Subaquática (CNANS). The upper part of the hull, lying over a 7-m-long area of the bed of the Arade river, was fully observed and recorded during the first two seasons (2001 and 2002) and dismantled in a third phase (2003). The 2004 and 2005 seasons aimed at the excavation, full recording and dismantling of the lower hull, briefly observed at the end of 2002. This second, detached, portion of the hull, was buried in the sediment and corresponds to midships.

Key words: shipwreck, shipbuilding, excavation, vessel, nautical archaeology, Portugal.

The Arade 1 shipwreck was found during dredging of the main channel and turning-basin of the Arade river (Portimão/Algarve) in September 1970 (Alves, 1999: 31; Castro, 2005: 55–8) (Fig. 1). It was explored by a team of sport divers shortly after being discovered. Knowledge of some of the essential characteristics of this ship and its main dimensions comes from a report made at that time, carefully illustrated with sketches (Farrajota, 1970) (Fig. 2). However, a few years after its discovery, Arade 1, already highly fragmented, disappeared again into the silt, without having been the subject of any archaeological intervention—a situation encouraged by the lack of an official body responsible for the management of nautical and underwater cultural heritage.

In 1983, the area where the Arade 1 wreck was discovered was declared a *Património Imóvel de Interesse Público* (Public Interest Heritage Site) (Alves, 1999: 33). However, dredging continued periodically, without any archaeological input until the end of the 1990s, when the Centro Nacional de Arqueologia Náutica e Subaquática (CNANS) was created, together with legislation to protect nautical and underwater cultural heritage. In 2001, aware of the potential heritage of the Arade river, CNANS undertook a survey and investigation of the river-bed, aimed at relocating the ships discovered during the dredging in 1970 (Alves *et al.*, 2002: 3–4). On 1 August 2001 the remains of a carvel-planked shipwreck were found, and were immediately associated with the Arade 1 wreck found in the 1970s. Indeed the two shipwrecks appeared to have identical characteristics.

According to the finders (Farrajota, 1970), the shipwreck seen in 1970 had smooth planking and robust construction, and was found broken in two parts: one stuck in the sandbank in a good state of preservation as if it had been sectioned; the other completely separated, lying horizontally, in front of the first, still connected to it by some planks. The frames had a rectangular section of 13 × 16 cm, while the hull planks, approximately 5 cm thick, were fixed to the frames by treenails of 3 cm diameter. Photographs taken at the time also show the existence of relatively well-preserved ceiling planking. However, neither in 2001 nor in the archaeological campaigns which followed were any remains found of the keelson seen in 1970,

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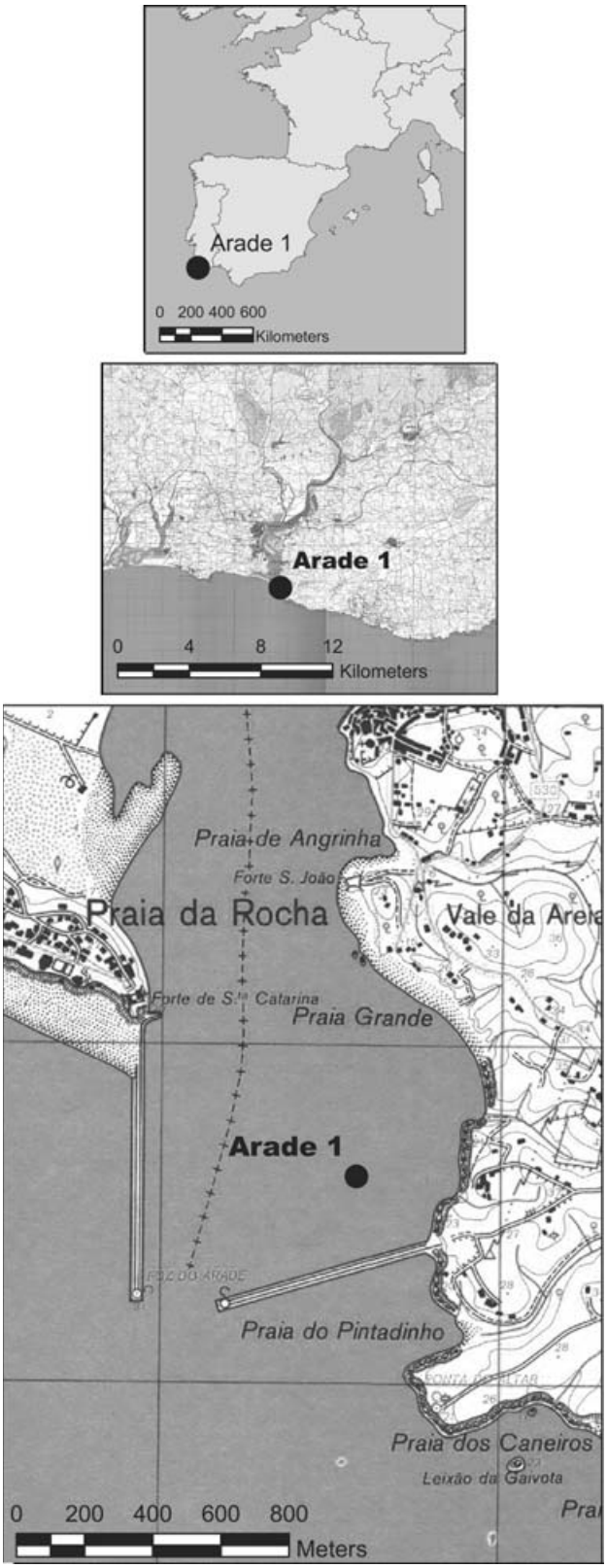

Figure 1. Location of Arade 1 shipwreck.

nor of the stringers and related wood partitions, which were photographed at the same time. Similarly no trace was found of the ship's supposed cargo (layers of grapevine brushwood covered with wicker mats). In fact, only in 2004 and 2005, the field seasons which focused on the second set of hull remains found at the end of the 2002 season, was it possible to identify decisively that the shipwreck discovered in 2001 was the shipwreck recorded in 1970.

2001 to 2003 field seasons

The remains found in 2001 consisted of two articulated structural complexes, carbon-dated to between 320 ± 40 BP and 420 ± 50 BP, most probably between the second half of the 15th century and the first half of the 17th century (Cabral, 1993; Hood, 2003) (Table 1). The upper portion of the hull, dismantled in 2003, lay in just under 6 m of water and occupied an area of approximately 21 m^2. The second structure, corresponding to the midships area, was deeply buried in the silt spreading to the west (Alves *et al.*, 2002: 5). The excavation and recording of this shipwreck (initiated in 2001 by CNANS's archaeology team) continued in the summer of 2002, under the direction of Filipe Castro, of the Institute of Nautical Archaeology at Texas A&M University. The aim of this season was the recording of the exposed hull and framing (Castro, 2002). At the same time, the archaeological team confirmed that the wooden structure had suffered significant deterioration, caused by *Teredo navalis*, over the previous year. Since its main objective was the protection of the remains, the 2003 season was devoted to the dismantling of the ship (Rieth *et al.*, 2004: 4), under the direction of Eric Rieth, CNRS and Musée de la Marine's researcher and teacher at Université de Paris 1. Dismantled piece by piece, the forward part of the Arade 1 shipwreck was transferred to CNANS's conservation and restoration laboratory in Lisbon. In view of the importance of this shipwreck for the study of 16th-century shipbuilding, the excavation and recording of the second section of coherent hull structure of Arade 1 became one of CNANS's priorities.

2004 and 2005 field seasons

Co-ordinated by the authors, the 2004 and 2005 field seasons concentrated on the midships area and on part of the aft extremity of the Arade 1

Table 1. *Arade 1 shipwreck radiocarbon dates.*

Year	Laboratory reference	Sample nature	Sample type	Date (BP)	Date calibrated (cal AD) 1 σ	2 σ
1972	GrN-7978	Unknown	Wood	325 ± 25*		
1992	ICEN-520	Unknown	Wood	420 ± 50**	1433–1481	1410–1520 1563–1630
2003	Beta-179040	Treenail	Wood	420 ± 50***	1430–1490	1420–1530 1560–1630
2003	Beta-179041	Futtock	Wood	320 ± 40	1500–1640	1460–1660
2003	Beta-179042	Frame	Wood	350 ± 40	1470–1530 1550–1630	1450–1650

* Calibration curves unknown (Alves, 1993: 151–63)
** (Stuiver and Pearson, 1986: 805–38)
*** (Stuiver *et al.*, 1998: 1041–83)

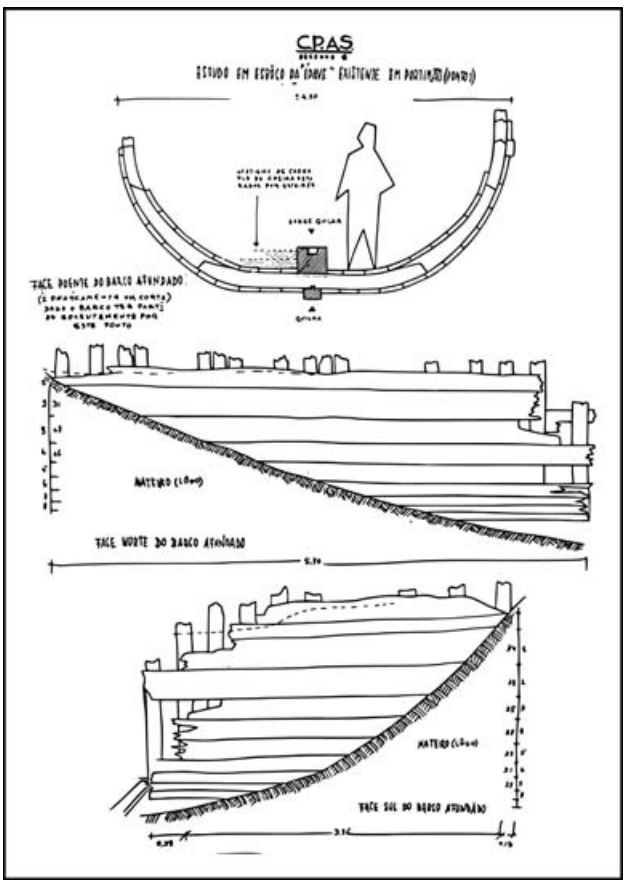

Figure 2. Arade 1 shipwreck sketches made in 1970. (Farrajota, 1970)

wreck. An extremely well-preserved and coherent nucleus was found, deeply buried in the silt, about 4 m long and 3.8 m wide. Over the surrounding area, mainly to starboard and south-west, was a spread of wooden pieces displaced from their original context, but in excellent condition (Fig. 3).

The hull is broken at both extremities. This may be the result of the two consecutive dredgings in 1970, and this appears to be confirmed by scratched fibres on the hull planking. The deterioration of the port and starboard edges, on the other hand, appears to be the result of time and the conditions in which they lay. The remains lay between 6 and 12 m deep on a slope formed by the dredges in the 1970s. Thus they show a NE/SW orientation stern and aft, with an inclination of about 40º, and SE/NW port/starboard. The entire starboard keel area lies on the NE/SW slope, while the port hull found support on the SE/NW slope. It is the nature of this positioning which explains the excellent state of preservation of the keel. In contrast, a large part of the starboard planking was not resting on the slope, having become displaced, which explains the dispersion of the planks in the starboard area (Figs 4 and 5).

In the SW zone, the accumulation of wooden pieces shows a somewhat different pattern. In addition to the various planks, which are difficult to recognise, there are stringers, floor timbers, wooden partitions, and first futtocks. Finally, there are many miscellaneous pieces associated generally with the structure. It is important to emphasise the shape of the frames detected in this area: they are frames in the process of closing, but not yet cants, of the type which would be found between the main frame and the aft of the ship. This area of the site was recorded in 2005, but not excavated, with the conclusion of the work being planned for summer 2008.

Associated with the structural remains of Arade 1 is an enormous anchor, of unknown type. It is still solidly buried, though a 2-m length of the shaft is visible. It is without doubt the anchor identified in 1970 (Loureiro and Alves, 2005: 16).

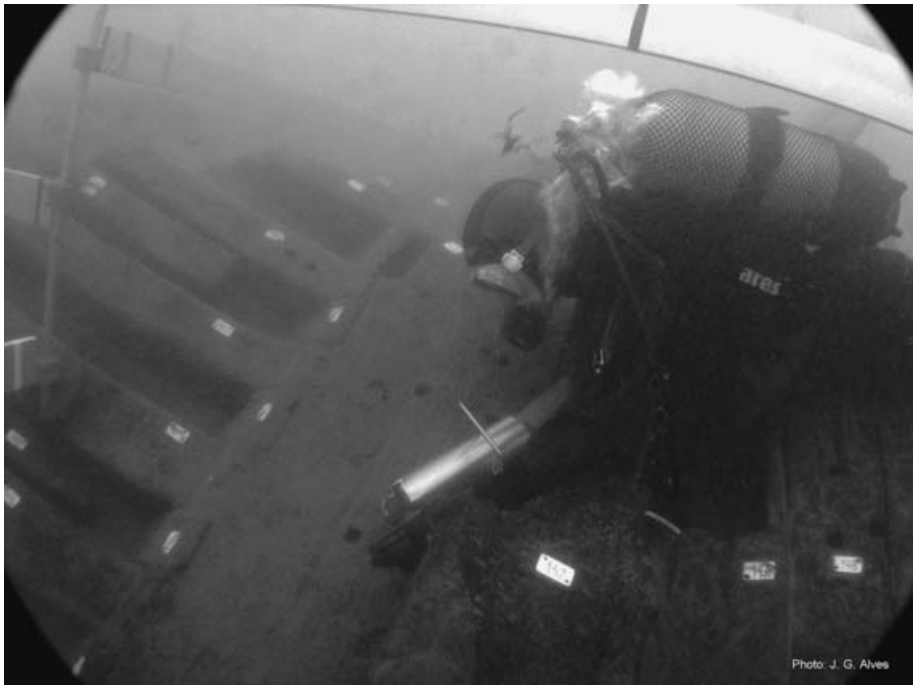

Figure 3. General view of the site. (J. G. Alves, 2005)

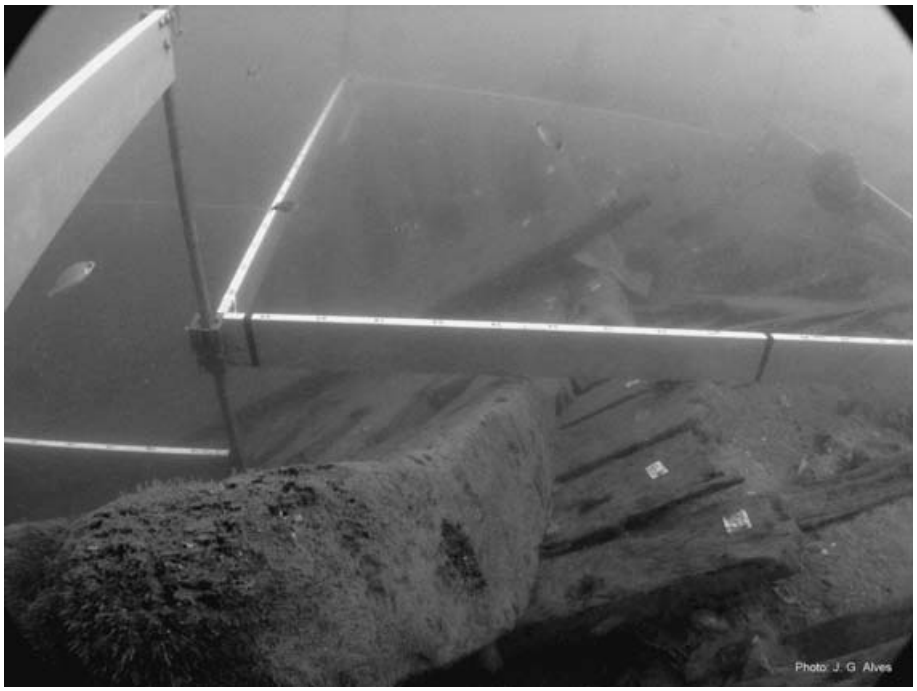

Figure 4. Excavation works, 2005 field season. (J. G. Alves, 2005)

Heavily concreted, it has a ring, with a diameter of *c*.50 cm, a small fragment of wooden stock and shaft with a 20-cm section, and it lies following the orientation of the slope and the wreckage of the ship itself.

The vessel's functional structures

Longitudinal frame

The surviving keel, which is in an excellent state of preservation, is in one piece, *c*.4 m long, and

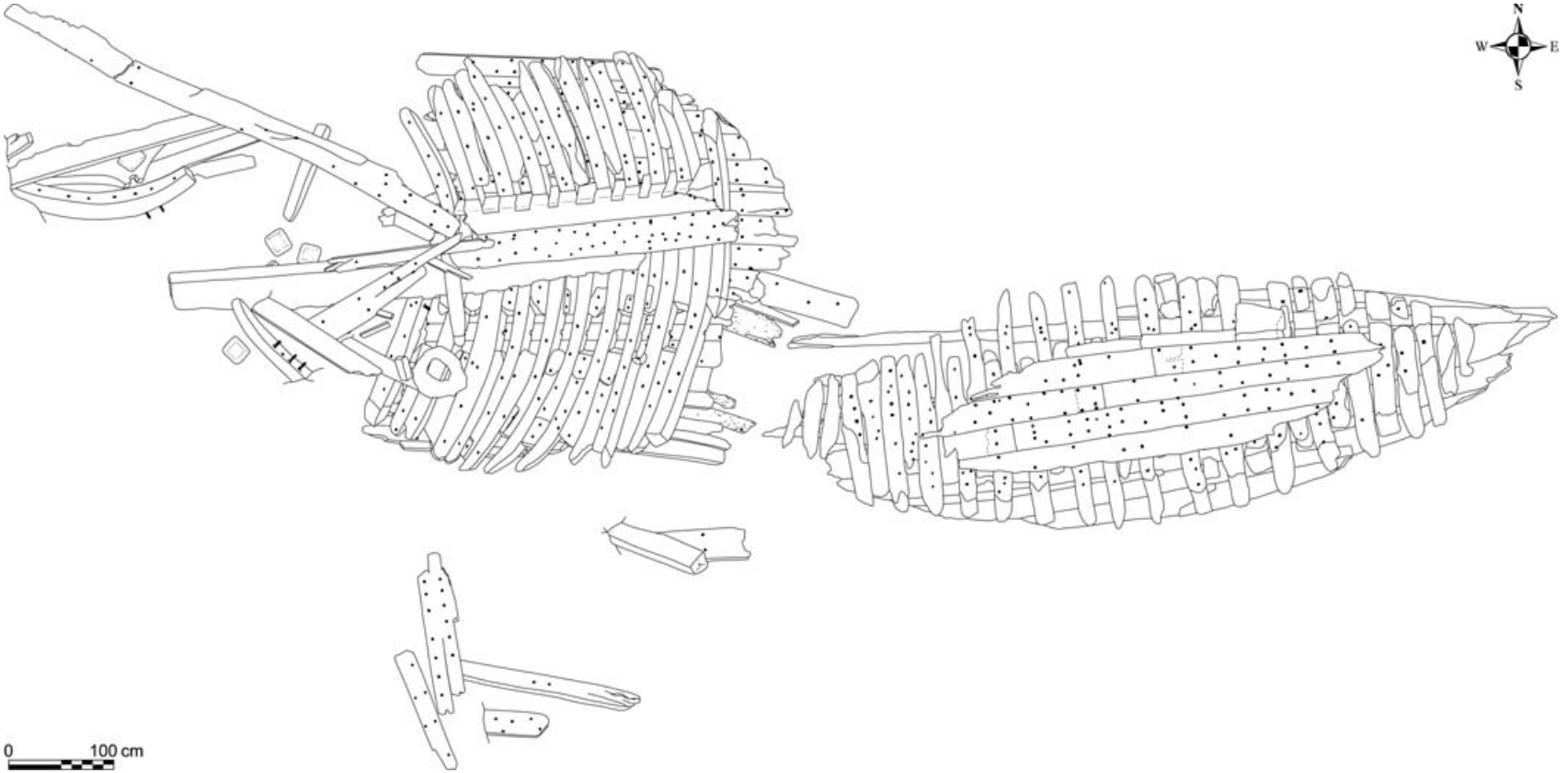

Figure 5. Arade 1 shipwreck plan made during the 2005 season. (V. Loureiro and J. G. Alves)

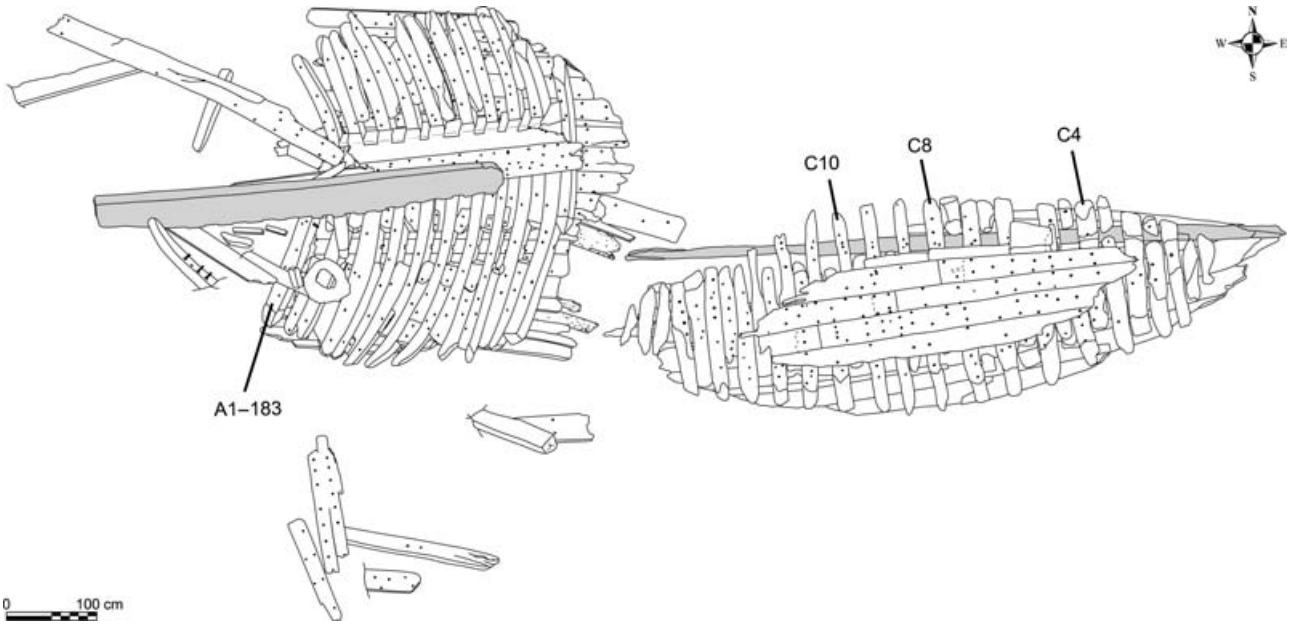

Figure 6. Identification of the keel and keelson in the Arade 1 shipwreck plan. (V. Loureiro and J. G. Alves)

in its aft end are the remains of a flat vertical scarf.[1] It has a rectangular section, about 17 cm high and 15 cm wide. These dimensions do not significantly differ between floor timbers C8 and A1–183, though from C8 the section tends to increase gradually until the area where it joins the sternpost.[2] The keel appears to be rabbeted throughout its length (Fig. 6).

The keelson was found separated from its original position, lying on its side. It is 4.4 m long and in the area of the mast-step has a section of 35 cm wide and 33 cm high. The 'dent' continues almost throughout its whole length, disappearing in the last 80 cm, where the dimensions of the section itself reduce. It is possible that this reduction is the result of erosion and not its construction. On the upper face of the keelson two large iron concretions are still visible, evidently iron bolts which connected it to the keel. The fragment of keel recovered in 2003 also has three large concretions on its underside, which were noted in the 2002 report, with the hypothesis that the keelson was bolted to the keel (Castro, 2003a).

Transverse frame

The coherent structure, recorded in 2004 and 2005, preserved ten frames, nine starboard first futtocks, ten port first futtocks, and six second futtocks also from port (Fig. 7). The assembly pattern of the transverse frame on the keel does not allow any spacing between the frame/first futtock pairs, in a clear continuation of the observations made at the extremity of the stern (Loureiro, 2004: 60). The frames have a shape in process of opening until A1–59 and closing from A1–149. The frames between these two pieces have a flat bottom, with the point at which the rods start to curve to join the curvature of the first futtocks being clearly visible. An interesting fact is that these frames have the same shape as the master-frame illustrated in the *Liuro da Fabrica das Naos* (Oliveira, 1580: 107–08).

The floor timbers are carefully cut and shaped, with a rectangular section and exceptional robustness. They all have a trapezoidal limber-hole and are connected to the keel by one or two pegs, inserted vertically into the upper side of the frame. The timbers have identical dimensions, the only exceptions being A1–161 and A1–179, substantially thicker than the others (in fact almost double). This dimensional homogeneity has already been noted in timbers C6 to C17, which like the pieces just referred to, are also pegged to the keel. Timbers C2 to C5 have dimensions which do not comply with any standard, as well as a more ample and robust structure and a less careful cut. These timbers are further distinguished from the others as they do not have any system connecting them to the keel. Some timbers still have small, thin fitting-boards on the port extremity (A1–145) or on both extremities (A1–161, A1–149 and A1–140), which enable the levelling of the framing, possibly to fit the stringers better.

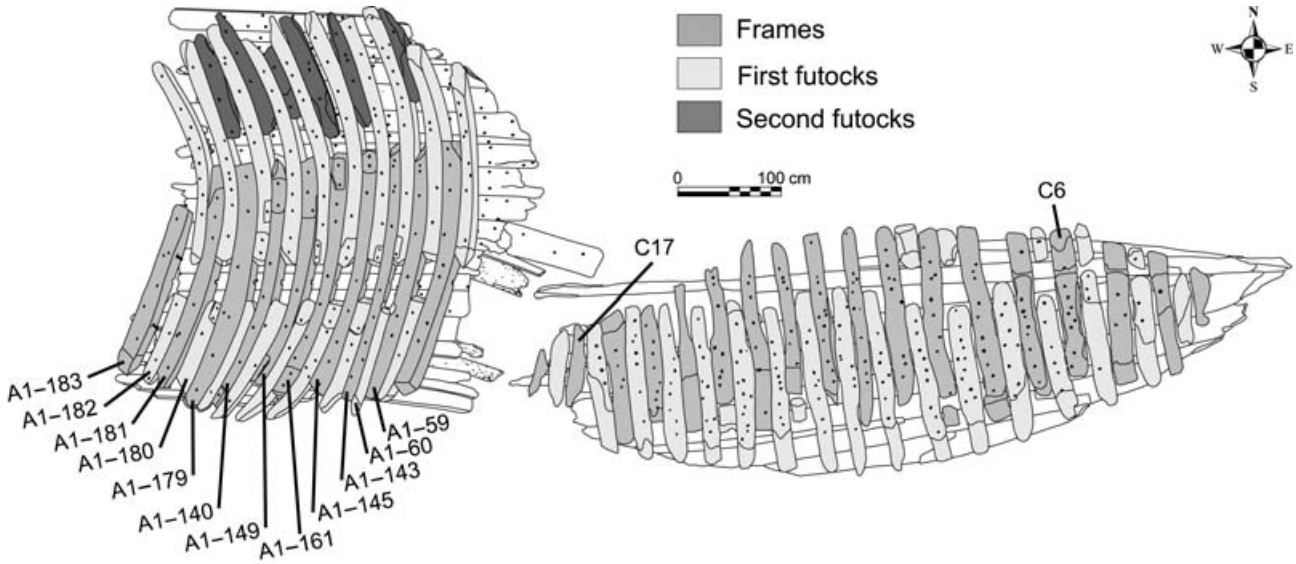

Figure 7. Identification of the frames, first-futtocks and second-futtocks in the Arade 1 shipwreck plan. (V. Loureiro and J. G. Alves)

The pump sump is carved between frames A1–59 and A1–143, reaching the end of the first futtock A1–60. The first futtocks have a section identical to the floor timbers, reaching lengths greater than 2 m on the port side. Only the first futtock of A1–180 has a more delicate appearance and is narrower than the average, and breaking with the assembly pattern of the framing on the keel—that is, only at this point is there spacing between the two pairs. Like the floor timbers, the first futtocks are carefully cut and almost all of them, from the surviving upper ends to the keel, have small thin fitting-boards. The horizontal connections between the floor timber and the first futtock were made by wooden pegs with an average of 4 or 5 per pair. This rhythm is interrupted at frames A1–143 and A1–161, where the pegging is more frequent.

One of this wreck's peculiarities is in the system of fastening the frames. Apart from the connections between the floor timbers and the first futtocks, there are connections between the composite frames themselves (with the exception of pairs A1–179/80 and A1–181/2). The perfectly horizontal orientation of the pegs is also enlightening—first futtocks were fastened to the floor timbers before the assembly of the pairs on the keel. The second futtocks, in turn, despite being as robust as the other pieces of the frame, are less carefully cut. In the same way, the carpenters do not appear to have been concerned about avoiding open spaces between the framing pieces in this area of the ship. The second sets of first futtocks are only pegged to the exterior planking.

Planking

The hull is carvel planked, with no fixings between one plank and the next. That is, the ship has a smooth hull, common throughout the Atlantic and Mediterranean regions since Classical Antiquity. The planks are straight and only connected to the transverse frame of the ship with a system of two pegs per frame, first futtock or second futtock. There are ten strakes on the port side of the keel, with a total of 19 pieces, and six on the starboard, with a total of seven pieces (Fig. 8). The relationship between the two halves of the hull is demonstrated by the dimensional homogeneity of the planks—that is, although the pieces all have distinct dimensions, plank St1 Bb has the same width as St1 Eb, St2 Bb matches St2 Eb and so on.

The connection between planks of the same run is made edge against edge. Although the hull planks are normally fixed to the frames by wooden pegs, at the scarfs there are, without exception, two iron nails, a clear reinforcement of the connection between the planks, and a similar situation is seen at the extremity of the stern (Loureiro, 2004: 77). The planks vary in length, reaching up to 3.2 m (St4 Eb). Their widths range between 250 and 315 mm, although the most common dimension is around 280–290 mm. The thickness varies from 45 to 55 mm. The existence of

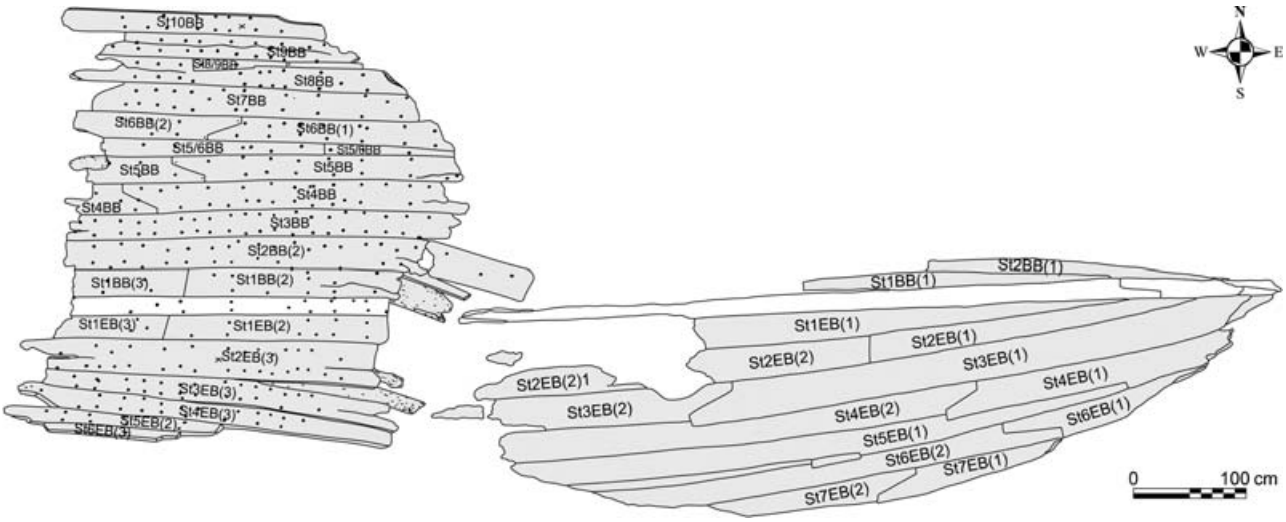

Figure 8. Identification of the hull planking in the Arade 1 shipwreck plan. (V. Loureiro and J. G. Alves)

two narrower sets of boards should also be mentioned: filling pieces or stealers between planks St8 Bb and St9 Bb (St8/9 Bb) and between planks St5 Bb and St6 Bb (St5/6 Bb). A similar arrangement was also evident on the starboard side of the stern area (Loureiro, 2004: 77). On the exterior starboard side of the wreck two strakes were found of double the normal thickness.

The garboard strakes have identical characteristics to the rest of the strakes, although they are slightly thinner. There is no connecting scarf between the planks, which are simply butt-joined. These are not connected to the keel, but are bevelled to fit snugly into the keel rabbet. This suggests that iron nails were only used to fix the garboard strake to the keel as the planks rise towards the extremity of the ship's stern (Loureiro, 2004: 79). In this area, the remains of ceiling planks are scarce, with only a port stringer and the board immediately following still *in situ*. The pieces accumulated in the SW area appear to include many ceiling planks, but their positive identification has still to be made.

The stringer is 3.5 m long and of identical thickness to the adjacent plank (6 cm). The stringer preserved on the left side of the lower portion of the hull covers the floors' extremities and presents notches where filler pieces were inserted. These filler pieces located between the first futtocks prevented the infiltration of debris among the transverse frame. This piece was found still connected to the first futtocks by a peg or an iron nail inserted into the tooth of the stringer—many of the teeth were broken during the process of dismantling the ship because of difficulty in sawing the pegs. There are still nine wooden partitions *in situ*. These were not connected to any piece, and by their oblique orientation and perfect notching between the first futtocks, show that they had to have been hammered into position. As for the board from the ceiling planking, there is nothing to mention except for the pattern of the timber and the first futtocks' pegging, which is in perfect union, in contrast to what was seen during the dismantling of the ceiling planking from the extreme aft of the ship in 2002 (Castro, 2003a) (Fig. 9).

Analysis

The strong build of the Arade 1 wreck is evident through both its transverse and longitudinal structure. All the essential wooden pieces of the ship show robust dimensions and sections, and special care in their cut and shape is evident. This idea of strength is also demonstrated by the solidity of the framing, with no spaces between the floor timbers and futtocks, and by the method of assembly, based mainly, but not exclusively, on treenails. The hull planking, which shows traces of a white paste which must be caulking from the plank joints, covers all this framework, but does not seem to have played an active role in determining the hull form. All the indications therefore show that the Arade 1 shipwreck was a 'skeleton-first' ship. This means that the hull shape was defined by the individual design of each frame, based on specific calculations and instruments.

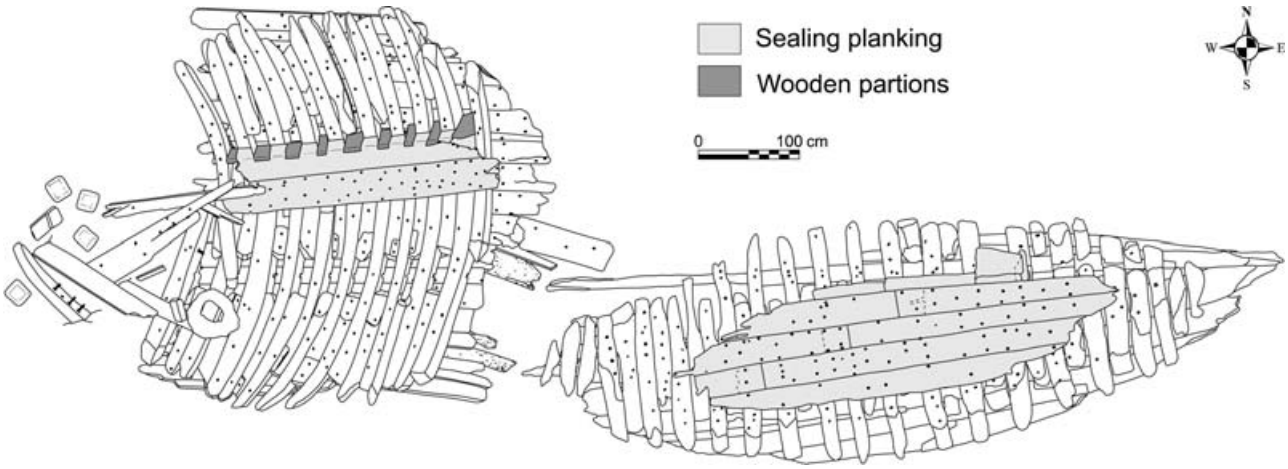

Figure 9. Identification of the ceiling planking in the Arade 1 shipwreck plan. (V. Loureiro and J. G. Alves)

However, before making any overall assumptions, it is important carefully to analyse some points.

Firstly, although the treenails which fasten the floor timbers to the futtocks show a horizontal orientation, it is important to understand how the joins between the different pairs are made and their significance to the building process. Secondly, despite the hull planking being exclusively fastened to the frames (there are no fastenings between the hull planks), it is important to determine the direction in which the treenails and iron nails were inserted (exterior/interior or interior/exterior), what is the relationship between the treenails' location and the iron nails' location, and how, or in what sequence, the second futtocks were inserted. Thirdly, the most central frames present a morphology similar to that illustrated by Fernando Oliveira for the main frame, with a flat bottom and the ends blending according to the circumference formula (Oliveira, 1580: 107–08). However, it will be interesting to determine whether the arc formed by each floor timber and its futtocks is based on a circumference of similar centre, and whether this centre is the same in each case. Fourthly, we need to verify the proportional relationship between the transverse frame and the longitudinal frame (*e.g.* does the master-frame bottom correspond to $^1/_3$ of the keel length as Fernando Oliveira proposes?).

Another question is whether the primary characteristics and particularities of the vessel might indicate a possible regional origin. For now, the possibility of a distinct shipbuilding tradition throughout the fluvial and maritime shipyards of the Arade region is just one line of research, as historical references are scarce and lacking in information, and the archaeological remains currently amount to only two coherent sites. One of them, the GEO 5 wreck, is of a date later than the 18th century (Fonseca, 2005: 15). Nevertheless, this line of research cannot be immediately abandoned, especially after the identification of a set of 20 wood samples from the Arade 1 structure. All were identified as *Quercus*; specifically 73% as Portuguese oak (*Q. faginea* Lam.), and 11% as cork oak (*Q. suber* L.) (Queiroz *et al.*, 2005: 2). The Portuguese oak is a species of Iberian distribution, while the cork oak can be found through the entire Mediterranean region. Thus, a probable regional origin, at least for the wood, is a logical hypothesis.

Conclusions

The Arade 1 shipwreck in one of CNANS's priorities within its 'Ship Archaeology' strand of research, having been the subject of five archaeological investigations (a total of 245 days of fieldwork, 1237 dives and 1700 diving hours). Dated to between the second half of the 15th century and the first half of the 17th century, this site is of twofold importance.

From a shipbuilding perspective, it is characterized by its excellent preservation. Among the nautical remains already excavated on the Portuguese coast, the Arade 1 shipwreck is the only one preserved almost complete from the stem to the main frame. Probably the isolated wooden pieces discovered in the surrounding areas will allow a partial reconstruction of the vessel aft of the main frame. The discovery, to the south-west of the main structure, of a closed frame from the

stern will perhaps allow the reconstruction of this end of the ship. The recovery of two strakes on the starboard side may also be significant in determining the design and construction of the vessel.

In attempting to place the shipwreck within a discrete shipbuilding tradition, the data is yet scarce and only after the conclusion of the analysis of structure and hull-form will realistic hypotheses arise. It is not yet possible to place the vessel within the context of navigational or commercial networks. This question may remain forever inconclusive, as the few artefacts or organic remains recovered do not offer much information. Between the frames were recovered two tin plates and a little tin cup, an olive jar, one cauldron and some fragments of ceramics, amongst them an enamelled plate (Castro, 2003b; Loureiro and Alves, 2005: 46–68). These pieces are mainly characteristic of the 16th and 17th centuries; however, we cannot make any assumptions about whether they were cargo or objects of the crew's daily use. Similarly, the grapevine brushwood,[3] the osier remains (Loureiro and Alves, 2005: 16) and the nut (Castro, 2003b) found between the frames provide no clear evidence as to their purpose.

The last season on the Arade 1 wreck, scheduled for 2008, will concentrate on the SW part of the side, which is full of isolated wooden pieces. The possibility that further structural remains may be found should not be discounted.

Notes

1. The fragment of keel recovered in 2003 is made up of two pieces joined by a smooth-edge scarf, which is developed between frames C8 and C10. The scarf is fixed by two wooden pegs which transversally cross the keel, and is reinforced by two iron nails inserted in the port and starboard extremities of the scarf. This method of mixed fixings demonstrates a robust longitudinal cohesion system.
2. At the level of frame C4, the section is 22 cm high by 14 cm wide (Loureiro, 2004: 45). The sternpost holds an identical section (25 cm high by 17 cm wide), also with rabbet throughout its extension, in a clear continuation of the keel.
3. These were identified by the Centro de Investigação em Paleoecologia Humana e Arqueociências as *Vitis vinifera* L. (Queiroz *et al.*, 2005: 4–5) and dated by C14, by the Instituto Tecnológico e Nuclear, from 210 ± 40 BP, what corresponds at 2σ to the probability intervals of 1530–1537 cal AD and 1635–1696 cal AD (Soares and Prudêncio, 2005).

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