THE SHIPS AND SHIPPING OF INDO-ROMAN TRADE

A VIEW FROM THE EGYPTIAN RED SEA PORTS

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Introduction

The trade networks between the Mediterranean World and the Indian Ocean represent some of the longest maritime routes of antiquity. Seaways stretched from the Red Sea ports of the Egyptian coast, along the East African coast as far as Zanzibar, around the Arabian peninsula to north-west India, and directly across the Indian Ocean from Socotra to modern day Kerala (Fig. 1). The mechanics of these routes are well attested through historical documents, for example the *Periplus Maris Erythraei* (PME)[1] provides an overview of the extent, general timings, goods and routes of trade. By contrast, the ships that were the main vehicles of this trade are harder to uncover, in part due to the absence of Indian Ocean and Red Sea shipwreck evidence of the type seen in the Mediterranean. Instead, archaeological work at the Egyptian ports of Myos Hormos and Berenike has provided a less direct means to uncover the ships of the Indo-Roman world through the discovery of recycled and discarded maritime components. This evidence forms the main focus of this paper, allowing a more detailed picture of construction methods, rigging practice, and potential performance to be formulated. These themes are explored across the course of this paper and in turn allow wider comment on the relationship between maritime technologies in the Indian Ocean and Mediterranean during the early first millennium AD.

1. Schoff 1912; Casson 1989.

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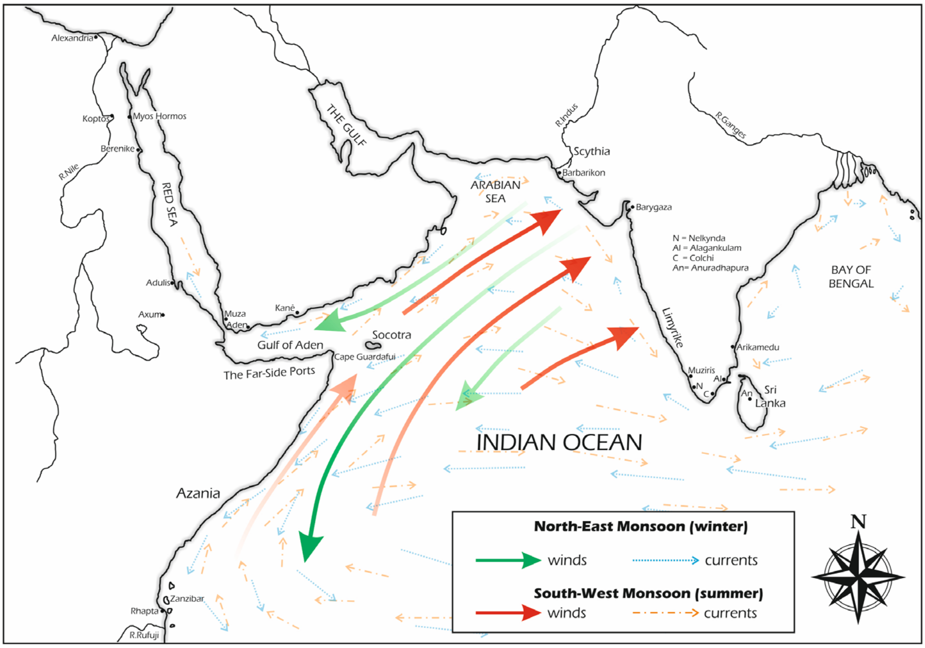

Fig. 1. The western Indian Ocean, Arabian Sea, Red Sea and Gulf, showing places mentioned in the text, destinations, ports of trade, and a schematic indication of the monsoon winds and currents (J. Whitewright).

The focus of the research presented here is directed firmly towards the material detail, and resulting analysis and interpretation, of the archaeological remains of Indo-Roman sailing ships found at the Egyptian Red Sea ports[2]. These objects are first described in terms of material derived from shipbuilding, ship repair and ship breaking activity, before focusing upon rigging components, including sails. The resulting analysis then aims to draw both of these themes together to present an understanding of the material detail of Indo-Roman shipping. As will become clear, wider analysis of Indo-Roman trade from the perspective of networks, institutions, exchange systems, etc is not part of this paper, being well served elsewhere[3]. Having stated that, much inspiration has however been drawn from the existing work of a number of

2. In general the archaeological material discussed in this paper is only found in the Egyptian port sites of Myos Hormos and Berenike, due to conditions of preservation, although as the text explains, the material has origins from across the Indian Ocean.
3. E.g. De Romanis and Tchernia 1997; Ray 2003; Boussac *et al.* 2012; Gurukkal 2016.

scholars, notably Roberta Tomber[4], Steve Sidebotham[5] and Eivind Seland[6] who have addressed the bigger picture of Indo-Roman trade and Indian Ocean networks.

The very phrase 'Indo-Roman trade' carries an increasing amount of academic baggage and inherently limits how we think about the systems, people and technology being studied[7]. Its use in this paper is simply intended to define a widely accepted period and place of study – the Red Sea and western Indian Ocean during the early centuries of the first millennium AD. Little interest is expressed in this paper regarding preconceptions of who is carrying on the trade, or the institutional structures behind that trade. Instead, the focus is firmly on the maritime technology that is visible through the archaeological record, with supporting historical and iconographic reference where appropriate. This record is sufficient to inform us of the complexities of understanding such ships, and the maritime technologies and cultures from which they stem. The view presented is therefore one that attempts to present a balanced interpretation of this material. This process illustrates beyond doubt the presence of ships on the Erythraean Sea that were built, rigged and used in a manner consistent with contemporary Mediterranean vessels. What is also evident is that the archaeological material of the Red Sea ports is potentially representative of Indian Ocean maritime cultures, as well as Mediterranean ones. This premise forms the basis of the research presented here, and ongoing since first working under the direction of David Peacock and Lucy Blue at Myos Hormos in 2001: primarily that there was a shared tradition of building, rigging and using ships that spanned the Mediterranean, Red Sea and western Indian Ocean in the early first millennium AD. The presentation and interpretation of the material that underpins this notion is the common thread that runs through this paper.

The archaeological sites that have provided the material described in the following sections are the twin ports of Myos Hormos[8] and Berenike[9], located on the Egyptian Red Sea coast (Fig. 1). The maritime artefacts from these ports provide a surprisingly detailed view of the nature of the shipping frequenting those sites. The word 'surprising' is appropriate because at first glance the arte-

4. E.g. Tomber 2008.
5. E.g. Sidebotham 2011.
6. E.g. Seland 2010, 2014.
7. Seland 2014, p. 388; also Gurukkal 2016 for a view of trade that plays down Indian involvement.
8. Peacock and Blue 2006, 2011.
9. Sidebotham 2011 provides a detailed view of the huge extent of work undertaken at Berenike.

facts seem uninspiring: fragments of broken wooden and horn rings, scraps of cotton cloth, and wooden elements that have been repurposed in buildings. As will be shown, these artefacts allow a detailed picture of the shipping that used the ports of Myos Hormos and Berenike to be developed. It is not so much the exact shape and size of individual vessels, but the overall traditions of construction, rigging and sailing that the mariners of the port employed. Such analysis follows below (Section 4), but, before that it is necessary to explore the artefacts themselves as a means to fully understand their material nature, disposition, advantages for study and inherent limitations. This is done by looking across the twin ports of Myos Hormos and Berenike from the perspective of the artefacts relating to hull, rigging and sails, although there is an emphasis on the former, especially during the first few centuries AD, because of the author's own work at that site. In each case, examples of comparative material is included where available as a means to fully contextualise and understand each class and type of artefact, although it should be noted that such examples are not intended to be an exhaustive catalogue.

Shipbuilding, ship-repair and ship-breaking

It is unsurprising that the Red Sea ports should produce archaeological evidence of ship building and related repair and breaking-up activity in relation to Indo-Roman trade. Much earlier Pharaonic period evidence from Wadi Gawasis gives an example of Nile-built vessels being transported across the eastern desert for use on the Red Sea[10]. The Egyptian Red Sea ports are the obvious location for the construction of the ships required by Mediterranean merchants for operation on the Red Sea and Indian Ocean. Likewise, once constructed, such vessels would have required annual and ongoing maintenance to allow them to complete the lengthy voyages to India and East Africa, and the Egyptian Red Sea ports are again the obvious location for such activity. Written sources (*O.Krok. 41)* attest to the transport of shipbuilding timber from the Nile to Myos Hormos, and that the timber itself was so valuable that the wagons carrying it were escorted by two cavalrymen (*O.Krok. 13*)[11]. Bülow-Jacobsen's analysis of this evidence concludes that timber was not transported to Berenike, perhaps because of the extra distance involved across the desert, and that Myos Hormos was therefore the main shipbuilding/ship repair location on the Egyptian Red Sea coast[12].

10. Ward and Zazzaro 2010.
11. Bülow-Jacobsen 2013, p. 567.
12. Bülow-Jacobsen 2013, p. 567; largely echoed by Sidebotham 2011, p. 201 with regard to Berenike being restricted to repair, rather than building.

Meanwhile, the trades of some of those working in the shipyard at Myos Hormos are described in the tariff from the Koptos toll-house, dating to AD 90, and including shipyard hands and caulkers[13].

Separating shipbuilding from ship-repair, and to a lesser extent ship-breaking, in the archaeological record is very difficult because of the similarity of the waste products produced and subsequently deposited. With this in mind, the archaeological material from Myos Hormos seemingly provides generic evidence for ship-repair and/or ship-breaking. Excavated material includes lead-sheathing fragments and associated iron tacks, lumps of pitch resin, and barnacles scraped from hulls and still bearing the impression of wood grain, all of which have been retrieved from the waterfront area of Myos Hormos[14]. Comparable material, identified as a ship-repair area, dating from the mid-3rd century BC through to the early Roman period has also been found at Berenike[15]. Taken together, the historical and archaeological material paint a picture of ships for the Indo-Roman trade network being built and repaired on the Red Sea. It can be reiterated that this is not a surprise, but simply sound evidence for an activity that must have taken place in order for the annual trading fleet to depart the Red Sea ports.

Turning to the ships themselves, it must first be noted that the underwater remains of wooden ships are extremely rare in the Red Sea and Indian Ocean region. Although Roman period shipwrecks have been documented in the Red Sea[16], they consist of amphorae rather than hull remains (Fig. 2). Any archaeological material that can fill this gap in the record is therefore highly significant for our understanding of the construction methods of the ships used in the Indo-Roman trade networks. At both Myos Hormos and Berenike, hull remains consisted of wooden elements that had been repurposed within buildings– beams and planks within walls, for roof beams at Berenike[17], and planking as a door threshold at Myos Hormos[18] – following ship-breaking activity. This statement raises the immediate and not unreasonable question of how it is possible to identify the wooden elements of a building as being recycled ship timbers. In the context of Mediterranean shipping from antiquity this is relatively straightforward, due to the construction

13. Blue *et al* 2011, p. 188.
14. Blue *et al* 2011, pp 185-188
15. Sidebotham 2011, p. 205; Sidebotham and Zych 2012, pp.32-33; Sidebotham and Zych 2016, p. 4.; Zych *et al.* 2016, pp. 328-331.
16. See Blue *et al.* 2012.
17. Vermeeren 1999, p. 316; Sidebotham 2011, pp. 198, 203, 239; Sidebotham and Zych 2016, pp. 4-14.
18. Blue *et al.* 2011, pp 179-181.

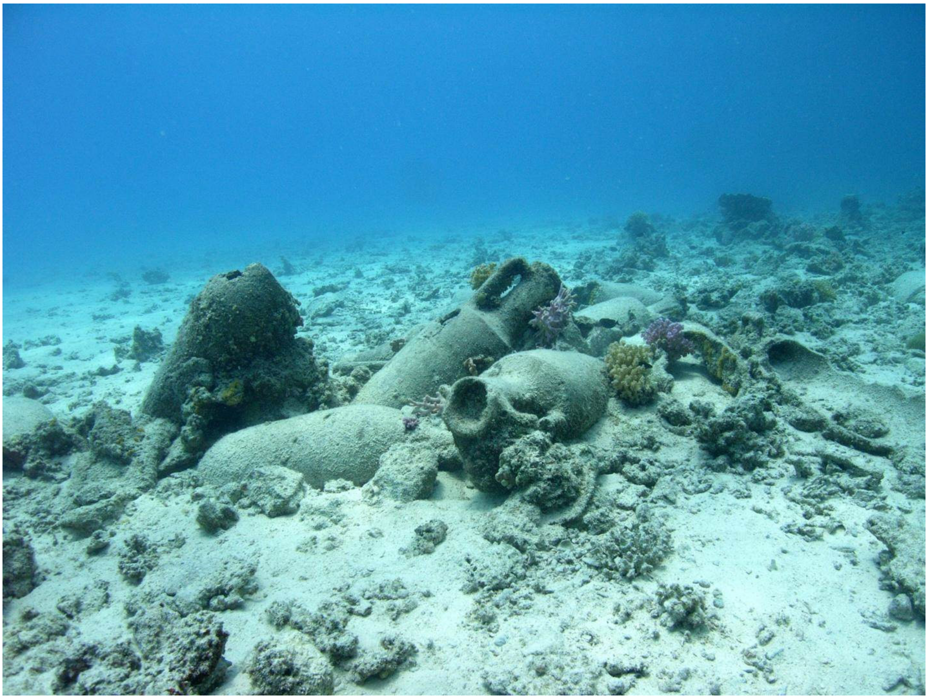

Fig. 2. Seabed scatter of Roman period amphorae (Amphore Égyptienne 4 and Dressel 2-4), comprising the Fury Shoals shipwreck, located between Berenike and Myos Hormos, and recorded through archaeological survey by a team from the University of Southampton (Image courtesy of Blue *et al.*, 2012, fig. 11.1)

tradition of the planks being joined along their edges, with a series of closely set mortise-and-tenon joints, secured in turn with wooden locking-pegs driven through the plank into the tenon[19]. This process is one of the defining features of ancient Mediterranean shipbuilding, and leaves behind a characteristic row of carefully carved mortises in the edges of planks. Timbers carrying such markers, dating to antiquity and in a Mediterranean or related context, are highly likely to represent ship or boat remains[20].

At Myos Hormos, two pieces of wooden planking were excavated during the 2002 season (Fig. 3), both reused in secondary Roman contexts, from Trench 8A[21]. One piece (WO383) is relatively complete while the other (WO467) is

19. Whitewright 2016, p. 874.
20. E.g. Basch 2015.
21. Blue *et al.* 2011, pp. 179-181.

fragmentary. Both planks were fashioned by sawing. WO383 appears to have been reused at least once previously before ending up in a 2nd century AD context as a doorway threshold. The dimensions and shapes of both planks have been altered due to reuse and degradation, however both display mortise-and-tenon joints with a number of tenons, and wooden pegs that would have secured the tenons, still *in situ*.

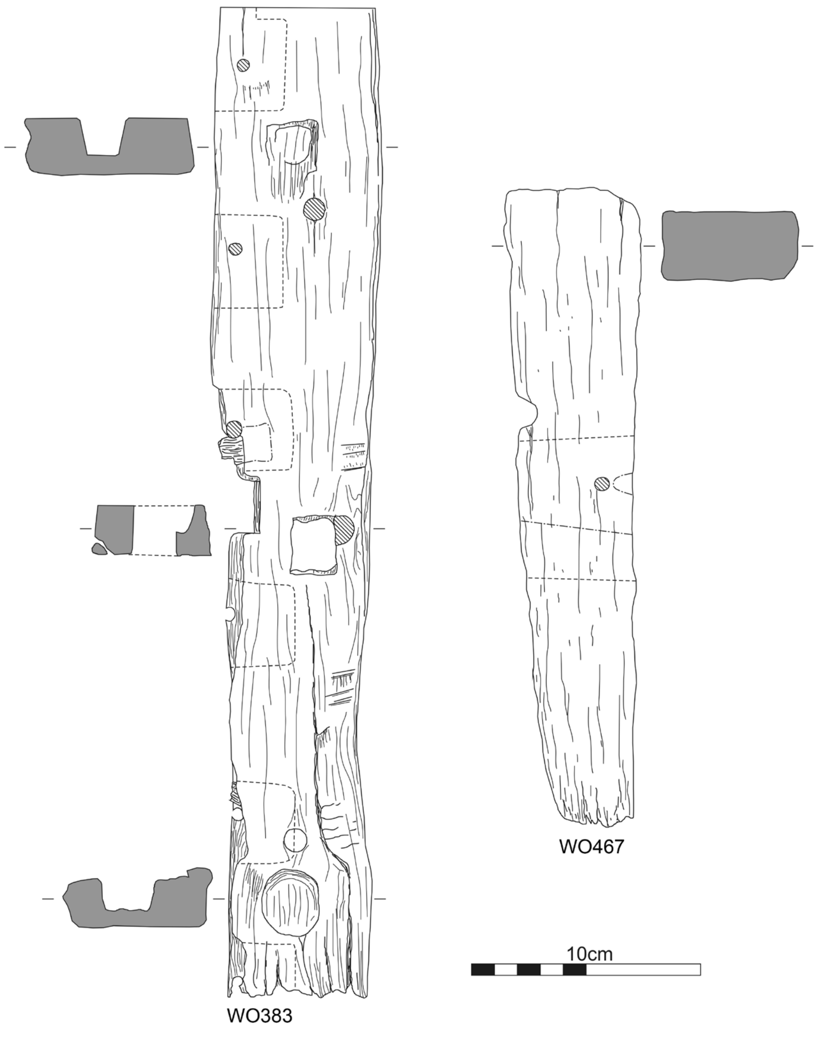

FIG. 3. Remains of ship-planking, reused in buildings at Myos Hormos, and demonstrating the characteristic Mediterranean mortise-and-tenon technique for edge-joining the planks (J. Whitewright).

The larger plank (WO383) is 862mm in length with an average width of 130mm and a consistent thickness of 50mm. The average dimensions of the mortises of the larger plank are 70-90mm deep by 60mm wide; the one surviving tenon is 6mm thick and the locking-pegs are 12mm in diameter. The mortice-and-tenon joints are spaced at an average of 80mm apart. Three additional features are present on the plank, probably resulting from reuse; a carved recess at either end of the plank, itself equidistant from a pair of square holes that are arranged in the centre of the plank. The second, smaller plank (WO467) is 275mm in length and of consistent width (60mm) and thickness (30mm). The smaller plank had one mortise 60mm wide; the tenon was still in place and measured 40mm wide with a 5mm diameter peg hole.

As noted above, planking of this type is characteristic of Mediterranean shipbuilding and examples date from the Late Bronze Age to Late-Antiquity[22]. Comparative classification of this material is challenging because of the temporal and spatial spread, combined with the difficulties in ascribing shipwrecks a precise origin in terms of their original construction. But, the material from Myos Hormos, and the comparative remains from Berenike can certainly be fitted very easily into the broader Mediterranean building tradition because of the characteristic mortise-and-tenons along the plank edges. Of further interest is the fact that from a materials perspective, analysis of timbers from Myos Hormos[23] demonstrates the use of timber species, such as teak or blackwood, that is Indian Ocean, rather than Mediterranean, in origin. Meanwhile, hull components from Berenike represent both Mediterranean[24] and Indian Ocean sources[25]. This can be taken alongside the written evidence cited above to indicate that timber resources from across the wider Indian Ocean networks, as well as Mediterranean ones, were brought to Myos Hormos and Berenike to facilitate the shipbuilding and ship-repair function of the two harbours.

The construction, maintenance, breaking-up and recycling of ships is therefore an important element of the activity of these ports, and indeed one that is critical to their actual operation as ports, through the provision of ships to service the trade routes themselves. Although often under-reported, this maritime element and the materials and people that it drew in from across

22. E.g. Pomey *et al.* 2012.
23. Gale and van der Veen 2011.
24. Sidebotham and Zych 2016, p. 4; Zych *et al.* 2016, pp. 328-329.
25. Hull fragments excavated at Berenike include cedar of Mediterranean origin, as well as Indian Ocean materials, see Sidebotham 2011, p. 198 for the former, pp. 203 and 239 for the latter.

the Mediterranean and Indian Ocean world offers a reflection of the Indo-Roman trade networks themselves, and the wider connections that were undoubtedly present across those routes. Such activity is of course inextricably associated with the long distance routes and networks to which the Red Sea ports were connected. Alongside this, and very much within the ports, were the day-to-day activities, for example fishing, that constituted an integral part of port activity and maritime life. Although not a direct focus of this paper, extensive artefactual remains of that aspect of Red Sea maritime cultures have been excavated from Myos Hormos, and are the subject of extended analysis and discussion elsewhere[26].

Rigging & Sailcloth

The material described above that can be associated with the building, repair and breaking-up of ships is primarily concerned with ships' hulls and the large wooden timbers, planks, frames and the like, from which these were made. The other essential component of a functioning ship comprised the rigging and sails of the vessel, and artefacts representing these parts also survive in the archaeological remains at Myos Hormos and Berenike. In particular, notable classes of material (discussed below) include brail rings, sail fragments, rigging deadeyes and fragments of pulley blocks[27], representing many of the main components required for the wooden hardware of a sailing ship rig. As with the hull elements, their presence in the Red Sea ports should not come as a surprise, but as an expected part of the archaeological record of a port site frequented by a large number of ships that required servicing and maintenance.

While the numbers of these artefacts at each site does not seem large, e.g. 169 brail rings at Myos Hormos, when set against the total corpus of rigging components present from the entirety of the ancient Mediterranean the numbers are very significant[28]. Only one other site, the 4th century BC shipwreck at Kyrenia, has quantities of rigging material comparable to those from Myos Hormos. It may be noted that the Kyrenia shipwreck material is representative of a single vessel, at a single point in time, rather than the several centuries of rigging practice and multitude of vessels from the Red Sea ports. The importance of this for our understanding of Indo-Roman shipping is returned to below, but first it is worth reviewing some of the archaeological

26. See Thomas 2010; 2011; 2012.
27. See Wild and Wild 2001; Whitewright 2007a; Blue *et al.* 2011.
28. For a summary of this rigging material see Whitewright 2008, pp. 221-261.

material in more detail, specifically the material from Myos Hormos that provides a useful proxy for the overall range and classes of material present from the Egyptian Red Sea ports.

At Myos Hormos, rigging components of all types were recovered from an arc fringing the western side of the main occupation ridge at the site, overlooking the harbour and waterfront area[29]. In particular, a large amount of material was recovered from rubbish dumps, implying deposition through intentional discard after its useful life was over. This is confirmed by the broken or damaged nature of many of these items, primarily brail rings, and speaks strongly of the processes of maintenance and repair of the shipping that served the port.

Brail rings

Brail rings were by far the most numerous class of maritime artefact from Myos Hormos. They were excavated during every field season, principally from the Roman *sebakh* deposits, and encompass the full Roman chronology of the site, from the 1st century BC to the 3rd century AD. In the ancient Mediterranean brail rings were sewn to the face of the sail and acted to guide corresponding ropes, termed brailing lines or brails, from the foot of the sail, up its face, over the yardarm and back to the deck towards the stern of the vessel. Hauling on the brailing lines allowed the sail to be furled, reduced in size, or its shape adjusted without the need to send sailors aloft. The system of brails and the brail rings themselves are one of the most characteristic elements of the ancient Mediterranean sailing rig. They are visible in abundant iconographic examples and can be considered as its 'archaeological signature'. Within the Mediterranean shipwreck corpus brails are primarily made from wood or lead[30]. By contrast, of the 169 brail rings excavated from Myos Hormos only 51 (30%) were made from wood, and the remaining 118 (70%) were made from cattle horn. The wooden brail rings are manufactured with the grain running across the flat face of the ring, and this technique is mirrored in the horn rings, which

29. For further analysis of this distribution see Blue *et al.* 2011, pp 205-209.
30. Comparative selected examples, made from lead as well as wood, have been excavated from the Cavalière (Charlin *et al.* 1978, pp. 57-60), Grand Congloué (Benoit 1961, 178-179, pl. 30), Grand Ribaud D (Hesnard *et al.* 1988, pp. 105-126), Kyrenia (H. Swiny pers. comm.) and Straton's Tower (Fitzgerald 1994, p. 169) shipwrecks and from the anchorage of Dor (Kingsley and Raveh 1996, pp. 55, pl. 49) in the Mediterranean and the river port of Naukratis in the Nile Delta (Thomas 2014, fig. 5). Additional material can be found in Carre 1983; Pomey 1997; Beltrame 2002; Whitewright 2008.

are cut from flattened pieces of animal horn[31]. The use of these two types of materials is consistent with finds of brail rings from Berenike, which were also made from wood and horn[32]. A sample of brail rings made from both wood (Fig. 4) and horn (Fig. 5) is included here in order to illustrate the characteristics of these artefacts.

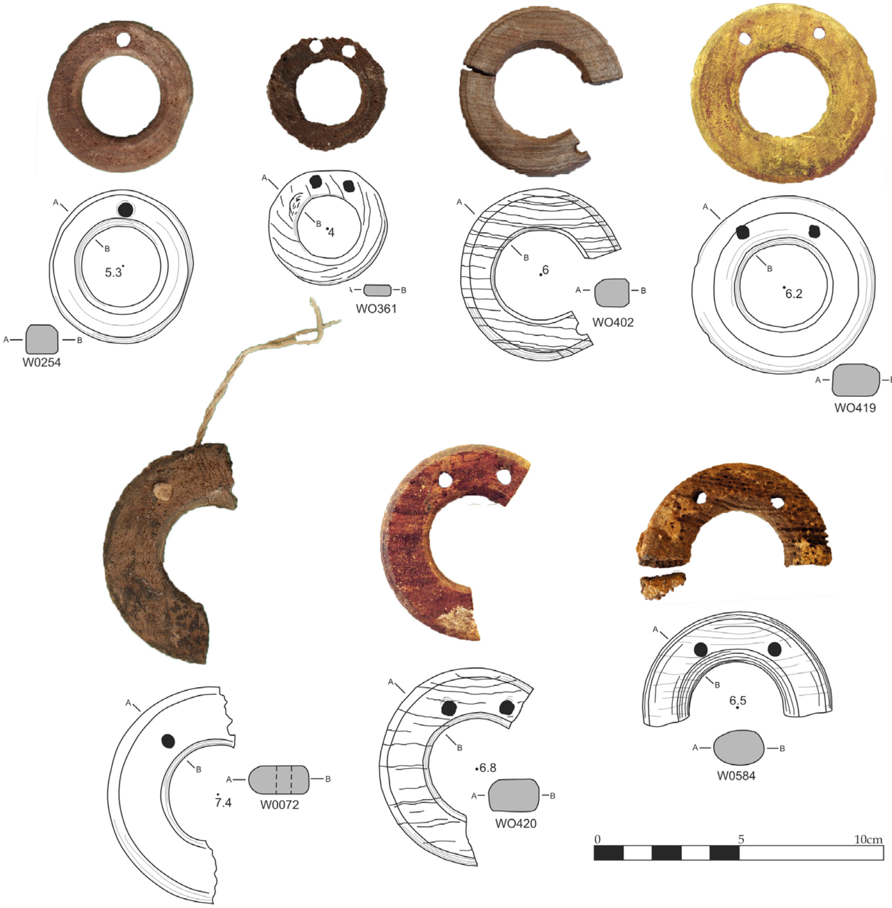

Fig. 4. Selection of wooden brail rings excavated from Myos Hormos. Each ring is shown in plan and cross-section; the centre number for each ring indicates the overall diameter of the ring (J. Whitewright).

31. S. Hamilton-Dyer pers. comm.
32. Wild and Wild 2001, p. 214; Sidebotham 2011, p.200.

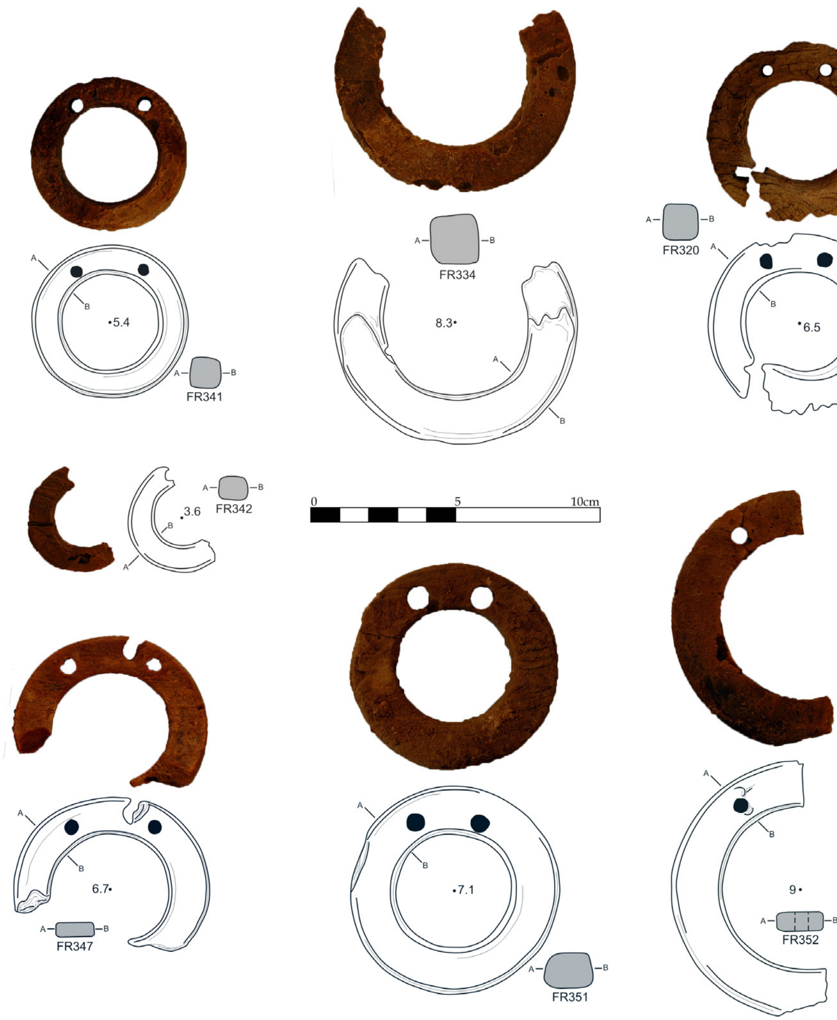

FIG. 5. Selection of horn brail rings excavated from Myos Hormos. Each ring is shown in plan and cross-section; the centre number for each ring indicates the overall diameter (J. Whitewright).

Although superficially similar, there are differences between individual rings from Myos Hormos with the illustrated examples representing diversity of detail in their manufacture. The most obvious of these is the large variation in size ranging from 27mm to 90mm in diameter in order to accommodate a correspondingly different range of brailing-line diameter (discussed further below). In the illustrated sample (FIG. 4) it is also possible to see differences in cross-sectional form; within wooden rings from almost circular or oval (WO584), to square (WO254) or rectangular (WO361) in shape, and in horn rings between square (FR334) and flattened rectangular (FR352).

The majority of the brail rings are pierced with two holes directly through the body of the ring, although some have a single hole. These holes were the point where the brail ring was attached to its sail, as demonstrated by a brail ring still attached to the fragment of sail cloth (Fig. 6). There is relatively little difference in the size of the attachment holes, ranging from 4-7mm, and with the largest brail ring (FR352) carrying an attachment hole only 1mm larger than that visible on the smallest ring (FR342). Attachment cordage itself was obviously a relatively consistent diameter. As well as the difference in form, the wooden rings also exhibit difference in their material origins. Some of the rings, as might be expected, are made from Egyptian and Mediterranean wood species, including olive and tamarisk[33]. But, many others are made of blackwood (African Ebony), which is a sub-Saharan species[34]. The importance of this, along with the use of horn, for informing our wider understanding of the shipping at the Indo-Roman ports is discussed below.

These apparently mundane rigging components allow a surprising amount of interpretation concerning the shipping that operated out of the Red Sea ports, their rigging and refitting. Critical to this is the sample size recovered from the archaeological record, which in conjunction with the long chronology of the remains, allows conclusions to be drawn that cannot be extracted from single shipwreck sites. Firstly, returning to the detail of the material from Myos Hormos, the difference in diameter between the largest (90mm) and the smallest (27mm) brail ring is striking, and possibly reflects some of the relative size differences between the largest and smallest vessels. Brail rings provide direct proportional evidence for the size of brailing lines because a larger brail ring will carry a larger rope. Larger diameter rope will logically be utilised to furl larger (heavier) sails, which would naturally occur on larger vessels. As such, the range of brail ring diameters present in the Red Sea ports is a direct reflection of the many different vessel sizes that operated out of them.

This model becomes more complex to apply when the wider variation in the Mediterranean square-sail rig is considered[35]. For instance, vessels carrying two smaller sails, rather than one large mainsail, would produce a sample of

33. Gale and van der Veen 2011, pp. 221-222.
34. *Ibid.*
35. See Whitewright 2016 pp. 879-884.

smaller brail rings than would otherwise be expected for a hull of the same size rigged with a single square-sail. Likewise a vessel rigged with an *artemon* foresail (small foremast) or a *mizzen* (small sail at the stern) would also have produced small rings in association with that sail, as well as larger rings from the mainsail. At least some of this variation is likely to be present in Indian Ocean shipping, where both single and two-masted ships are depicted. The exact nature of the sail-form on these vessels is ambiguous, but a single-masted ship is depicted on a pot-sherd from Berenike[36], from Alagankulam in south India[37] and from Anuradhapura in Sri Lanka[38]. Meanwhile, a number of depictions from Indian sources, including both pottery and coinage show two-masted vessels illustrating that such a rig was in concurrent use in the Mediterranean and Indian Ocean[39].

Returning to brail ring size as discussed above, it may be noted that the most important characteristic of the brail rings rigged on a single sail is that the diameter of the rings is uniform enough so that a small ring cannot fit inside a large ring when the sail is furled. Such an occurrence is likely to result in a tangle or jam when the sail is subsequently unfurled. With this in mind, the variation in the size of brail rings from Myos Hormos (27-90mm) can be usefully contrasted with the brail rings from the 4th century BC Kyrenia ship where a total of 171 lead brail rings were excavated[40]. Of these, 131 were similar to those from Myos Hormos (with two attachment holes punched through the body of the ring) and measured between 59mm and 67mm in diameter. The remainder, which measured between 65mm and 72mm in diameter, had a rectangular lug on one side where the attachment holes were located [41]. In both groups, the relatively tight clustering of the overall diameters is striking when compared to the wide range present at Myos Hormos.

Further comparative evidence comes from the Grand-Congloué site (210-70 BC), where lead brail rings also occur in two different forms. Around 80 rings (without lugs) exhibit a consistent diameter of c. 80mm, while another group (with lugs) ranged between 90-120mm[42]. Further analysis of the brail rings from the Grand-Congloué site is problematic because they are repre-

36. Sidebotham 1996.
37. Sridhar 2005, pp. 67-73, fig. 24.
38. Coningham *et al.* 1996, fig. 16; Rajan 2002, fig. 4c.; Allchin 2006.
39. Elliot 1885, pl. 1, fig. 38, pl. 2, fig. 45; Deloche 1996, pp. 243-244; McGrail 2001, pp. 253-255; Rajan 2002, fig. 4b; Sridhar 2005, pp. 67-73, fig. 7, pl. 23.
40. L. Swiny pers. comm.
41. *Ibid.*
42. Benoit 1961, p. 178.

sentative of at least two shipwrecks mixed together during excavation[43]. Each of the two groups of brail rings, with discreet forms and size, probably corresponds to a different ship.

Overall, the relatively close size of the brail rings found on the Kyrenia and Grand-Congloué sites backs up the observations made regarding the diversity in size of the Myos Hormos brail rings. The brail rings from Kyrenia and Grand Congloué are similar in size because they each come from a single vessel that would have required a single size of brail ring for a single sail. This provides a direct contrast with Myos Hormos, where the range of vessel size using the port is reflected in the diversity of brail ring size. At this point, an important caveat should be noted: that because of the variation in rig-type it is not possible to equate a specific brail ring diameter with a specific tonnage of vessel.

The overall form and material of the Myos Hormos brail rings is also significant. With regard to form, there is a lack of uniformity (visible mainly in cross-section) suggesting that individual makers had differing preferences for production techniques, resulting in different end products. Comparable diversity in cross-sectional form was also present in the lead brail rings from the Grand-Congloué shipwreck where three different forms of cross-section were observed[44]. There seems no reason at present to suggest that any of the different forms would have been superior to the others and it may have just been a matter of personal choice. Likewise, there is no obvious chronological patterning, or grouping, based on Mediterranean/non-Mediterranean materials. The materials used for the production of the brail rings from Myos Hormos are also significant. Most obviously, lead, which is a common brail ring material on Mediterranean shipwrecks, is absent and all the rings are made from wood or horn; the latter of these comprises 70% of the total. The wider faunal record from Myos Hormos, including a sawn-off cattle horn-core, suggests that cattle were driven to the site on the hoof[45], and so the horn brail rings probably indicate the reuse of horn from animals slaughtered at the site for food. The alternative is that the horn rings were manufactured on the Nile, as a bi-product of cattle slaughtered there, before being transported to the coast, either as finished rings or as horn in its raw material form.

43. Long 1987; Parker 1992, pp. 200-201.
44. Benoit 1961, p. 178.
45. Hamilton-Dyer 2011, pp. 246-247.

At Berenike, an ostracon (*O.Ber*. II 131) records the storage of rigging material at that site[46]. Given the number of ships visiting both ports it is likely that large stores of rigging material, or the raw material to manufacture it, would have been brought from the Nile. This view is further corroborated by the contemporary Koptos Tariff recording the transport of a ship's mast from the Nile to the Red Sea coast[47]. Of course, the archaeological remains indicate that the Nile, and the Mediterranean world beyond it, was not the only source for fitting and refitting rigging. As noted above, many wooden brail rings from Myos Hormos were of non-Mediterranean origin, specifically from sub-Saharan Africa. This corresponds closely with the trade routes attested in the *Periplus Maris Erythraei* that stretched down the coast of East Africa. Overall the evidence suggests that vessels were being refitted with locally produced horn brail rings prior to an outbound (from Egypt) voyage, while those lost or broken along the route would be replaced using local materials at the next port of call. The final stage of this cycle is the discard of these wooden rings and re-fit with local materials following a vessel's return to the Red Sea coast. It is such diversity of origin that probably explains the differences in the cross-section of the wooden brail rings. Different vessels visited many ports around the Indian Ocean in the course of trade and damaged or broken rigging may have been replaced at each. It is impossible to tell whether the rings were made in overseas ports and bought by the visiting vessels or made on board by the sailors from wood procured whenever they made landfall.

Sailcloth

The brail rings were the most numerous class of rigging component found at Myos Hormos, but they are surpassed in archaeological significance by the fragments of sail cloth that have been excavated at the site[48], with near-identical finds from Berenike[49]. In the context of maritime antiquity, the sailcloth found at these two Red Sea ports is virtually unparalleled in the material record. Sailcloth from any period is an archaeological rarity, and so the dozens of fragments from Myos Hormos and Berenike are exceptional. The key moment in the identification of sailcloth at Myos Hormos came in 2003 when a small fragment of textile (T331) was found from a late 1st or early 2nd century AD rubbish dump. It was possible to distinguish this as sailcloth, when compared to other textiles, because of the remains

46. Bagnall *et al*. 2005, p. 47.
47. Sidebotham 2011, p. 201.
48. See Handley 2011.
49. For the Berenike material see Wild and Wild 2001.

of a wooden brail ring still attached. Sewn to the sailcloth was a reinforcement strip of heavier, herringbone-style webbing material and it was to this that the ring was attached. The brail ring measured 50mm in diameter and its attachment orientation (with the holes uppermost) confirmed that the reinforcement strip ran horizontally across the face of the sail. Discovery of this fragment (Fig. 6) permitted the subsequent identification of a further 68 pieces of reinforcement webbing and fragments of sail and/or reinforcement webbing to add to the existing corpus of material from Berenike.

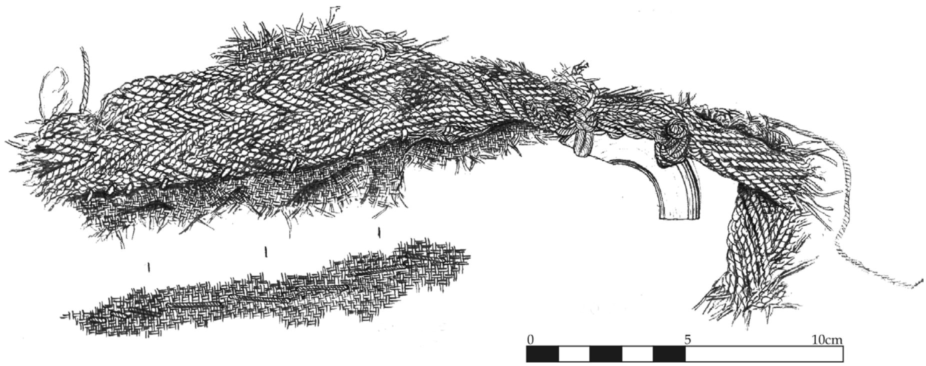

Fig. 6. Fragment of sail excavated from Myos Hormos, dating to the late 1st or early 2nd century AD with wooden brail ring attached to the reinforcement webbing (J. Whitewright).

While archaeological examples of ancient sails are extremely rare, there are numerous iconographic depictions from antiquity that are extremely useful for informing our general view of ancient sailing rigs[50]. These often show sails with a series of vertical and horizontal lines running across their face, interpreted as brailing lines (vertical) in conjunction with strips of textile or leather (horizontal) used to reinforce the seams between strips of sailcloth[51]. It is likely that as well as reinforcing the sailcloth, the webbing strips also served to reduce the amount of stretch to which the sailcloth would have been subject while under sail. The widely held interpretation of the iconography is confirmed by the examples of sailcloth from Berenike, Myos Hormos and also a contemporary find from the Nile at Edfu[52]. Sailcloth from Berenike was made with cotton reinforcement strips running both vertically

50. For discussion of such use see Whitewright 2017a.
51. Casson 1995, pp. 68-69, 234.
52. Rougé 1987; Black 1996, figs 5-6.

and horizontally[53]. Likewise, the sail from Edfu has a brail ring attached to the horizontal strip at the point of intersection with the vertical one[54]. One sail fragment from Myos Hormos (T392) comprises the sail's edge with the remains of a webbing strip in which the alignment of the surviving brail ring attachment indicates that the webbing strip ran vertically up the face of the sail. This arrangement is mirrored in another example (T27), which has two brail ring attachment points aligned in such a way as to indicate that the webbing ran in a vertical direction with no evidence for horizontal webbing present at either brail ring attachment point. In contrast to this, the original sail fragment T331 shows no sign of a vertical webbing strip at the point of attachment of the brail ring to a horizontal webbing strip.

The detail of the sailcloth finds from the Red Sea ports greatly expands our understanding of the physical construction of ancient sails. In particular, it seems to indicate that there were at least three possible approaches to sail-making in use amongst the shipping operating out of Berenike and Myos Hormos. One involved the use of vertical and horizontal reinforcement webbing strips intersecting across the face of the sail and to which the brail rings were attached. A second technique utilized only horizontal webbing strips to reinforce the sail, while a third technique seems to have utilised only vertical webbing strips. It may also be noted that in some cases the webbing spans across the seam between two lengths of sailcloth, and where brail attachments survive this can indicate the original alignment of the bolts of sailcloth. As this narrative indicates, some of these sails were made from cloth set horizontally, while others demonstrate vertically set lengths of sailcloth.

The material of the sailcloth also provides an insight into the wider sourcing of maritime materials within the Indo-Roman networks. The sailcloth excavated from Berenike and Myos Hormos was constructed from cotton; a contrast with the linen cloth and flax reinforcement used on the Edfu example[55], and the wider historical sources which also point to linen as the normal material for sailcloth in the ancient Mediterranean[56]. Moreover, in many examples from the Red Sea ports, both sailcloth and reinforcement strips were originally made in India[57], although several examples from Myos

53. Wild and Wild 2001, p. 214.
54. Black 1996, figs 5-6.
55. Wild and Wild 2001, p. 213; Wild 2002, p. 13.
56. Black and Samuel 1991, p. 220.
57. Indian and Egyptian produced cotton are distinguished from one another through the use of a 'z' spun (clockwise Z/Z) yarn for the former and an 's' (anticlockwise S/S) spun yarn for the latter. For Berenike see Wild and Wild 2001, pp. 211-220. For Myos Hormos see Handley 2011, pp. 325-330. See also Handley, this volume.

Hormos were also made from Egyptian cotton. This suggests that vessels engaged in the India trade may have been fitted out with Indian cotton imported into Egypt, or repaired upon arrival in India using local products[58]. If sails were constructed in Egypt from bolts of imported cloth, they could represent part of a return trade in relatively low value cotton. Indian cotton is mentioned in the *Periplus* (*PME* 41) as being one of the products of the land around the port of *Barygaza* and might therefore be a source of the cotton used in the sailcloth. It is interesting to consider how such imported material would have competed with the Egyptian cotton attested from Myos Hormos.

Sheaves and Deadeyes

In a ship's rigging the sail is raised and controlled by a system of ropes termed the 'running rigging', because it is free to move and be manipulated by the crew. Meanwhile, the mast is supported by 'standing rigging,' which is more permanently fixed in place and less readily adjusted during use. The final element of the ancient sailing rig represented in the archaeological record at Myos Hormos were seven wheels, termed sheaves, from pulley blocks (Fig. 7), and single large deadeye (Fig. 8). The latter is almost certainly from the standing rigging of a ship, while the sheaves could be from the pulley blocks that facilitated a vessel's running rigging, or from pulleys put to general use around the port.

Six of the sheaves date to the latter half of the 2nd century AD, while one (W0198) is early Roman in date. In all cases the accompanying outer shells, and axles upon which the sheaves would rotate within those shells, were absent. Six of the sheaves were flat, circular pieces of wood, termed disc sheaves, the design of which has changed little from antiquity to the present day. The sheaves range in size from 46mm to 81mm diameter with a consistent thickness of 14-16mm. The outer edges of the disc sheaves, where not decayed, were grooved to carry rope running through the block. It might be possible to account for the difference in sheave diameter by the use of bigger sheaves in blocks designed to resist higher loads, by contrast, the ropes that ran around these sheaves seem to have had a very consistent diameter. Comparative disc sheaves, or blocks utilising disc sheaves, have been excavated from a large number of shipwrecks or terrestrial sites dating to antiquity[59]. Disc sheaved blocks are also visible in the depiction of naval spoils on

58. Wild and Wild 2001, pp. 217-218.
59. Selective examples include Cavalière (Charlin, *et al.* 1978, pp. 57-60), County Hall (Marsden 1974, fig. 8.2), Grand Ribaud D (Hesnard *et al.* 1988, pp. 105-126), Laurons 2 (Ximénès and Moerman 1990, pp. 5-6 and fig. 1), Madrague de Giens (Carre 1983,

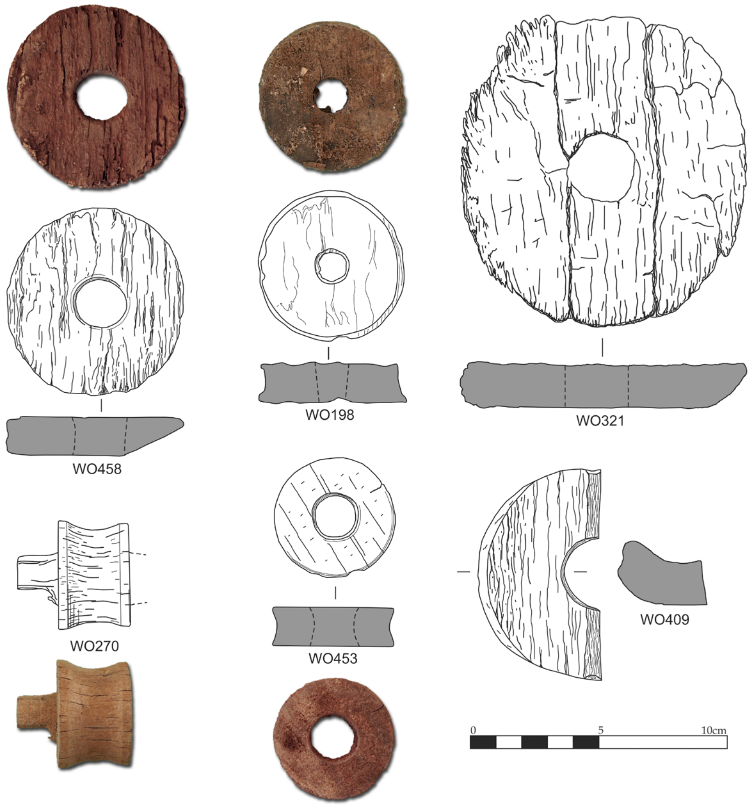

FIG. 7. Wooden sheaves excavated from Myos Hormos. All date to the second half of the 2nd century AD with the exception of WO198 which is 1st century AD in date (J. Whitewright).

the triumphal arch at Orange[60], further indicating their widespread use and likely ubiquitous nature.

By contrast, the seventh sheave excavated at Myos Hormos (W0270) was quite different. Although damaged it was clearly cylindrical in its original overall form with integrated axles. Such cylinder sheaves are distinctive to the ancient Mediterranean and a number of comparable examples have been excavated

pp. 20-26, 49-50, 83, 94, 131, 154) shipwrecks and from a terrestrial context at the site of Kenchreai (Shaw 1967, fig. 1). Additional material can be found in Carre 1983; Pomey 1997; Beltrame 2002; Whitewright 2008.

60. Amy 1962, pl. 25.

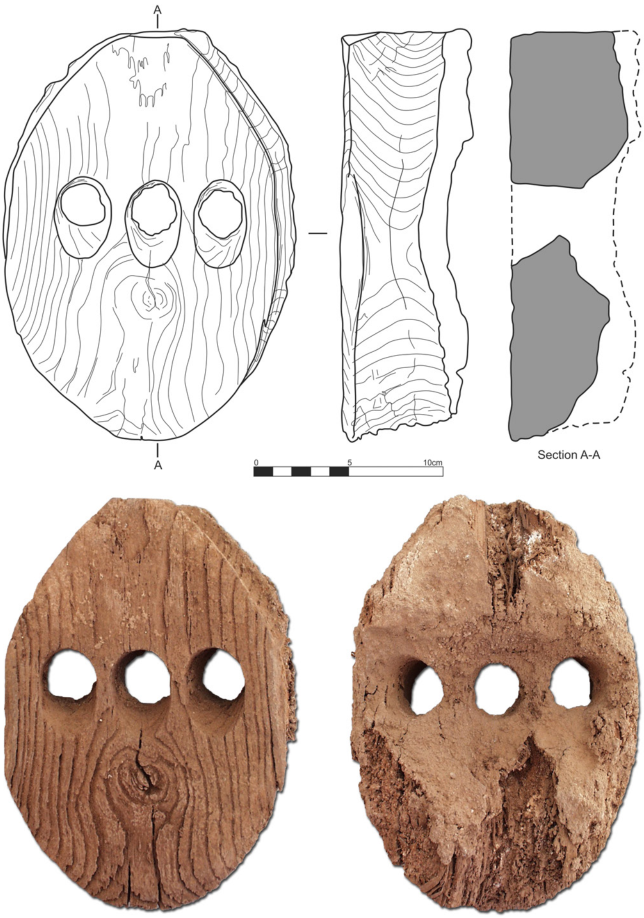

Fig. 8. Wooden deadeye excavated from Myos Hormos, dating to the mid/late 2nd century AD (J. Whitewright).

from shipwreck and harbour sites[61]. W0270 represents the only evidence of the use of this form of sheave block at Myos Hormos. The size of the sheave suggests a block of similar size to one found at Caesarea Maritima: 130mm long by 90mm wide. As with the brail rings described previously, the sheaves from Myos Hormos were made from wood with a variety of geographic ori-

61. Selective examples originate from the harbour of Caesarea Maritima (Oleson 1983; Oleson 1994, p. 104, fig. 33, pl. 22) and also from the Cap del Vol (Foerster 1980, fig. 5), Comacchio (Berti 1990), Grado (Beltrame and Gaddi 2005, fig. 2), Grand Ribaud D (Hesnard *et al.* 1988, pp. 105-126) and Kyrenia (Swiny and Katzev 1973, p. 351 and fig. 12) wrecks.

gins including the Mediterranean (alder), but also the wider Indian Ocean region (teak from India, blackwood from sub-Saharan Africa)[62].

The rigging deadeye was excavated in the 2001 Myos Hormos season and dated by associated material to the mid-late 2nd century AD[63]. Deadeyes are usually rigged in pairs, allowing them to be tensioned at the base of shrouds or stays (ropes rigged to provide lateral and fore-and-aft support for the mast). Components of a broadly similar shape and function are still found on traditional square rigged sailing vessels today. The deadeye from Myos Hormos is an oval shaped piece of blackwood (*Dalbergia* sp.), pierced by three holes set alongside one another in the centre of the block. It measures 214mm long, 144mm wide and 55mm thick, although the reverse side had been heavily degraded. The outside edge had been grooved in order to take a rope strop which could have been up to 28mm in diameter. The three central holes could have carried ropes of up to 25mm in diameter. Comparable deadeyes, albeit much smaller in overall size, have been excavated from a number of Mediterranean shipwreck sites[64]. Apart from the overall size, other observable differences with the comparanda relate to the number of holes (two rather than three in some examples), or their arrangement. So although deadeyes from different contemporary sites in antiquity were serving the same general purpose, the detail of how they were deployed within a sailing rig differs from place to place[65].

Interpretation and Discussion

The previous sections summarised the archaeological detail of the hull elements and rigging components found at Myos Hormos, which can also be taken as a representative of those found at Berenike. With this in mind, the following section sets out the broader interpretation of this material with regard to the implications it has for our understanding of the shipbuilding, rigging and sailing traditions used on the vessels of Indo-Roman trade that operated from, or visited, the Egyptian Red Sea ports. More specifically, this concerns construction sequences and overall traditions, the role of shipbuilding and maintenance within the port sites, the forms of sailing rig used

62. Gale and van der Veen 2011, pp. 221-223.
63. Thomas and Masser 2006, pp. 131-132.
64. Selective examples occur through five deadeyes from the Grado site (Beltrame and Gaddi 2005, p. 80), and fourteen from the Laurons 2 site (Ximénès and Moerman 1990, p. 7, fig. 2). Additional material can be found in Carre 1983; Pomey 1997; Beltrame 2002; Whitewright 2008.
65. For further discussion of this see Whitewright 2007a, pp. 287-288.

on merchant ships, and the likely resulting potential performance of such ships. Finally, it allows broader comment to be made on the technological relationship between Mediterranean maritime technology and Indian Ocean maritime technology during the peak period of Indo-Roman trade in the first centuries of the first millennium AD.

Shipbuilding and Rigging Traditions

Turning attention initially to shipbuilding and ship construction traditions, it is clear from the archaeological remains at Myos Hormos and Berenike that ships were being repaired and broken-up at both ports. The wider historical evidence indicates that shipbuilding was taking place at Myos Hormos during the Roman period, and probably at Berenike prior to the foundation of Myos Hormos. Indeed, it is possible to speculate that one of the reasons for the development of the latter port was because of its relative proximity to the Nile, several days closer when compared to Berenike, making Myos Hormos more easily accessible and therefore cheaper for the transport of supplies, materials, etc., including shipbuilding timber. It is beyond doubt that the vessels attested to in the archaeological record were built in the same construction tradition as contemporary Mediterranean ships: shell-based with edge-joined mortise-and-tenon planking. Furthermore, the material origins of the hull remains indicate that such shipbuilding timbers, utilised in a Mediterranean tradition, were sourced from the wider Indian Ocean region, as well as the Mediterranean. Of course, the exact origin of the ships themselves can never be known with certainty; they may have been variously under Mediterranean, Egyptian, Arabian or Indian ownership, and built, in theory at least, anywhere around the shores of the Indian Ocean. As noted by a referee of this paper, vessels could easily have been built under Mediterranean oversight in an Indian location. Similarly, the extent of vessels built in distinctly Indian Ocean construction traditions, within the Indo-Roman trade networks, is hard to fully quantify from the available evidence[66]. Such craft certainly played a role at individual ports and within local systems[67], but there can be no certainty regarding the use of long distance merchant ships built using an Indian Ocean, rather than Mediterranean, method. The overall picture is one of great potential complexity and the extent of the data available simply allows a reasonable interpretation that the main Red Sea ports of Myos Hormos and Berenike were engaged in the building (in the case of the former), refit and breaking up of Mediterranean style ships. Meanwhile, the geographical origin of the hull timbers highlights two possibilities. First, that

66. See Deloche 1996; Ray 2003, pp. 55-81; Kotarba-Morley 2017, pp. 197-202.
67. Kotarba-Morley 2017, p. 199.

timber as a raw material was transported to the ports along the Indian Ocean trade networks, and would have been a companion material to that attested to have arrived from Mediterranean sources. The second possibility is that the hull timbers represent ships from across the Indian Ocean, of Indian Ocean origin, but built in the same building tradition as contemporary vessels from the Mediterranean.

The same overall patterns are reflected in the rigging components recovered from the archaeological record at Myos Hormos and Berenike. Again, the basic comparative analysis of the material places it firmly within the square-sail rigging tradition of the contemporary Mediterranean; all of the maritime archaeological material described and discussed above is consistent with that found at contemporary sites in the Mediterranean. Within such a tradition, vessels may have been rigged with a single-mast, two equal sized masts, an *artemon* and mainsail, or a three-masted rig of *artemon*, mainmast and mizzen[68]. As seen with the hull timbers, rigging components of all types are derived from Indian Ocean sources, as well as Egyptian/Mediterranean ones, raising the same set of possibilities for the origin of the ships they are rigged upon.

Moreover, material from the Red Sea ports represents several centuries of consistent rigging and shipbuilding traditions at the same site, especially with regard to rigging. This represents hundreds, even thousands, of vessels across the time period concerned within broadly the same geographical, economic and cultural context. In terms of technological practice and trajectories, it represents a view of how people were rigging and using their ships that is of much greater value than a small collection of single shipwreck sites. The ships represented in the archaeological record are thus of Mediterranean cultural origin (some of them almost certainly are), and also representative of Indian Ocean maritime cultures operating long distance sailing ships within a tradition of construction of rigging shared with their Mediterranean contemporaries. This possibility was raised by the present author in 2007 as a result of initial interpretation of only the rigging material from Myos Hormos[69]. Continued work on the archaeological material, extended here to the ship remains, has not diminished this argument; it remains entirely plausible to suggest that the material from the Red Sea ports represents a tradition of building and rigging vessels that was shared across the Mediterranean, Red Sea and western Indian Ocean in antiquity.

68. For a fuller outline of ancient Mediterranean rigging arrangements see Whitewright 2016, pp. 879-884.
69. Whitewright 2007a, pp. 290-291.

Ships and Sailing Performance

Of course, understanding the construction and rigging traditions of a sailing ship allows a reasonable estimation of overall performance to be made and the ships of the Indo-Roman trade networks, attested through the archaeological evidence of the Red Sea ports, are no exception to this. As outlined above, it is clear that a significant proportion of these vessels were built and rigged with traditions that are normally classed as 'Mediterranean'; shell-based mortise-and-tenon hulls, powered by a loose-footed brailed square-sail. What is unclear is the nuance of individual vessels within such traditions. For example, the absence of substantial hull remains means that an understanding of hull form can only be estimated, while the ambiguous nature of iconographic depictions of sailing rigs in the western Indian Ocean region means that overall sail-plan cannot be confirmed[70]. Consideration of performance, and the implications of such performance, therefore, requires some assumptions to be established through reference to the wider comparative evidence of the building and rigging traditions.

Firstly, in relation to hull form, the archaeological remains of ships and boats of all classes, shapes, sizes and purpose have been excavated from the ancient Mediterranean[71]. These range from harbour dredgers[72] and fishing boats[73] through to very large merchant ships of over 40m in length[74], and encompass vessels with flat bottoms as well as those with deeper keels[75]. Hull form in antiquity was therefore variable enough to indicate that vessel purpose, rather than sailing performance, was the key driver in the selection of shape. But, hulls did exist that were large, capacious, deep-keeled[76], and would have had the most effective hulls for long-distance open-water voyaging on a variety of different courses to the wind, including upwind. Secondly, research[77] has established the overall potential performance of the Mediterranean square-sail of antiquity in its various collated forms[78]. This can be summarised as upwind performance *in optimum conditions* of 60-65° for maximum heading angle to the wind, and with a VMG (velocity made good) of no more than 2 knots in a windward direction. Meanwhile,

70. For wider discussion of Indian Ocean sailing rigs in this period see Whitewright 2015.
71. Summarised by Whitewright 2017b.
72. Pomey and Rieth 2005, p. 50.
73. Boetto 2006, pp. 123-129.
74. Tchernia *et al*. 1978.
75. Whitewright 2017b, pp. 210-212.
76. For example, the 1st century BC Madrague de Giens shipwreck.
77. Whitewright 2011.
78. Whitewright 2011, table 6.

on courses across the wind (reaching) and downwind (running), average speeds of c.4-6 knots might be expected in favourable conditions with an estimated maximum speed of c. 12+knots.

Establishing the possible performance of at least some of the ships engaged in Indo-Roman trade permits some reconsideration of how mariners and merchants used such ships within the trade routes described by the ancient sources. Such activity must have paid significant attention to the weather patterns thought to have existed in the Indian Ocean in the early first millennium AD, namely the Indian Ocean monsoon system (Fig. 1). The seasonally predictable nature of that weather system has resulted, perhaps unsurprisingly, with sailing between Egypt and the wider Indian Ocean being conducted when the weather was most favourable: generally to the south and east in the late summer, and west and north in the winter and spring. Despite sailing vessels rigged in a Mediterranean tradition having some capacity to sail to windward in ideal conditions, it makes little sense to sail an upwind course unless totally necessary; courses to windward offer the slowest passage times while placing the greatest physical strain on a vessel and crew. By contrast, voyages made under favourable wind conditions offer the fastest passages with the least physical cost to ship or sailors. Acknowledging this, when attempting to reconstruct distance and time in maritime antiquity, is critical if a reasoned understanding of the spatial relationship between ports, along trade routes, and within networks is to be achieved.

Within the archaeological/historical literature associated with the Red Sea it is common for the perceived challenges associated with sailing against the Red Sea's northerly wind to be highlighted[79]. However, whatever the reality of these challenges in the Roman period, they did not prohibit the placement of important ports of trade at Myos Hormos, Clysma and Aila, at the northern end of the Red Sea. A simple exploration of this can be found in the north/south position of Myos Hormos and Berenike[80], with the latter often seen as facilitating easy trade because it did not require vessels to sail further north, against the prevailing northerly winds of the Red Sea. Analysis of vessel speed, terrestrial travel time and potential economic costs indicates that the situation is far more complex than this. In reality Myos Hormos was just as likely a destination as Berenike and one that could be regularly reached by sailing against the northerly wind.

79. Casson 1980; Facey 2004; Sidebotham 1989, pp. 198-201.
80. For an exploration of this particular case study see Whitewright 2007b.

With the concept of windward sailing in mind, it is interesting to note the observation by the authors of the *Red Sea Pilot* that 'Anyone used to sailing to windward will not find the Red Sea markedly worse than anywhere else'[81]. Sailors native to areas where upwind sailing was a part of life may have taken for granted the techniques required to sail to windward in the northern part of the Red Sea. By contrast, sailors from areas where favourable trade winds generally prevail during the sailing season, such as the Indian Ocean, may have had far more difficulty adapting to the unfamiliar conditions of the northern Red Sea. In the medieval period Indian Ocean merchant ships sailed only as far as Jeddah, and goods were then trans-shipped to Egypt by vessels from the northern Red Sea itself[82]. This strongly suggests a scenario where Indian Ocean sailors were unable to cope with the environmental conditions of the Red Sea, leaving sailors and vessels familiar with the requirements of upwind sailing to carry the cargoes. To Mediterranean sailors, the northern third of the Red Sea simply represented a region where favourable winds would not be encountered. Although an inconvenience after the favourable monsoon winds of the Indian Ocean, the rig, hull and sailing techniques of Mediterranean vessels and mariners would have been well able to cope with an extended period of upwind work. Such analysis is, of course, a counterpoint to the possibilities raised above regarding the presence of Indian ships in the Red Sea ports.

Finally, the corpus of brail rings from Myos Hormos indicates a range of rig sizes, assumed to represent a range of vessel size. Given what is known of the range of ship/boat-types and hull forms from the contemporary Mediterranean, it might be expected that a similar variety of craft was present in Myos Hormos. This would of course include very large merchant ships within the fleet of 120 ships attested by Strabo[83], but it must also have encompassed fishing vessels and ships of a size more suited to local coasting. Likewise, the nature of the harbour front at Myos Hormos[84] strongly suggests a system of lightering, whereby small boats unloaded merchant ships, moving the goods from ship to shore. Additionally, papyrological evidence indicates the presence of military vessels operating out of Myos Hormos[85]. Without significant hull remains, accurate reconstruction of these vessels is challenging – for instance in the case of military vessels or fishing vessels, where even the Mediterranean archaeological record is limited. But,

81. Davies and Morgan 1995, p. 26.
82. Facey 2004, pp. 9-11.
83. *Geography* 2.5.12.
84. Blue 2011.
85. Van Rengen 2011.

it is possible to arrive at a reasoned visualisation of what a large merchant ship, of Mediterranean cultural origin, operating out of Myos Hormos might have looked like. The vessel shown in Fig. 9 is a very large[86] merchant ship created for commercial consultancy work within the Centre for Maritime Archaeology at the University of Southampton. It is based on the shipwreck record present in the Mediterranean and is underpinned by a process of computational modelling and hydrostatic testing to prove stability, prior to visualisation and rendering. Its extreme size is deliberate, representing and exploring the maximum size and capacity such vessels might have reached, while remaining viable, seaworthy vessels. Its inclusion in this paper is not a statement that such vessels were the norm on Indian Ocean routes, rather an acknowledgement of the ultimate interpretation of the archaeological material presented here – that such vessels could have existed.

Fig. 9. Visualisation of a very large Roman merchantship, dating generally to the late 1st/early 2nd century AD. Top: waterline view from the port side. Bottom left: aerial view from the port quarter. Bottom right: aerial view from the port bow (Image courtesy of Science UK Ltd).

86. Critical vessel dimensions: length overall: 61m, beam: 13m, draught: 6.5m, displacement (overall): 2005 tons, displacement (cargo capacity): 1374 tons, total sail area: 937m^2.

Conclusion

The preceding sections demonstrate the extent of analysis and interpretation that is possible when reference is made to the detail of the maritime artefactual material from the Red Sea ports. In the case of the ships of the Indo-Roman trade networks it is only through reference to this archaeological material that it is possible to begin to understand the technological make-up of those ships in any depth. Moreover, this material must be considered with clear reference to the wider comparative, contemporary material. These comparisons, alongside the established historical, epigraphic and iconographic material, can potentially paint a vivid picture of the ships and shipping of Indo-Roman trade seen through the lens of the Red Sea ports.

That picture itself is one of technological continuity with the neighbouring Mediterranean; hardly surprising given its proximity, and the origin of much of the other cultural material from the Red Sea ports. It can be clearly stated that the shipping of the Egyptian Red Sea ports, at least that element represented in the archaeological record, were built with a shell-based mortise-and-tenon system of construction, and rigged with a loose-footed brailed square-sail. In this regard they would have been technologically indistinguishable from their Mediterranean contemporaries, and because of the present knowledge of the potential performance of Mediterranean shipping, such performance can be extended to the vessels operating on Indian Ocean routes. But, there are clear variations in the applied form of the rigging components discussed in this paper, when compared to their Mediterranean counterparts. This is hardly surprising when considered against the technological variation that is visible within the overall continuity of the Mediterranean square-sail rigging tradition in antiquity, and highlights the regional variation that is likely to be identifiable in maritime cultural artefacts, providing an adequate archaeological sample was available. Similarly, with regard to the materials of these components, the archaeological record tells a story of hull and rigging components manufactured from Indian Ocean materials, as well as Mediterranean ones. This in turn raises the question of whether or not the material related to shipping, excavated from the Red Sea ports, is as much a record of Indian Ocean maritime cultures as it is of those from the Mediterranean. The answer to this is unlikely to be proved decisively, but the possibility raised by careful analysis of the archaeological material must be acknowledged and considered further.

It can only be hoped that some future archaeological discovery, underwater or terrestrial, will unearth material within the wider Indian Ocean region that is comparable to that found in the Red Sea ports. Such a discovery would render our interpretation less reliant on an image of the shipping of Indo-Roman trade that is filtered through the narrow field of view available from the Egyptian Red Sea ports. For now, however, that narrow view is one that continues to offer the plausible reconstruction of a shared tradition of building, rigging, and by extension, use of ships and shipping that extended across both the Indian Ocean and Mediterranean world during the first centuries AD. With this in mind, it is striking to consider the possibility that an ancient mariner might have been equally at home, in the sense of a continuum of technical practice, working aboard a vessel in areas as geographically diverse and far apart as the province of Britannia or the ports of southern India.

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