UNDER THE MEDITERRANEAN I

Studies in Maritime Archaeology

edited by
STELLA DEMESTICHA & LUCY BLUE

WITH KALLIOPI BAIKA, CARLO BELTRAME,
DAVID BLACKMAN, DEBORAH CVIKEL, HELEN FARR
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HONOR FROST FOUNDATION

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Published by Sidestone Press, Leiden
www.sidestone.com

Imprint: Sidestone Press Academics

Lay-out & cover design: Sidestone Press

Photograph cover:
- Main image: Mazotos shipwreck, Cyprus (photo: Al. Erdozain © MARELab)
- Inset: Mandirac 1 near Narbonne France (photo: C. Durand, CNRS, UMR 7299–CCJ)
- Inset: *Ma'agan Mikhael II* before being launched in Haifa, Israel (photo: A. Efremov)

ISBN 978-90-8890-945-0 (softcover)
ISBN 978-90-8890-946-7 (hardcover)
ISBN 978-90-8890-947-4 (PDF e-book)

Series editor: Miranda Richardson
Copy editor: Alva MacSherry
Text preparation: Bob Holtzman

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The Mazotos Shipwreck, Cyprus

A preliminary analysis of the amphora stowage system

Stella Demesticha

Although amphora cargoes have been extensively used for the calculation of a ship's carrying capacity, less has been done about the reconstruction of their spatial arrangement – partly because well-preserved, coherent shipwrecks are rare in the archaeological record. New applications in digital mapping and 3D parametric modelling techniques have been used in the interpretation of the Mazotos shipwreck cargo, a 4th-century-BCE site off the south coast of Cyprus. The methodology, based on stratigraphic analysis, is presented in detail in this paper, with particular emphasis on the reconstruction of the cargo arrangement at the fore end.

Keywords: spatial analysis, Greek transport amphorae, shipwreck archaeology, 3D visualization.

Amphora cargoes, abundant in the Mediterranean, are an important source of information for diverse aspects of seaborne trade and economy. When little or nothing of the ship's hull is preserved, such cargoes are also the only piece of evidence at the archaeologist's disposal for estimating the ship's carrying capacity or, at least, its freight at the time of wrecking. Furthermore, well-preserved shipwrecks, with coherent stratigraphic units, can provide comprehensive information about the reconstruction of the ship's space, especially if their cargoes are accurately recorded. This is a rare class of shipwreck sites, however, with very few fully excavated examples in the archaeological record. The Mazotos shipwreck, currently under excavation, belongs to this class of site. It was found at -44 m, 1.5 nautical miles off the south coast of Cyprus, near the modern village of Mazotos, in the Larnaca District (Fig. 1). The University of Cyprus in collaboration with the Cypriot Department of Antiquities completed six excavation seasons between the years 2010 and 2018.

The shipwreck lies on a sandy, almost flat seabed and before any excavation took place consisted of an oblong concentration of amphorae, which were partly or totally visible. From the beginning of the project, careful recording, use of digital 3D technologies, and detailed stratigraphic documentation have been prioritized. Thus, although excavation is still ongoing, spatial analysis has already been possible and has shown that two to four amphora layers were stowed in several parts of the hold. Where excavation has advanced, in specific parts of the cargo, digital applications and 3D technologies have been used to reconstruct the stowage arrangement. The preliminary results are discussed in this paper, which aims to demonstrate the importance of amphora cargoes in the study of ancient ships, the potential of 3D technologies, and the methodological issues involved in building a comprehensive hypothesis of spatial reconstruction.

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in: Demesticha, S. and Blue, L. *et al.* (eds) 2020, *Under the Mediterranean I. Studies in Maritime Archaeology*, Leiden: Sidestone Press, pp. 43-58.

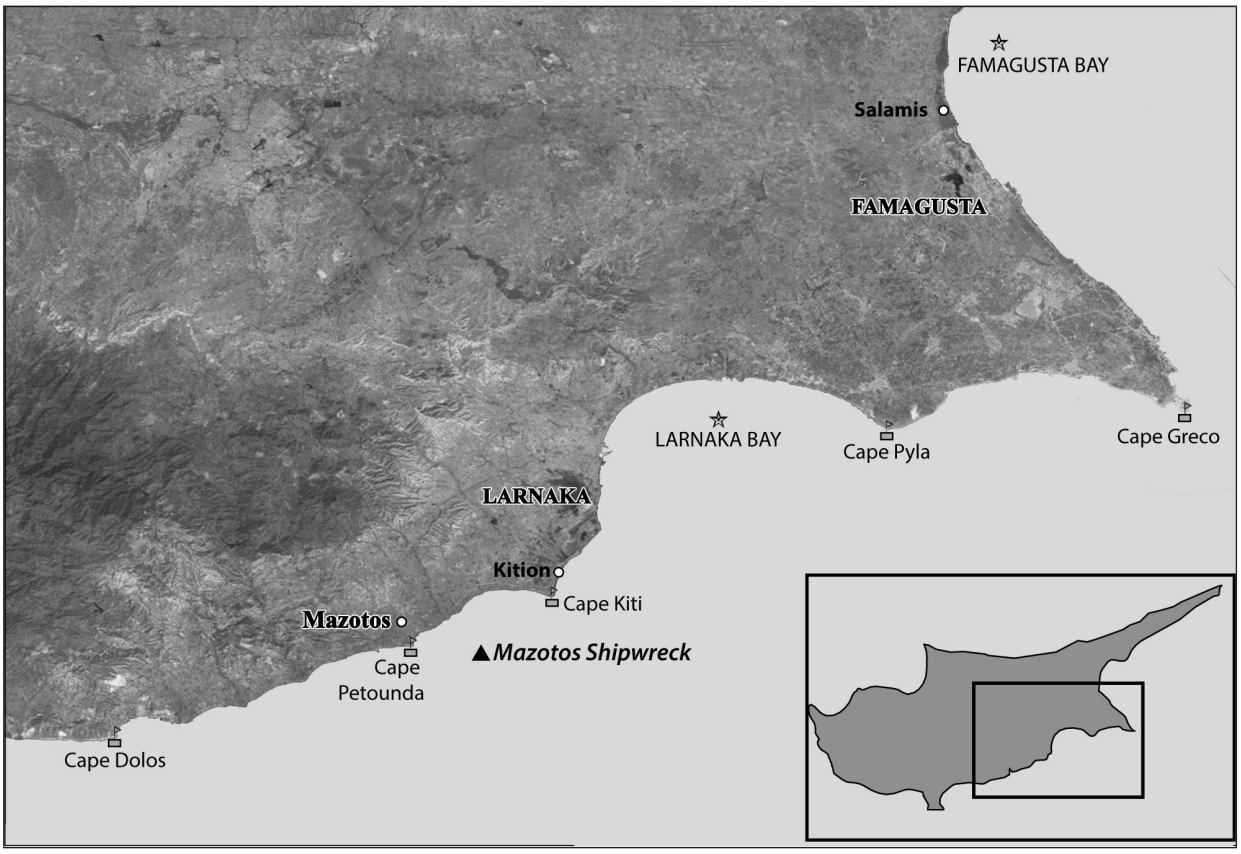


Figure 1. Map of Cyprus showing the location of the Mazotos shipwreck (Map: Andonis Neophytou, Irene Katsouri).

Reconstructing amphora stowage systems

The relationship between the shape and function of transport amphorae has been discussed in the literature either in general terms (Grace, 1979: 9; Radić-Rossi, 2006) or with reference to specific types (*e.g.* Vandiver and Koehler, 1986: 202-203 for the Corinthian amphorae). One of the commonly shared conclusions is that their elongated body shape, and their narrow bases ending in knobbed or stem-toes, made these containers suitable for stowing firmly and effectively, so that cargo shifting, and hence casualties, was avoided. A lading experiment with amphora copies carried out by the team of the Kyrenia shipwreck showed how important cargo stowage-patterns could be for the reconstruction of the ancient ship, even in cases where the hull was well preserved. Copies of 384 amphorae were loaded into the hold of *Kyrenia Liberty*, a full-scale replica of the Kyrenia ship, but 'the sheer volume of the jars excavated from the wreck was not fitting comfortably into the conjectured hull' (Katzev, 2008: 78); this made Steffy, who reconstructed the ship, reconsider the ship's lines and add 0.70 m to its height amidships. The cargo could not be taken into consideration in the cases of other replica ships, like those of Ma'agan Mikhael (Ben Zeev *et al.* 2009; Cvikel and Hillman, this volume) and Jules-Verne 9 (*Gyptis*) (Pomey and Poveda, 2018), because it had been seriously disturbed in antiquity in the former and was completely absent in the latter.

Hypothetical reconstructions of cargo-amphorae stowage systems have been studied since the very early days of shipwreck archaeology, particularly after Roman shipwrecks with hundreds of amphorae were excavated in France and Italy. Fernard Benoît (1961; see also Long, 1987) suggested that the Dressel 1A excavated from the shipwrecks of Grand Congloué were stowed in staggered rows ('*en quinconce*'). According to his schema, the amphorae of the upper layer were set down halfway into the lower layer. Herman Wallinga (1964: 28-36) called on the experience of a professional stevedore (a person responsible for safe stowage of cargo in modern shipping) to argue that Benoît's system would jeopardize the cargo; he proposed a more compact configuration that took dunnage – the brushwood used to secure the cargo – into consideration.

Wallinga (1964: 31) was rather pessimistic about the possibility of understanding stowage systems from shipwrecks because of the site-formation processes that affected the amphorae positions – although he certainly

didn't use this term. Almost a decade later, however, after the excavation of the Madrague de Giens shipwreck (Tchernia *et al*., 1978), things had fallen into place – or at least stowage systems were no longer just hypothetical. André Tchernia and Patrice Pomey meticulously studied the positions of the cargo items in the wreck's assemblage; not sharing Wallinga's pessimism, they tried to make the best out of an exceptionally preserved shipwreck and the accuracy that stereo-photography could provide at the time. Although three amphora layers were documented, the stowage system was reconstructed in detail only in the first two, because the upper one had been disturbed (Tchernia *et al*., 1978: 19, 21). Nonetheless, some key observations were made, the most important being that it would be very difficult to apply any single stowage pattern all along the hold because of the ship's complex geometry. Four different patterns were suggested for Madrague de Giens, in staggered rows or square configurations. Stowage in staggered rows was the most space-efficient and the predominant configuration found in that shipwreck. Excavation also confirmed Wallinga's suggestion about the dunnage: pieces of juniper, heather, and rushes were found wedged between the amphorae of the first layer.

The method developed at the shipwreck of Madrague des Giens was also used for conjectural stowage reconstructions of less well-preserved Roman sites. For the dolia wreck of Grand Ribaud D (Hesnard *et al.,* 1988: 139-140), the arrangement fore and aft of the central compartment was reconstructed with both stowage configurations, which resulted in two different quantities of stowed amphorae. However, in most reconstructions, for example of the Cala Culip IV (Nieto *et al.,* 1989: 229-231) or the Dramont C shipwrecks (Joncheray, 1994: 21, 33), the excavators opted for staggered rows both in the main part of the hold and in the ship's extremities, where the ship's shape is irregular, because it is an easily applied pattern. Even the Canaanite jars in the Late Bronze Age shipwreck of Uluburun cargo (Lin, 2003; Pulak, 2008: figs 92, 94) were 'digitally stowed' in staggered rows. This pattern was confirmed archaeologically when marks left on the outer walls of the Dressel 7-11 amphorae excavated from the Bou Ferrer shipwreck were plotted in a 3D digital environment (De Juan *et al.*, 2011: 101-102). Interestingly, in this case, the distance between the amphorae was almost 100 mm, that is much farther than the 10-30 mm attested in the main hold of Madrague de Giens. Random stowage has only been suggested for the Late Roman ship Dramont E, which carried a heterogeneous cargo (Poveda, 2012).

In all cases discussed above, the stowage-patterns were tested for one or two tiers but not more. The gap for the dunnage was not taken into consideration for the hypothetical reconstructions, except for the two cases where it was archaeologically attested – that is, in Bou Ferrer and Madrague des Giens. However, excavation of the latter showed that this gap was modified according to the position within the ship and that it played a key role in the configuration of the upper layers, and hence the height of the cargo assemblage. Moreover, room for dunnage around the containers must have been crucial if random stowage configurations were applied. Such must have been the case of heterogeneous cargoes, where unavoidable gaps created between containers of different shapes should be filled because they would jeopardize the cargo's safety. The same must be true for parts of the hold with irregular geometry, such as the bow or the hull sides.

The Mazotos shipwreck

Before any excavation took place, what was visible of the Mazotos shipwreck was an assemblage of partly buried or totally exposed amphorae lying on a flat seabed. This ship-shaped concentration was 17.5 m long and 8 m wide. Thus far, excavation has focused on the two extremities, the southern and the northern ends of the site (Fig. 2), and has provided evidence that they were the fore and aft parts of the ancient ship, as initially suspected. At the southern end, three anchors and a stone weight were found. Comparison with other shipwrecks with anchors found in situ (Haldane, 1984: 63 note 147), such as the Ma'agan Mikhael (Rosloff, 1991) and Kyrenia (van Duivenvoorde, 2012), shows that they were usually carried to the fore of the ship. The most important evidence came from the northern end of the site, however, where a cooking pot, a mortarium, and seven small vessels of tableware indicated that this was the stern cabin of the ship.

The keel was preserved to a length of 15.2 m. Only small parts of it were excavated at each end and these were found broken and partly destroyed, obviously having been exposed to woodborers for a while before the ship was buried. The starboard side of the hull is better preserved than the port side because the ship seems to have tilted to starboard after it landed on the seafloor: as a result, the cargo shifted westwards into the starboard pile, covering this side and thus protecting it from decaying.

Three pairs of lead cores and one pair of heavily conglomerated, iron arm-tips was what survived of the bow anchors (Demesticha/Δεμέστιχα, 2017: 287-288), which belonged to a known, 4th-century-BCE, wooden type, with two arms and a stock filled with molten lead – type IIA in Douglas Haldane's typology (1990: 21). The arm-tips were associated with the starboard anchor; they were found 2.2 m south of the pair of lead stocks, in a position that implies that they fell off the arms when the wood deteri-

Figure 2. The Mazotos shipwreck. 3D models of the excavated amphorae have been added to the original 3D point cloud of the site to show the progress of the excavation at the bow and stern of the ancient ship (3D model and image composition: Irene Katsouri, MARELab).

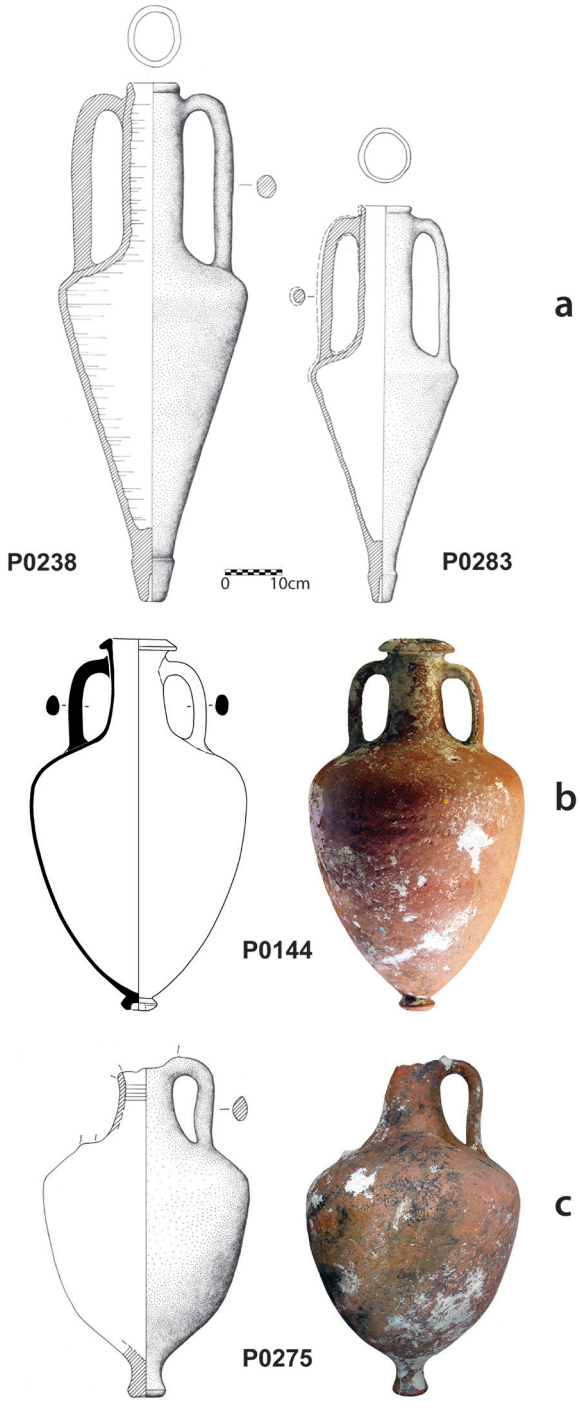


Figure 3. Amphorae from the Mazotos wreck: a) the two sizes of Chian amphorae, large (l) and small (r); b) A Solokha 1 ('Mushroom-Rim') amphora; c) possibly Lycian amphora (Drawings: Alvaro Ferreira, Jean Humbert, Image composition: Irene Katsouri, MARELab).

orated. If this was the case, then the distance between the lead cores and the tips provides a good indication of the minimum length of the anchor (Demesticha *et al.*, 2014: 146, fig. 10). A third anchor, half the size of the other two, was found next to the starboard bower anchor and under three amphorae lying on their sides; they had either fallen on top of the small anchor after the starboard side of the hold collapsed, or the anchor was stored inside the hold, next to or under them.

Between 2010 and 2016, a minimum number of 149 individual transport amphorae (MNI) were raised from the seabed. The vast majority of them belonged to a well-established type of Greek maritime transport containers from the island of Chios (Fig. 3a). They bear the typical 4th-century-BCE features of the series – a long cylindrical neck with a simple, rounded rim, a sharp-edged shoulder that continues to a conical body, and a 'dunce cap'-shaped, hollowed toe (Anderson, 1954: 170; Grace and Savvatianou-Pétropoulakou, 1970: 259-260; Lawall, 1998: 80-81). Chian amphora production has been attested since the Archaic period, with a wide distribution in and outside the Aegean. The island's wine, praised by ancient authors (Salviat, 1986: 187-92), must have been their principal content. In the 4th century BCE, in particular, it seems that Chios was one of the main exporters of Aegean wine, especially to the Black Sea, which can be associated with the involvement of Chian merchants with the transport of grain (Sarikakis, 1986: 123-124; Bylkova, 2005: 219-223). The distribution of Chian amphorae in the eastern Mediterranean during the same period seems to have been significantly smaller (Demesticha, 2009), with the Mazotos shipwreck being the only one in the region thus far with Chian amphorae as cargo.

All recovered amphorae from the shipwreck have been documented in three dimensions and their digital models have been plotted in the 3D model of the site (the process is described in Demesticha *et al.*, 2014). In order to proceed with preliminary stowing experiments of the Mazotos cargo in a digital environment, however, an average Chian amphora model was used for amphorae found in a fragmentary condition. To do this, the dimensions of 74 containers with preserved profiles were taken into consideration. They formed two consistent groups – one of large and one of small amphorae. The vast majority, 67 out of 74, belonged to the large variant: their height was 910-980 mm and their capacity (up to the top of the neck) was 22-24 litres.

Based on their capacity and linear measurements, a parametric 3D model was created with the average dimensions as follows: total height, 940 mm; neck height, 287 mm; rim diameter (external), 99.4–116 mm (oval shape); maximum shoulder diameter, 360 mm (Fig. 4a).

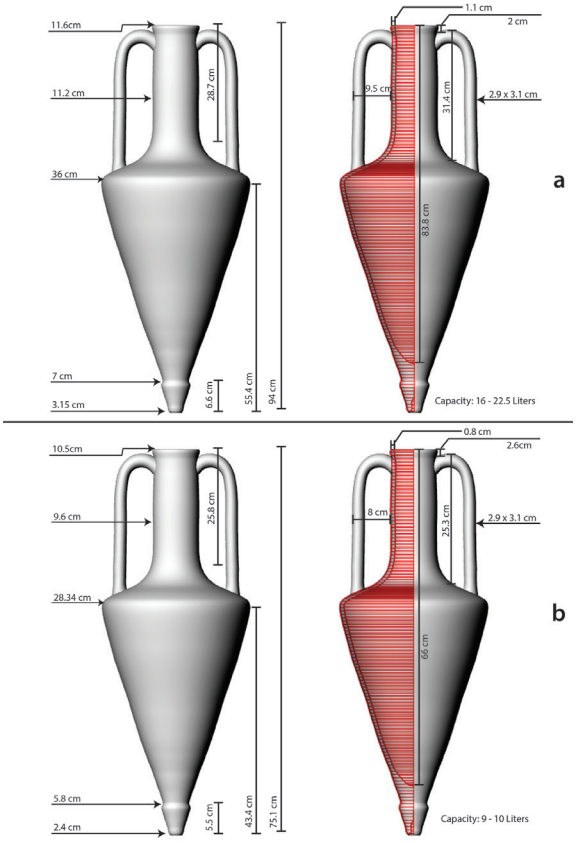


Figure 4. Average models of Chian amphorae with their dimensions: a) large; b) small (3D model and image composition: Irene Katsouri, MARELab).

The capacity of the average model was 21.5 litres, which is close to the value range of the measured containers.

The dimensions of the remaining seven, small-sized amphorae were more consistent: their height was 738-775 mm and their capacity 9.7-10 litres. The dimensions of the small-sized parametric model were as follows: total height, 751 mm; neck height, 258 mm; rim diameter (external), 105 mm; maximum shoulder diameter 283.4 mm (Fig. 4b).

More types were found in the cargo but only in insignificant numbers. No more than nine containers (MNI) could be classified within a broad amphora family known as Solokha I or Mushroom-Rim amphorae (Fig. 3b) (Lawall, 2005: 33, n. 14). They were very common in the Aegean from the beginning of the 4th century BCE and come from diverse centres. Their production has been verified by kiln discoveries in Klazomenai (Doger, 1986), Paros, Ephesos, Knidos, the Datça peninsula, Rhodes (Empereur *et al.*, 1999: 289; Garlan, 2000: 73) and Cos (Kantzia/ Κάντζια, 1994: 335-337). In the Mazotos shipwreck, they were found in the top layers, mostly in the front half of the assemblage.

Figure 5. North Aegean amphorae, still standing in the aft part of the hold (Photo: Andreas Kazamias, MARELab).

Figure 6. One of the 55 jugs excavated from the aft part of the hold (Photo: Irene Katsouri. Drawing: Jean Humbert / image composition: Irene Katsouri, MARELab).

A third amphora group comprises six containers, of north Aegean origin with characteristic stem-toes (Lawall, 1997: 114-118). The Mazotos type presents more similarities with amphorae from Mende (Papadopoulos and Paspalas, 1999; Filis, 2012), but it is difficult to attribute them to a specific workshop before any fabric analysis is conducted. They had been stowed in the bottom layer of the aft part of the hold, under and among the amphorae from Chios (Fig. 5), and more of them are likely to be found in the unexcavated part of this area.

A few non-cargo amphorae were also found in the hold. At the starboard side of the bow, the upper part of a Coan amphora was found broken *in situ*. Characterized by their double-barrelled handles, Coan amphorae appeared at the beginning of the 4th century BCE and were widely distributed and imitated in the Hellenistic and Roman periods (Georgopoulos, 2004; Moore, 2011). The Mazotos examples belong to the early variants of the series. Close to the Coan amphorae, two partly preserved containers of a less-known type were excavated. Their base ends in a short stem and their shape and features are very similar to amphorae attested in Lycia and Pampylia, with only a regional distribution (Fig. 3c) (Dündar, 2012: 47-50).

Apart from foodstuffs packed in transport amphorae, the Mazotos ship was also carrying tableware: at least 55 jugs were excavated at the aft part of the hold (Fig. 6). A layer of pitch on their interior associates them with serving wine. They have a squat body and fabric very similar to that of the Chian amphorae, although no analysis has been done as yet. A jug with a similar body was found on the Chios-Oinnousses wreck (Foley *et al.*, 2009: 290). Similar jugs with ring foot and a characteristic ridge below the rim were also common in Hellenistic layers of Athens, appearing at the end of the 4th and continuing to the 1st century BCE (Rotroff, 2006: 73-76).

Amphora stowage and the ship's interior space

From the beginning of the Mazotos shipwreck project, we have tried to estimate the total number of cargo amphorae: in the first preliminary report, approximately 500 amphorae were counted on the photomosaic (Demesticha, 2011). As the excavation has progressed and we have gained a better sense of the site and what part of the cargo was still completely buried under the sand, the estimated number has increased to approximately 800 amphorae (Demesticha *et al.*, 2014). It soon became obvious that a more consistent method had to be applied for the study of the ship's carrying capacity. The first step was to determine the stowage system. Thanks to the detailed documentation used in the project, the positions of all finds have been plotted in a 3D model of the site, which is updated after every new field season. Thus, all stratigraphic data were documented and could be used for the stowage-system reconstruction, at least for the areas where excavation has advanced adequately.

One of the first issues to be tackled was relocating the original positions of amphorae that have been disturbed since the wreckage, mainly as a result of site-formation processes. A few amphorae must have bounced off the assemblage when the ship reached the flat seabed. Most of them either, however, broke *in situ* or were shifted (or tilted) from their original position. This happened when the ship listed as it settled on the seafloor, or later, when they lost their support-surface as the wooden hull gradually disintegrated. This was especially true for the upper and side layers of the assemblage. The fact that the ship listed to its starboard side after it reached the seafloor is demonstrated by the position of the amphorae on the western (starboard) side; most of them are inclined outwards along the entire assemblage, from bow to stern. Some have been found away from the main concentration lying on their sides; having come from the upper tiers, they possibly fell on the seabed when the exposed parts of the hull decayed (for a very instructive plan of this procedure, see Tchernia *et al.*, 1978: fig. 14).

The stratigraphy of the centre of the hold, where the bulk of the cargo is concentrated, was the least affected by the post-wreckage formation processes. Even before excavation, there were places where amphorae had preserved their upright positions and it was obvious that no less than three amphora tiers had been stacked. Excavation is still ongoing at this part and has not yet fully exposed the lower tier. Plotting the amphora positions in three dimensions, however, has corroborated the initial hypothesis that three or four amphora tiers were stowed in the main part of the hold (Fig. 7). At the current stage of research, it is difficult to determine which stowage pattern was used: nonetheless, the square configuration

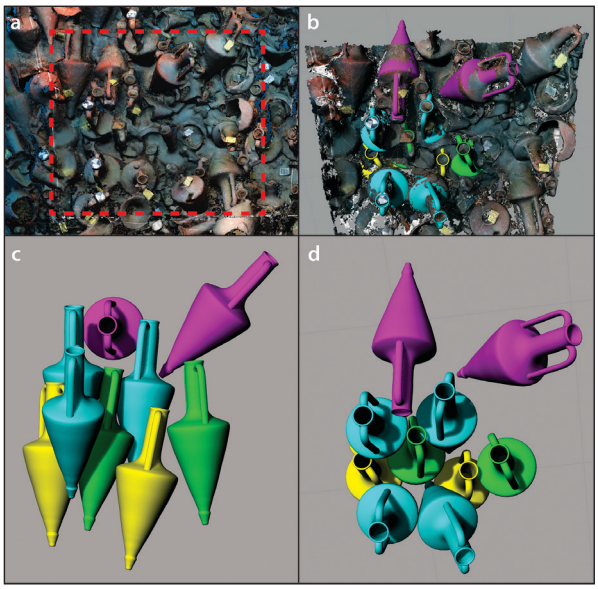


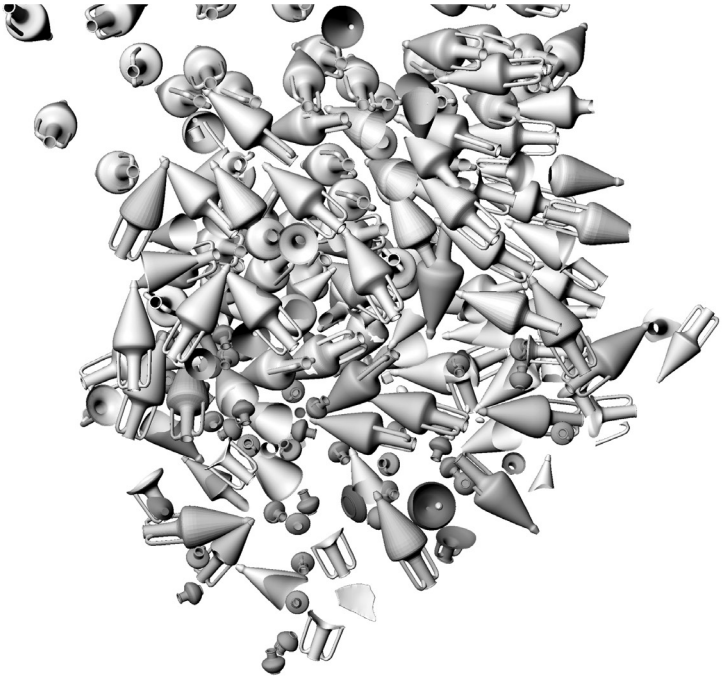
Figure 7. Reconstructing the stowage system in the partly excavated central part of the assemblage: a) 3D point cloud of a section where different tiers are visible; b) and d) the same section with the Average Large Chian amphora models, in situ; c) a side view of the position of the amphora models (3D model and image composition: Irene Katsouri, MARELab).

seems to be the most likely choice. Careful study of the 3D point cloud also showed that there was a distance of about 80 mm between the amphorae at the centre of the assemblage. This, of course, can only be used as an indicative value, because the amphora positions have been affected by the wreckage and because no dunnage, which may have been used to maintain a distance between them, has been preserved.

The excavated part of the stern seems to correspond to the area between the aft end of hold and the cabin (Fig. 8). The hull and the keel were found broken, but towards the centre of the assemblage the hull was better preserved under amphorae still standing in their original position. Although the bulkhead was not preserved, the location of the finds left little doubt of the spatial arrangement: the cargo amphorae that were originally standing against the bulkhead were found lying on the seafloor, in a south-to-north orientation, over non-cargo items that must have been stored in the stern cabin. This seems to have been a rather dramatic episode of collapse: jugs, most probably having fallen from somewhere higher up, broke the amphorae within which they were later found, and other cargo items spilled far from the main assemblage.

The excavation of the bow area is in a more advanced stage and has completely exposed the fore end of the hold (Fig. 9). Stratigraphic analysis showed that no more than two layers of amphorae were stowed in this part

Figure 8. Plan view of the northern end of the assemblage, which corresponds to the aft end of the hold. Cargo amphorae and jugs were found scattered, having spilled off the main assemblage after the hull collapsed (3D model and image composition: Irene Katsouri, MARELab).



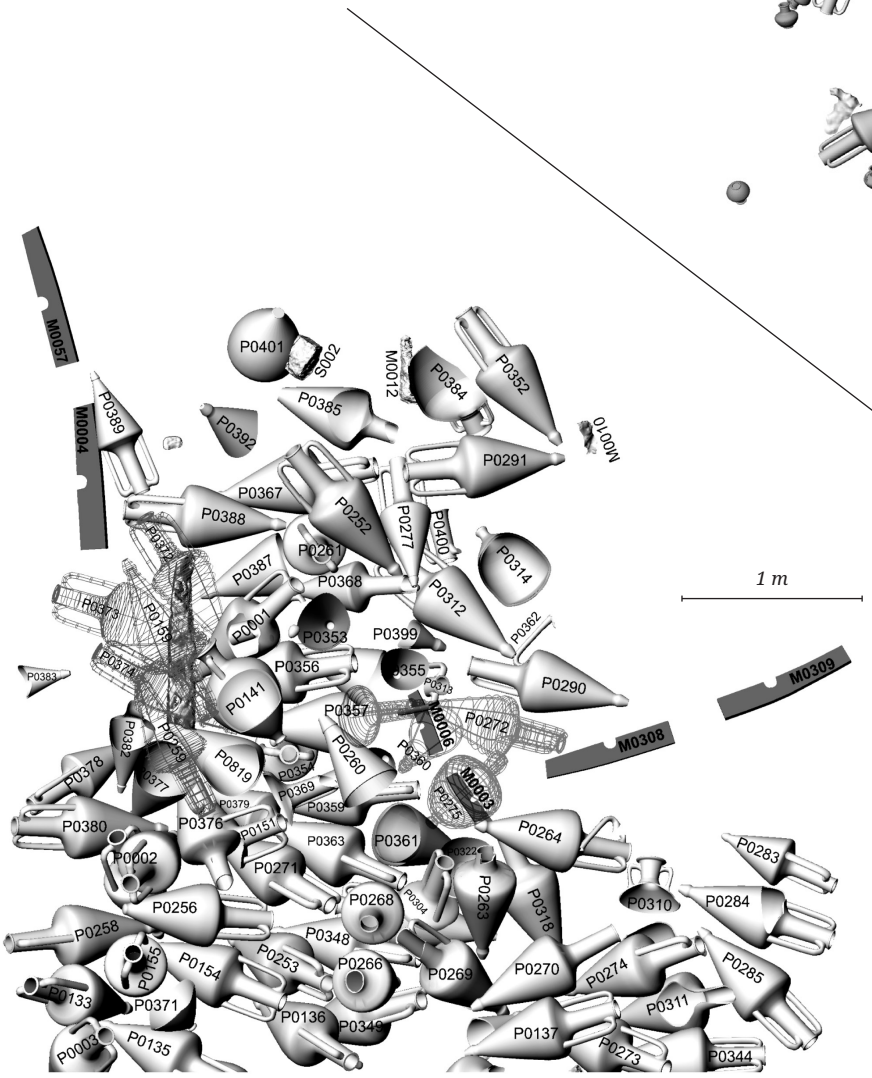
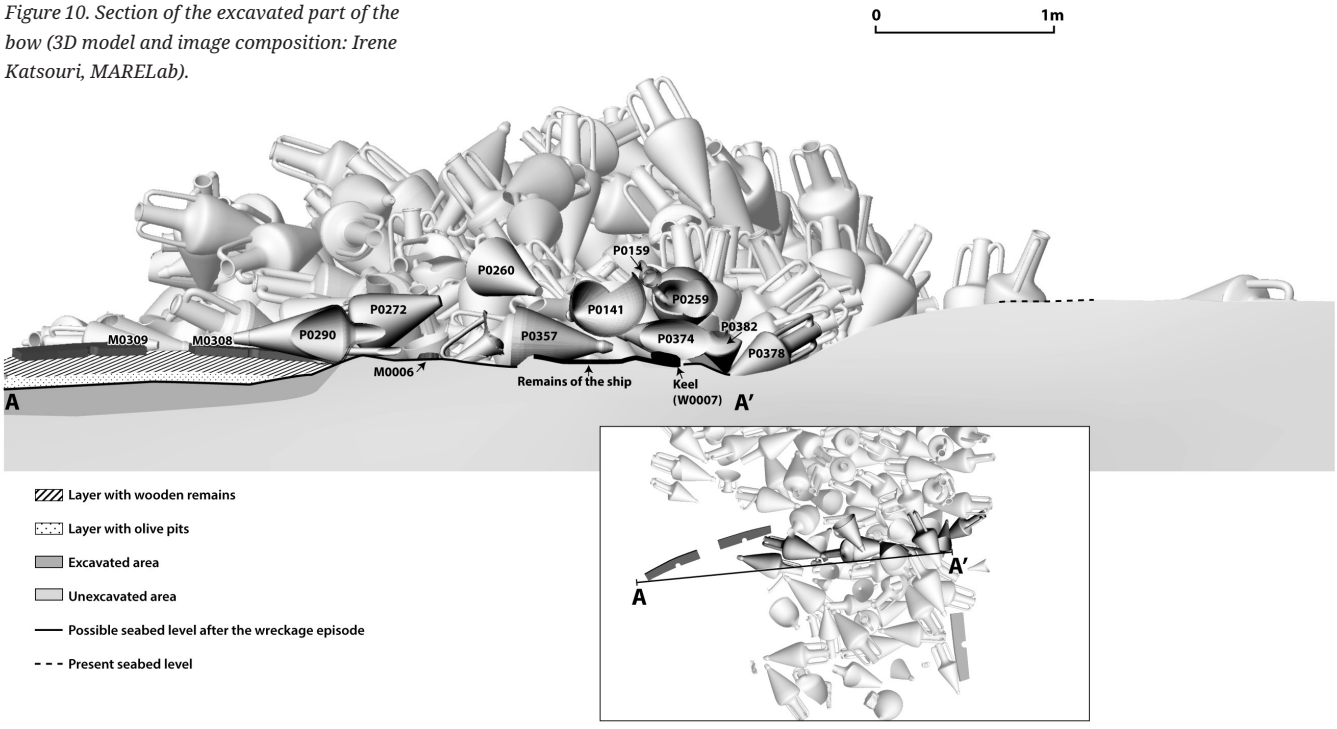


Figure 9. Plan view of the excavated part of the bow. The lead cores of the small anchor (M0006-M0003) can be distinguished under the wire-frame models on the right, and the preserved part of the keel under the models on the left. M0308 and M0309 are parts of the starboard bower's stock; M0010 and M0012 are its arm-tips. M0004 and M0057 belong to the port bower (3D model and image composition: Irene Katsouri, MARELab).

Figure 10. Section of the excavated part of the bow (3D model and image composition: Irene Katsouri, MARELab).



of the ship (Fig. 10). Most of them were either broken *in situ* or had fallen on their sides and shifted – not far from their original positions. This small movement must have been the result of an impact, after the collapse of the foredeck under which the amphorae were stacked. The location of the three anchors is indicative of this collapse: after the ship tilted to starboard, the anchors must have fallen to the seabed, one to port and one to starboard of the bow. No artefacts were found underneath them, so most probably the anchors were stored outside the gunwale, not on the deck.

The 42 excavated amphorae that comprise this cargo block at the fore end of the hold were found between the two bowers. These anchors must have created a barrier that prevented the amphorae from spilling farther off the concentration, which seems to be what happened along the remaining western side of the assemblage. The positions of the amphorae support this hypothetical scenario:

1. There is a line of amphorae at the starboard (western) side that has fallen eastwards (rim to the east and toe to the west), instead of westwards (rim to the west and toe to the east); these must have been stored against the starboard side of the bow, inside of where the anchor was attached. When this part collapsed, it seems to have pushed them eastwards against the rest of the amphorae, that had fallen westwards when the ship tilted.
2. The port side of the cargo shifted into the starboard side and this must have caused some of the breakages found *in situ*. Most of the upper-tier amphorae were found at the port side.
3. In the fore end of the concentration, some amphorae were found broken and turned upside down: perhaps they were bounced from their original positions when the ship reached the seabed and broke open.

According to the above observations and stratigraphic analysis (Table 1), 26 amphorae were stowed in the lower tier and 16 at the upper one (42 in all).

If this hypothesis describes, even roughly, the episodes of the ship's gradual collapse, the positions of the anchors and the amphorae can provide clues to the size of the ship's bow. The minimum width of the hold's bottom between the two bowers must have been enough to accommodate the amphorae of the lower tier and certainly no less than double the current distance between the starboard anchor and the keel (2 x 1.19 m = 2.36 m), given that the starboard anchor fell on the seabed, most probably next to ship's bilge, whereas the port anchor was moved toward the keel when the ship tilted westwards.

To test this hypothesis, we tried to stow these 42 amphorae in a virtual space that roughly follows the lines of a ship's bow. A gap of 100 mm was left between the amphorae. Although they had moved from their original positions, it was obvious that there had been

Find No.	Description	Layer/ Orientation			Interpretation	3D Model Used
		Lower	Upper	Uncertain		
P0001	Chian, almost complete, missing one handle. Large hole on its shoulder and body		W		Upper layer, in the middle	Actual
P0141	Mushroom-Rim, almost complete. Large hole on its shoulder and body		E		Starboard side, upper tier	Actual
P0159	Chian, complete		W		Port side, upper tier	Actual
P0252	Chian, almost complete, missing part of the rim		E		Upper tier, in the middle	Actual
P0259	Chian, almost complete, with large hole on body and part of rim broken		W		Port side, upper tier	Actual
P0260	Chian, lower part		W		Uncertain side because it was a free surface find	Average Large
P0264	Chian, almost complete, with one handle broken *in situ*		W		Starboard side, upper tier	Actual
P0272	Chian, almost complete, missing the toe		W		Starboard side, upper tier	Actual
P0275	Almost complete Lycian?, missing one handle, part of neck and rim			W/ U	Starboard side, uncertain tier	Actual
P0277	Chian, complete, small size		S		Starboard side, upper tier, against the hull?	Actual
P0283	Chian, complete, small size			W	Starboard side, upper tier	Actual
P0290	Chian, missing one handle, as well as part of rim and neck			E	Starboard side, against the hull?	Actual
P0291	Chian, broken *in situ*			E	Starboard side, against the hull affected by the anchor collapse	Actual
P0312	Chian, complete			E	Starboard side, lower tier	Actual
P0313	Chian, broken *in situ*	W			In the middle; it collapsed and then P0355 fell on top of it and broke it *in situ*	Average Large
P0314	Lycian? half of lower part			W	Starboard side, against the hull?	Average (P0275)
P0352	Chian, complete			W	Starboard side, against the hull affected by the anchor collapse	Actual
P0353	Chian, lower part	U			Lower tier, in the middle	Average Large
P0355	Chian, lower part		U		Upper tier in the middle; it fell and broke P0313	Average Large
P0356	Chian, complete	W			Port side, lower tier	Actual
P0357	Chian, broken *in situ*	W			Lower tier, in the middle	Average Large
P0360	Chian, lower part	U/W			Starboard side, lower tier	Average Large
P0367	Chian, complete	W			Port side, lower tier	Actual
P0368	Small Chian, missing part of rim and neck and one handle	W			Lower tier, in the middle	Actual
P0372	Chian missing part of rim and neck		W		Port side, lower tier	Actual
P0373	Chian, complete with a hole below its shoulder	E			Port side, against the hull	Actual
P0374	Chian complete	E			Port side, against the hull	Actual
P0377	Chian, lower part	U/W			Port side, lower tier	Average Large
P0378	Chian, small size, partly visible (still *in situ*)	E			Port side, lower tier, against the hull	Average Small
P0382	Chian, lower part	S			Port side, lower tier	Average Small
P0383	Chian, lower part			E	Port side, tier uncertain because it was found off the main concentration	Average Large
P0384	Coan amphora, upper part			N	Starboard side, against the hull?	Average (P0144)
P0385	Chian, broken *in situ*			W	At the foremost end of the hold	Average Large
P0387	Chian, lower part	W			Port side, lower tier	Average Large
P0388	Chian missing part of rim and neck	E			Port side, against the hull, higher that the lower tier	Actual
P0389	Small Chian missing part of rim and neck			N	Port side, against the hull, possibly foremost end of the hold	Actual
P0392	Chian, lower part			NA	Port side, lower tier, close to the fore most end of the hold. It was found upside down	Average Large
P0399	Chian, lower part			E	Starboard side, uncertain tier (it was hypothetically placed in the upper tier)	Average Large
P0401	Mushroom-Rim, lower part			NA	At the fore most end of the hold. It was found upside down	Average (P0144)
P0818	Chian, lower part	U/E			Starboard side, lower tier	Average Large
P0819	Chian, lower part	W			Lower tier, in the middle	Average Large
P0359	Chian, complete	W			Lower tier, in the middle	Average Large

Table 1 (Opposite page). The stowage arrangement of 42 amphorae discussed in the paper, with descriptions of their original and the reconstructed positions (W= westwards, E=eastwards, S=southwards, N=northwards, U=upright, NA = not applicable).

Figure 11. Amphorae at the bow: No. 359 is lying between two lower halves, still standing in an upright position (Photo: Andonis Neophytou, MARELab).

space among them before the collapse. For example, in more than one case, the necks of amphorae lying on their side were found between the lower halves of amphorae still standing in an upright position (Fig. 11), which means that they could not have moved significantly from their original positions. Moreover, despite the confined space, most amphorae had collapsed on the seafloor. In addition, the ship's geometry at this part, with curved surfaces under and at the side of the cargo block, does not allow for dense stowage, as the example of Madrague des Giens has demonstrated. Ample space between the amphorae must have also facilitated stowage under a deck; the upper layer was stowed from the side, not from above – in which case, it was important to leave enough room for manoeuvring between the lower-tier containers. The limited number of containers in the upper tier also corroborates this scenario.

To reconstruct the original location of each individual amphora, the following factors were determined: its stratigraphic unit (upper or lower layer), its orientation and its position as found in relation to the keel (port, starboard, or in the middle) (Table 1). Actual 3D models of the finds were used wherever possible but when only partly preserved ones remained, the parametric model was used to represent the originals. As a result of this analysis six rows of amphorae, transversal to the keel axis, were detected in the lower tier, although the number of containers in each row was not always straightforward: in other words, it was not always clear in which row to place an amphora when its original position had been seriously disturbed. Following the pattern created by the amphora find-spots, six containers were placed in

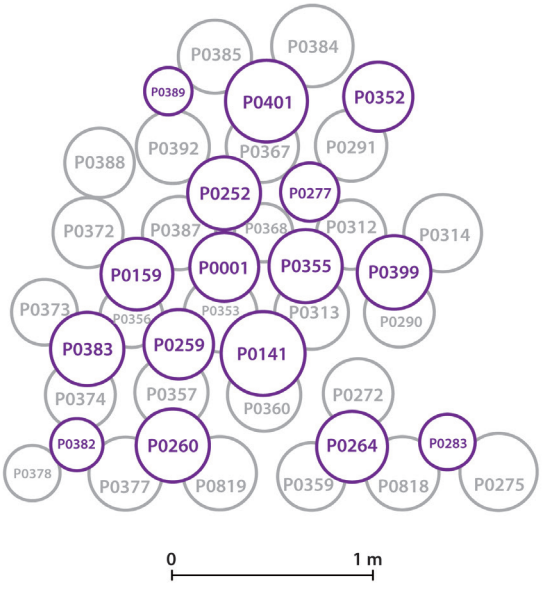


Figure 12. Schematic plan of the suggested stowage reconstruction, at the fore end of the bow. The lower tier is marked with grey circles and the upper tier with purple.

the first row (counting from north to south), four in the second, six in the third row and then five, three and two in the remaining rows (Fig. 12). Such an arrangement can be explained by the irregular shape of the hold's space at the bow but it still leaves several gaps that would have had to be filled to stop the cargo from moving around.

For example, the 16 containers of the upper tier were found mainly at the port side, so their reconstructed

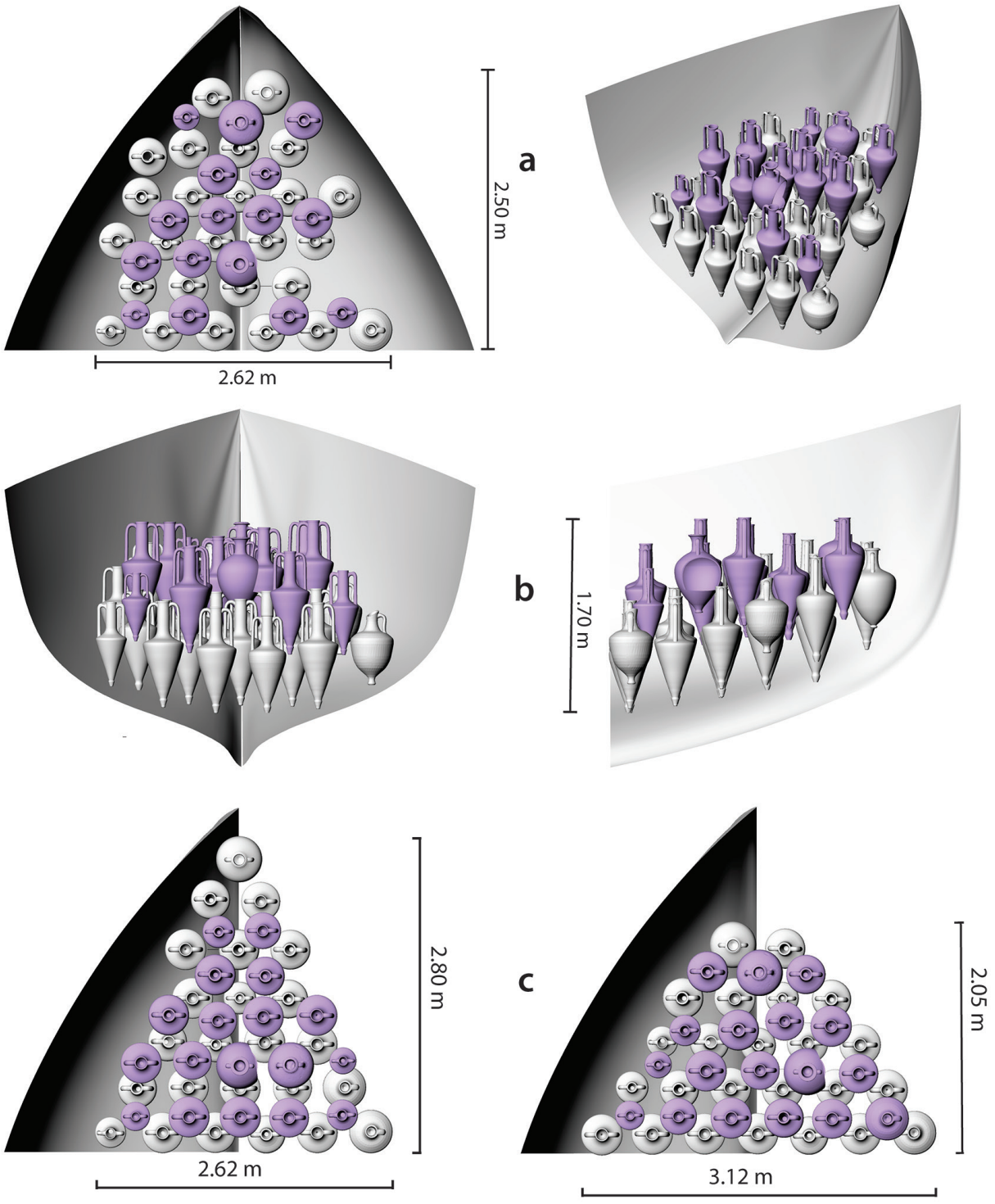


Figure 13. Stowage reconstructions at the bow end: a) and b) views of the suggested stowage reconstruction, with the find spots taken into account; c) two different hypothetical reconstructions where find-spots are not taken into account (3D model and image composition: Irene Katsouri, MARELab).

distribution is uneven, leaving a large gap at the starboard side. If this is not the result of disturbance from the deck collapse, it may represent a true gap, where organic material (nets or rope, now destroyed) was stored. In this hypothetical reconstruction, staggered rows are used instead of the square arrangement, because they work better with irregular distribution. Based on this arrangement, the minimum dimensions of the ship's bow compartment excavated thus far should be as follows: height, 1.70 m; width, 2.62 m; length, 2.50 m (Fig. 13 a-b).

The last phase of this project was to stow the 42 amphorae without taking their specific find-spots into consideration, a procedure that is usually followed for scattered assemblages, where the ship's internal stratigraphy is completely disturbed. The maximum width and length of these conjectural blocks differed in each arrangement (width, 2.62-3.12 m; length, 2.05-2.80 m) (Fig. 13c) but the height remained the same.

Discussion

In conducting this spatial analysis of the Mazotos bow area, several challenges arose that are more typical of disturbed than of well-preserved shipwreck sites. The reconstruction discussed above was based on find-spots that have been affected by diverse processes, impossible to determine with certainty, so the stratigraphic permutation (the detection of the temporal relationship of different units of stratification) remains hypothetical. Nonetheless, the process was very instructive, in several respects:

First, it demonstrated that hypothetical reconstructions that do not include stratigraphic data can provide a rough estimate of the volume, but cannot demonstrate potential particularities of specific ships, especially as far as depth is concerned. The distance between the containers of the lower tier is decisive because it determines how far down the upper tiers can be set into the lower ones. Although in well-preserved shipwrecks, such as the Madrague de Giens or Mazotos, there is a good chance that this distance is preserved at the centre of the hold, it is difficult to detect at the extremities, which suffer most from impact with the seafloor. Still, accurate mapping of the relative positions of the Mazotos finds, even the fragmentarily preserved ones revealed useful clues that indicated gaps of around 100 mm between the containers. For methodological reasons, this was kept for the entire lower tier, although most probably no such strict rule was applied in antiquity. The maximum height of the cargo block reconstructed with the proposed arrangement was 1.7 m but more space should be allowed between the top layer and the deck above, to enable safe loading and manoeuvring. For ships of this period, there is no other archaeological evidence regarding the foredeck, so this is the first indication of the foredeck's place in the hull (the maximum distance of the *Kyrenia II* foredeck from the keel is 1.35 m but this was not determined based on stratigraphic data, Kariolou, pers. comm., 2018).

Second, the compartment under the foredeck was unlikely to have been loaded all the way to the stem, since some space must have been left for non-cargo items that also had to be stored there. The lading processes are also among the unknowns of the hypothetical stowage, especially in the case of the compartment under the deck, not only are we unable to determine the system used when it was necessary to rearrange the cargo or accommodate non-standard containers and other artefacts in the hold, but it is also uncertain if there was a hatch or another opening to facilitate stowage. Although the gaps among the recorded amphorae at the starboard side of the Mazotos ship bow may suggest such use, the reconstructed cargo block can only be considered indicative of the compartment's minimum size. What the stratigraphic and spatial analysis did demonstrate, however, is that random stowage with irregular gaps may have been a common practice in the limited covered space of ancient merchantmen. Such practices cannot be reconstructed with precision but cannot be ignored either, since they contribute to the discussion of specific spatial arrangements (as, for example, non-cargo items storage), which must be taken into account when replicas are designed.

Where and how the anchors were stored was also an issue when attempting to explain the amphora positions. Stratigraphic evidence from Mazotos implies that the anchors were stored outboard, not on the deck, which makes sense for practical reasons: the limited space of the foredeck would have been too small for two anchors, each more than 2.5 m long. Such an arrangement finds parallels in iconographic evidence: two Hellenistic ship graffiti from the House of Dionysus on Delos show merchantmen with the anchors fixed on the hull's outboard sides (Basch, 1987: 373, nos 7 and 9).

Apart from information on the ship itself, spatial analysis of the cargo can also provide useful insights into the ship's possible ports-of-call before it sank off the coast of Cyprus. The homogeneity of the cargo allows us to assume with some confidence that all the Chian amphorae were loaded on the island of Chios. The northern Aegean amphorae of the stern were found stowed among and under Chian ones, so they might also have been loaded on Chios. The provenance of all the non-Chian amphorae of the cargo block analysed above, however, is located south of Chios, on the sea route from the Aegean to the eastern Mediterranean. These include the Coan (P0384), the southern-Aegean Mushroom-Rim (P0141) and the two possibly Lycian amphorae (P0314 and P0275). Since none of them belonged to the lower tier (Fig. 9), it seems plausible to suggest that they could have been bought *en route* to Cyprus, either as cargo or

as provisions, and were stowed in the bow compartment, on top of the Chians, as shown in the reconstruction in Figure 13.

Conclusions

The spatial analysis of the Mazotos finds conducted thus far, while partial, has demonstrated how digital mapping and visualization in three dimensions can open new paths for shipwreck archaeology. As excavation progresses to less disturbed areas, more clues will be added to the puzzle of the original ship's spatial arrangement. For example, when the bow compartment has been fully excavated, a more comprehensive reconstruction of its destruction will be possible. In addition, apart from the documentation of the amphora positions, different kinds of evidence can be plotted in three dimensions: this would include marks on the exterior of the amphorae, break patterns, and the stratigraphy of organic finds. The goal is to understand better the natural site-formation processes and combine not only spatial but also temporal information to explain the sequence of collapse episodes that took place in the wrecked ship.

Micro-scale documentation can lead to more advanced archaeological hermeneutics and contribute significantly to the study of ancient ships and trade mechanisms. As measurement and data-gathering become less complicated and the accuracy of data acquisition helps advance documentation methods, more specific and incisive questions can be asked. Thus, despite the numerous unknown factors, reconstructing the lost spaces within ancient shipwrecks is now certainly more feasible than ever before.

Acknowledgements

The past three field seasons at the Mazotos shipwreck project (2015, 2016, and 2018) were conducted thanks to the support of the Honor Frost Foundation, CYTAVISION and the University of Cyprus, to whom the author is grateful. Special thanks are also owed to the Honor Frost Foundation for funding my research assistant, Irene Katsouri, who has processed all the stratigraphic data of the excavation and produced the detailed drawings which are the basis of the analysis discussed in this paper; I cannot thank her enough for her excellent work and our flawless collaboration. I am grateful to Glafkos Kariolou for the information he provided about the *Kyrenia II* dimensions. Last but not least, I thank all the members of the Mazotos team for their valuable contribution to the project.

References

Anderson, J.K., 1954, Excavations on the Kofina Ridge, Chios, *Annual of the British School at Athens* 49, 123-172.

Basch, L., 1987, *Le musée imaginaire de la marine antique*. Institut Hellénique pour la Preservation de la Tradition Nautique, Athens.

Ben Zeev, A., Kahanov, Y., Tresman, J., and Artzy, M., 2009, *The Ma'agan Mikhael Ship. Volume III: A Reconstruction of the Hull*. Israel Exploration Society, Leon Recanati Institute for Maritime Studies, University of Haifa, Haifa.

Benoît, F., 1961, Premiers résultats de fouilles sous-marins: architecture navale et tonnage des navires à l' époque hellénistique et romaine, in *Actes du IIe Congrès International d'Archéologie Sous-marine, Albenga, 1958*, 347-357. Bordighera.

Bylkova, V.P., 2005, The Chronology of Settlements in the Lower Dnieper Region, 400-100 BC, in L. Hannestad and V. Stolba (eds), *Chronologies of the Black Sea Area in the Period c.400-100 BC. Black Sea Studies* 3, 217-47. Aarhus.

De Juan, C., Cibecchini, F., and Vento, E., 2011, El pecio romano Bou Ferrer, un velero de comercio naufragado en la costa de La Vilajoiosa, in A. Espinosa (ed.), *La Vila Joiosa. Arqueologia i Museu, Museos Municipales en el MARQ*, 178-197. Alicante.

Demesticha, S., 2009, Questions on trade: the case of the Mazotos Shipwreck, in A.-M. Guimier-Sorbet and D. Michaelides (eds), *Actes du Colloque Chypre à l'époque hellénistique et impériale Recherches récentes et nouvelles découvertes, Nanterre-Paris, 25-26 September 2009. Cahier de Centre d'Études Chypriotes* 39, 387-402.

Demesticha, S., 2011, The 4th-century-BC Mazotos shipwreck, Cyprus: a preliminary report. *International Journal of Nautical Archaeology* 40.1, 39-59.

Δεμέστιχα, Σ., 2017, «…καταδύσης της ολκάδος, απολέσθαι άπαντα…». Η υποβρύχια αρχαιολογική έρευνα στο ναυάγιο Μαζωτού, in Ν. Παπαδημητρίου and Μ. Τόλη (eds), *Αρχαία Κύπρος. Πρόσφατες εξελίξεις στην αρχαιολογία της ανατολικής Μεσογείου*, 285-300. Αθήνα.

Demesticha, S., Skarlatos, D. and Neophytou, A., 2014, The 4th-century-BC shipwreck at Mazotos, Cyprus: new techniques and methodologies in the 3D mapping of shipwreck excavations. *Journal of Field Archaeology* 39, 134-150.

Doger, E., 1986, Premiers remarques sur les amphores de Clazomènes, in J.-Y. Empereur and Y. Garlan (eds), *Recherches sur les amphores grecques. Bulletin de Correspondance Hellénique* Supp. 13, 461-471. Paris.

Dündar, E., 2012, A Group of amphorae from Side Museum and a new type of amphora: the Lycian Amphora? *Archäologisher Anzeiger* 2012.1, 43-61.

Empereur, J.-Y., Hesse, A., and Tuna, N., 1999, Les ateliers des amphores de Datça, péninsule de Cnide, in Y. Garlan (ed.), *Production et commerce des amphores anciennes en Mer Noire: colloque international organisé* **à** *Istanbul, 25-28 mai 1994*, 105-115. Provence.

Filis, K., 2012, Transport amphorae workshops in Macedonia and Thrace during the Late Classical and Hellenistic times, in S. Drougou and I. Touratsoglou (eds), *Topics on Hellenistic Pottery in Ancient Macedonia*, 60-85. Athens.

Foley, B., Dellaporta, K., Sakellariou, D., Bingham, B., Camilli, R., Eustice, R., Evangelistis, D., Ferrini, V., Hansson, M., Katsaros, K., Kourkoumelis, D., Mallios, A., Micha, P., Mindell, D., Roman, C., Singh, H., Switzer, D., Theodoulou, T., 2009, The 2005 Chios ancient shipwreck survey. New methods for underwater archaeology. *Hesperia* 78, 269-305.

Garlan, Y., 2000, Amphores et timbres amphoriques grecques. Entre érudition et ideologie. *Memoires de l´Academie des Inscriptions et Belles-Lettres XXI.* Paris.

Georgopoulos, V., 2004, The archaeological evidence of Coan Amphorae from Kardamaina (ancient Halasarna), in K. Hoghammar (ed.), *The Hellenistic polis of Kos: state, economy and culture: proceedings of an International Seminar organized by the Department of Archaeology and Ancient History, Uppsala University, 11-13 May, 2000*, 129-132. Uppsala.

Grace, V., 1979 (1961 1st edn), *Amphoras and the Ancient Wine Trade, Agora Picture Book 6.* Princeton.

Grace, V. and Savvatianou-Pétropoulakou, M., 1970, Les timbres amphoriques grecs, *Exploration archéologique de Délos XXVII, L'îlot de la maison des comédiens*, 277-382. Paris.

Haldane, D.D., 1984, *The Wooden Anchor.* Unpublished Master's Thesis, Department of Anthropology. Texas A&M University. College Station, TX.

Haldane, D.D., 1990, Anchors of antiquity. *The Biblical Archaeologist* 53.1, 19-24.

Hesnard, A., Carre, M.B., Rival, M., Dangreaux, B., Thinon, M., Blaustein, M., Dumontier, M., Chene, A., Foliot, P., Bernard-Maugiron, H., 1988, *L' epave romaine Grand Ribaud D (Hyeres, Var)*. Paris.

Joncheray, J.-P., 1994, L'epave Dramont C. *Cahiers d' Archéologie Subaquatique* 12, 6-51.

Κάντζια, Χ. 1994, Ένα κεραμικό εργαστήριο αμφορέων του πρώτου μισού του 4ου αι. π.Χ. στην Κώ, in *Γ' Επιστημονική Συνάντηση για την Ελληνιστική Κεραμική. Θεσσαλονίκη 24-27 Σεπτεμβρίου 1991*, 323-354. Αθήνα.

Katzev, S., 2008, The Kyrenia ship: her recent journey. *Near Eastern Archaeology* 71, 76-81.

Lawall, M. L., 1997, Shape and Symbol: Regionalism in 5th-century Transport Amphora Production in Northeastern Greece, in C. Gillis, C. Risberg and B. Sjöberg (eds), *Trade and Production in Premonetary Greece, Production and the Craftsman. Proceedings of the Fourth and Fifth International Workshops, Athens, 1994 and 1995*, *Studies in Mediterranean Archaeology Pocket-Book* 143, 113-130. Jonsered.

Lawall, M.L., 1998, Ceramics and positivism revisited: Greek transport amphoras and history, in H. Parkins and C. Smith (eds), *Trade, Traders and the Ancient City*, 75-101. London and New York.

Lawall, M.L., 2005, Negotiating chronologies, in L. Hannestad and V. Stolba (eds), *Chronologies of the Black Sea Area in the Period c.400-100 BC*, 31-67. Aarhus.

Lin, S.-H.S., 2003, *Lading of the Late Bronze Age Ship at Uluburun*. Unpublished Master's thesis, Texas A&M University.

Long, L., 1987, Les épaves du Grand Congloué. Étude du journal de fouille de Fernand Benoît. *Archaeonautica* 7, 9-36.

Moore, J., 2011, When Not Just Any Wine Will Do..? The Proliferation of Coan-type Wine and Amphoras in the Greco-Roman World, in H.-J. Drexhage, T. Mattern, R. Rollinger, K. Ruffing, and C. Schäfer (eds), *Marburger Beiträge zur Antiken Handels-, Wirtschafts- und Sozialgeschichte*, *vol. 28*, 89-122. Rahden/Westfalen.

Nieto, P.J., Jover, A., Izquierdo, P., Puig, A.M., Alaminos, A., Martin, A., Pujol, M., Palou, H., Colomer, S., 1989, *Excavacions arqueològiques subaquàtiques a Cala Culip, I.* Girona.

Papadopoulos, J.K., and Paspalas, S.A., 1999, Mendaian as Chalkidian wine. *Hesperi*a 68.2, 161-188.

Pomey, P., and Poveda, P., 2018, *Gyptis:* Sailing replica of a 6th-century-BC Archaic Greek sewn boat. *International Journal of Nautical Archaeology* 47.1, 45-56.

Poveda, P., 2012, Hypothetical reconstruction of the Dramont E Shipwreck, in Gunsenin, N. (ed.), *Between Continents. Proceedings of the Twelfth Symposium on Boat and Ship Archaeology, Istanbul 2009*, 331-336. Istanbul.

Pulak, C., 2008, The Uluburun Shipwreck and Late Bronze Age Trade, in J. Aruz, K. Benzeland, and J. M. Evans (eds), *Beyond Babylon: Art, Trade and Diplomacy in the Second Millennium BC*, 288-305. New York.

Radić-Rossi, I., 2006, The amphora's toe – its origin and function. *Skyllis* 7, 160-171.

Rosloff, J.P., 1991, A one-armed anchor of *c.*400 BCE from the Ma'agan Michael vessel, Israel. A preliminary report. *International Journal of Nautical Archaeology* 20.3, 223-226.

Rotroff, S.I., 2006, Hellenistic Pottery: The Plain Wares. Results of Excavations conducted by the American School of Classical Studies at Athens, in *The Athenian Agora, vol. 33.* Princeton.

Salviat, F., 1986, Le vin de Thasos, amphores, vin et sources écrites, in J-Y. Empereur and Y. Garlan (eds), *Recherches sur les amphores grecques, Bulletin de Correspondance Hellénique Supplement* 13, 145-200.

Sarikakis, T.C., 1986, Commercial Relations Between Chios and Other Greek Cities in Antiquity, in J. Boardman and C. Vaphopoulou-Richardson (eds), *Chios: A Conference at the Homereion in Chios 1984*, 121-131. Oxford.

Tchernia, A., Pomey, P., and Hesnard, A., 1978, *L'épave romaine de la Madrague de Giens (Var), campagnes 1972-1975: fouilles de l'Institut d'Archéologie Méditerranéenne*. Paris.

van Duivenvoorde, W., 2012, The anchor of the 3rd-century-BC ship from Kyrenia, Cyprus: a one-armed wooden anchor with a lead-filled stock. *International Journal of Nautical Archaeology* 41.2, 397-407.

Vandiver, P.B., and Koehler, C.G., 1986, Structure, Processing, Properties, and Style of Corinthian Transport Amphoras, in W.D. Kingery (ed.), *Technology and Style, Ceramics and Civilisation II*, 173-215. Columbus.

Wallinga, H.T., 1964, Nautika (I): The Unit of Capacity for Ancient Ships, *Mnemosyne* 17, 1-40.