

Sailing and Sailing Rigs in the Ancient Mediterranean: implications of continuity, variation and change in propulsion technology

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Ships and boats form the foundations of the maritime connectivity that is a central part of our understanding of the ancient Mediterranean. While the general chronological sequence of sail and sailing-rig development is well established, the implications are less-well discussed. This article sets out how sails and sailing rigs developed in antiquity, with emphasis on the Greco-Roman world. Subsequently, instances of innovation are defined. Why specific pieces of maritime technology were, or were not, widely adopted is considered. Long-term technological continuity can be comprehended, and a shared maritime culture of sailing in the ancient Mediterranean is suggested.

Keywords: Mediterranean, sailing, seafaring, square sail, spritsail, lateen.

The sea, and the opportunities it afforded for sustenance, travel, communication, commerce, and warfare, is often placed at the centre of large-scale studies of the Mediterranean and adjoining regions in antiquity. Notable examples include the work of Broodbank (2013) for prehistory, and of Horden and Purcell (2000) for the Classical World. Brief recourse to the geography of the region illustrates that such a focus is unsurprising, indeed even quite logical given the oft-quoted view of Plato (Pl. *Phd.*, 109b) in antiquity itself about the people of the Mediterranean being arranged like frogs around a pond. For this position to be fully justified an understanding of the maritime technology of antiquity, in other words the ships and boats, should be viewed as implicit to our wider appreciation of the complexities of the ancient world. In particular, if maritime connections are deemed so essential to the maintenance of commerce and communication, then an account of watercraft must be equally essential to any account of the economic context of antiquity. This is acknowledged by Schneider (2013: 147) who makes specific mention of ‘means of transport’ when discussing the link between technological and economic development.

Yet, perhaps because of the lack of a definitive classical work concerning shipbuilding and use such as that outlined by Vitruvius on specific aspects of architecture, analytical coverage is mixed. For example, the existence of a recent dedicated volume on *Maritime Technology within the Ancient Economy* (Harris and Iara, 2011) was noted as ‘unique’ by its *American Journal of*

Archaeology reviewer (Leidwanger, 2013), and offers a sharp contrast with the *Cambridge Economic History of the Greco-Roman World* that contains only two paragraphs on maritime transport, within a 27-page chapter on ‘Technology’ (Schneider, 2013). By any standards of coverage, the latter might be considered disappointing. In the absence of a historical handbook, our understanding of maritime technology must therefore draw heavily on archaeological evidence and, where that is insufficient, on a rich iconographic record (for example Basch, 1987), further enhanced by historical literary material (for example Casson, 1995). Archaeological remains, in particular those excavated from the second half of the 20th century onwards have shed light on the methods, processes, and traditions of shipbuilding in the ancient Mediterranean. This is especially true of the Greco-Roman world where an abundance of ships, both under water and in terrestrial deposits, have been located, excavated, and published in a general catalogue (Parker, 1992), with extended focus on construction (Pomey *et al.*, 2012), or with the specific concern of understanding design methods (Olaberria, 2014). Regrettably, the propulsion of these vessels is less well served, especially with regard to their sailing rigs where there is a relatively small amount of direct archaeological evidence compared to hull remains. As a consequence of this there must be a much greater reliance on iconographic material, despite its interpretative limitations.

This paper therefore sets out to achieve two things. First, to present a chronological account of sail and rig development in the Greco-Roman world as currently understood from the available evidence: iconographic, literary and archaeological (Fig. 1). To do this, it is necessary to initially reach further back in time in order to fully contextualize later developments. Reference to such an overview highlights both long periods of technological continuity, specific examples of variation within wider traditions, the invention of novel forms of sailing technology, and the adoption/non-adoption of those forms. All of which are themes worthy of investigation and discussion. The second aim stems from this, which is to offer a consideration of the implications of these observations from a nautical perspective, set against the backdrop of our current understanding of connectivity and technology within the ancient Mediterranean. Doing this highlights some of the shared traditions that prevailed in the ancient world and at times extended beyond the confines of the Mediterranean. It also emphasizes that, even without the wealth of historical material that serves other forms of ancient technology, it is still possible to identify, trace, and begin to comprehend considerable periods of technological continuity, to define instances of invention, and to consider why specific pieces of maritime technology were, or were not, adopted more widely in antiquity. The implications of this allow a revised view of innovation within maritime technology to be put forward, for a shared maritime culture associated with seafaring to be postulated, and for our understanding of the linkages between technological elements of such a maritime culture to be better related to their surrounding context.

Pre-Classical developments

By the 2nd millennium BC, Egyptian imagery shows vessels carrying a low, broad square sail with yard and boom in which the former is lowered downwards to the latter when furling the sail, and the boom itself is often supported by a web of boom-lifts (for example Vinson, 1994: 38–41; McGrail, 2001: 41–42). These depictions encompass Egyptian vessels, but also ships classified as Levantine/Syrian in origin, indicating a likely use of this rig-plan outside Egypt (Davies and Faulkner, 1947: pl. 5; Basch, 1987: fig. 111–114; Wachsmann, 1998: 42–47; Broodbank, 2013: 357). Alongside this, although still reliant on iconographic sources, there is evidence from outside of Egypt. Perhaps most notably on Minoan seals, which, although highly stylized, show a series of vessels carrying single-masted square sails (Basch, 1987: 95–107). Such sails are often shown filled with a criss-cross pattern and in some cases have rings drawn on, or near them (Fig. 2). Such evidence is certainly equivocal, but it is possible to suggest that these vessels represent the earliest artistic attempt to illustrate the brailed square-sail rig, with its distinctive attachment of fairlead rings to the face of the sail. Similar, ephemeral traces of this eventually long-lived technique for furling sail are pictured across the 2nd millennium BC, and Egyptian sources are cited as evidence of introduction of brails to Egypt from the wider Mediterranean (Vinson, 1994: 41–43; Wachsmann, 1998: 251–254). Eventually, the iconic naval battle between Egyptian forces and those of the Sea Peoples, pictured at Medinet Habu in *c.* 1200 BC (Nelson, 1943; Vinson, 1994: 44–45; Jones, 1995: 59–60; Wachsmann, 1998: 29–32) offers confirmation of the widespread adoption of the loose-footed, brailed, square sail across a variety of cultures in the eastern Mediterranean (Casson, 1995: 38–39). In a seemingly related development, important developments in weaving technology have also been noted as taking place at the same time (Tiboni, 2005). The potential performance of sailing rigs across the Late Bronze Age is difficult to assess because interpretation is restricted to iconographic evidence alone. However, the lack of obviously depicted shrouds, coupled with the continued depiction of oars and sails in conjunction, suggests that sailing on courses above 90 degrees to the wind was probably highly restricted and ineffective.

The technical details of the sailing rigs commonly depicted at the end of the 2nd and into the 1st millennium BC generally comprise relatively broad square sails, set on a single mast. The sail is hoisted on a yard that is characterized by commonly depicted down-curving ends, either because the yards are made from several pieces of timber fished together, because no lifts are used to support the yard, or a combination of the two. The sail is loose-footed, which is to say the lower edge is not connected to a boom in the manner of earlier vessels. The lower edge of the sail is therefore free to assume a much more curved shape (greater camber), with a probable increase in effectiveness as a result. Finally, the sail is no longer furled by lowering the yard down to the deck, as in mid 2nd millennium BC depictions. Instead, the system of brails allows the loose-foot of the sail to be drawn

upwards, with a system of lines attached to the foot of the sail and led up its face, through the brail ring fairleads, over the yard and down to the deck. This version of the square sail is greatly simplified from its earlier forms, but also more efficient and effective in its use due to the system of brails that allowed the shape of the sail to be manipulated, and rapidly furled, without the need to send any sailors aloft. If the depiction at Medinet Habu is taken as a relatively firm date, it is in this form that the square sail continues in use in the Mediterranean for the next 1500 years or so, until it seemingly begins to fall from use during late antiquity. In this regard it is possible to see this iteration of the Mediterranean square sail as the ‘main trunk’ of sailing-rig technology from which later developments and variations largely stem, but which has its roots firmly planted in the 2nd millennium BC.

Sailing as primary propulsion

During the early development of the Mediterranean square sail, most vessels were propelled by oars as well as sails. This serves to remind us of the period when paddling or rowing was the primary form of propulsion, but also offers a meaningful line of discussion about the implications arising from the abandonment of such combined propulsion systems in favour of sailing alone. In the broadest sense, watercraft will always have been party to some form of specialism as a result of their propulsion system and overarching purpose, including periods and places when paddling or rowing, not sailing, was the primary form of propulsion. Typically, this specialism of form is likely to have been longer, more slender hulls, to facilitate speed, and shorter, broader hulls for the purpose of cargo transport (McGrail, 1998: 194–202). Likewise, watercraft that utilized both rowing and sailing in different measures in order to be able to fulfil the tasks they were intended for have existed across broad temporal and spatial contexts. An example of this might be an ancient warship that used sails for cruising over longer distances, but whose primary propulsion system for combat purposes was the oar.

The concept to be addressed here is an even more fundamental one. That is, when a ship with a sailing rig becomes a pure sailing vessel, in the sense of having no other form of propulsion? Across great swathes of Mediterranean history, and pre-classical periods in particular, representations of watercraft emphasize the fact that they could be paddled or rowed, as well as sailed, or *vice versa*. The extent to which either of these forms of propulsion—the sail or the paddle/oar—was the primary one, with the other serving an auxiliary role can never be clear to us from the iconographic evidence alone. Likewise, early literary sources indicate that sailing and rowing were to a large extent interchangeable and depended on the conditions encountered at any particular time. This can be well illustrated by one of several passages within the *Odyssey* recording the use of oars, until the wind is from a fair or favourable direction:

Swiftly they went aboard and sat at the thwarts, and the ship moved out over the river Ocean above the billowing waters; there was rowing for us at first, then a fair wind. (*Odyssey IX*, 637–640)

In such Homeric accounts of seafaring, sailing is conducted when possible, but the oar is just as likely to be used as the sail. This is very much in agreement with the iconographic record, the creators of which were consistent in their depictions of vessels with both sail and paddle/oar, which suggests such vessels were considered by the on-looking consumers of the iconography as both sailing and rowing/paddling vessels. Bearing this in mind, something very profound begins to occur with increasing regularity during the course of the first half of the 1st millennium BC. Namely that sailing vessels are regularly depicted without the auxiliary propulsion that had been part of their illustrated make up for at least a millennia (see examples from this period in Basch, 1987; Wachsmann, 1998). An example of such a vessel, dating from the 8th/7th century BC, is shown on a Cypriot bichrome jug (Fig. 3). In that instance, the sail is furled up to the yard and its equal distribution of the sail on either side of the mast, along with the evidence from contemporary depictions, indicates it is likely to be a square sail. The depiction of vessels with heavily down-curved yards had been a common artistic convention in the Levant from the Late Bronze Age onwards. The absence of any indication of oars, along with the depiction of large transport amphora, gives the impression of a ship engaged in mercantile activity. Meanwhile, both a pure sailing vessel and contemporary oared/sail vessel are depicted on a late 6th-century-BCE, black-figured *kylix* (Fig. 4). On the left is a vessel with a sailing rig alone and on the right a galley propelled by both oars and sails. The images have been interpreted as a pirate galley attacking a merchant ship (Casson, 1995, 128, n.114). The latter is shown (top) with its sail furled, before they are loosed in order to flee (bottom). Meanwhile the galley is undertaking the opposite manoeuvre in moving from full sailing (top) to beginning to furl sail (bottom).

For this differentiation to be reflected so vividly in the iconographic record we can only conclude that in the eyes of the artists viewing such vessels, their representation should accurately reflect the status of the ships themselves as specialist sailing vessels, rather than anything else. The advent of such vessels allows us to suggest that the sailing rigs of such ships had been refined by their users to a position where auxiliary propulsion, normally oars by this point, could be dispensed with in most circumstances, with perhaps a small number of oars being retained for work in harbours where service craft were not available. This more than anything is clear indication that the ancient Mediterranean square sail now allowed its users to operate in an increasingly wide range of conditions. Freed of the constraints of large rowing crews, especially the need to accommodate and maintain them, such pure sailing vessels are likely to have had a much increased capacity, and to

have been able to sail longer distances using only the provisions carried on board. The broader implications of this are returned to and discussed below.

Variation: the Mediterranean square sail

As noted, from the Late Bronze Age onwards, the primary sail of the ancient world was the loose-footed, square sail, set from a single mast and furled using a system of brails. Vessels carrying such a rig were able to operate as pure sailing vessels, and this rig was still being depicted in the early 7th century AD (see below). While such depictions might not be definitive proof of the existence of such rigs at that later date, they were obviously still readily recalled from the memories of some people and rendered into the depictions that survive as our evidence. It is thereby possible to establish a line of technological continuity that stretches right through the period under discussion, from the Late Bronze Age to late antiquity, for the use of this type of rig. As such, the single-masted, loose-footed, brailed, square-sail rig can be considered as clear point of reference to which other instances of sailing-rig development, direct, indirect, tangential, or otherwise, can be related (Fig. 5).

To this central line of continuity, the use of a small foresail, the *artemon*, can be added from the middle of the 1st millennium BC (Basch, 1987: fig. 880; Casson, 1995: 70; Beltrame, 1996). The nature of the iconographic evidence dictates that differentiating between dedicated *artemon* foresails used for steerage, and a foremast providing propulsion within a two-masted rig is sometimes very difficult. But from the perspective of studying sailing practices, our interest in this feature is the same in both cases; that the *artemon* is a sail the primary purpose of which was to aid in balancing the interaction between hull and sailing rig (see Palmer, 2009; Davey, 2015). The apparent size and location of the *artemon* indicates that on downwind courses it would be largely shielded by the mainsail and add little to a vessel's overall speed (Arnaud, 2011: 153). In this regard, it is an indication that ancient mariners were attempting to sail on courses to windward and reacting to the problems that they encountered when attempting this in a manner more consistent than in previous centuries. The result of this was the development of a form of technology that was widely recognized enough to begin to be reflected in artistic depictions of those vessels.

The *artemon* provided a means to increase the manoeuvrability of sailing vessels by allowing a steerage point, via the forces acting through the sail at one extreme end of the vessel. In a related, later development, some rare depictions offer evidence of further refinement through the addition of a third mast at the stern of the vessel; nowadays a mizzen-mast in English nautical terminology. The depictions and corroborative literary evidence (for example Pliny *NH.* 19.1.) are relatively scarce for this sail-plan, but it is likely to have been in use from the 1st century BC. A well-known example occurs at Ostia, on the floor of the *Foro delle Corporazioni* (The Square of the

Corporations) outside an office belonging to ‘the shippers of Sullecthum’, a town on the east coast of Tunisia (Basch, 1987: fig. 1076; Casson, 1995: xxiv, fig. 145). The left-hand vessel of the two depicted is shown with a mainmast, *artemon*, and mizzen. How long such a rig remained in use is difficult to tell with any certainty, because it is depicted so rarely. Like the *artemon*, the main purpose of the mizzen-mast was to increase the ability of mariners to balance the sailing rig and manoeuvre the vessel. Again, as with the *artemon*, the development and use of the mizzen tells a tale of mariners who are prepared to adopt innovative solutions to the problems of sailing to windward, or perhaps of manoeuvring the larger ships that other archaeological data suggests were increasingly used from the 1st century BC (Parker, 1992: 26; Wilson, 2011: 39–40).

Finally, in consideration of the Mediterranean square sail it is possible to trace a further line of development from the 2nd century AD, through depictions of vessels carrying a rig of two seemingly equally sized square sails (for example Basch, 1987: fig. 1077 and 1111) (Fig. 6). This suggests that the vessel is truly two-masted rather than being rigged with mainsail and *artemon*. Similarly the location of the masts suggests a balanced two-masted rig. Each mast is depicted in identical fashion: ropes are shown running from masthead to deck on either side of the mast, which may represent shrouds or stays; both sails are also depicted with braces. In such circumstance, the additional sail would have added significant capacity to the propulsion of the vessel, as well as improving its manoeuvrability relative to the single-masted form of rig. It is again possible to speculate about the wider implications of this development, perhaps relating to the building of vessels large enough to render a single mast impractical, either because it could not be adequately provided for from available timber resources, or could not be made secure enough through existing engineering capabilities or techniques. In the early 5th century AD, such a rig is explicitly associated with large sea-going freighters in the account given by Bishop Synesius of his voyage from Alexandria to Cyrenaica (Fitzgerald, 1926: 82; Casson, 1995: 268; Kahanov, 2006).

Although the archaeological corpus of rigging components is limited when compared to the wider shipwreck and hull material, from the mid 1st millennium BC it is possible to trace the Mediterranean square sail through archaeological evidence as well as through iconographic and literary sources. Specifically, brail rings, cylindrically sheaved pulleys, deadeyes, and sail cloth (examples in Table 1 and Fig. 7) have all been documented in a range of shipwreck and port contexts. Meanwhile, related tools for sail-making and maintenance have been recovered from shipwreck and port contexts (Rosen and Galili, 2014). Two key conclusions can be drawn from reviewing this range of material. Firstly, that it is possible to identify a range of rigging components that can be specifically associated with the Mediterranean square sail and secondly, its method of use. In particular, the system of brails and brail rings can be viewed as highly characteristic rigging components that are largely incompatible with the other sailing rigs known in antiquity. Other

components, such as the cylindrical pulley sheaves, are not necessarily confined to use within a square-sail rig, but do seem to be unique to the ancient Mediterranean, as least so far as the current evidence base informs us. The second point stems from the fact that such characteristic rigging components are not limited to a single cultural tradition, geographical area, or chronological period. They occur variously in Etruscan, late-period Egyptian, Hellenistic, and Roman sites, across different port sites and a range of vessel types, including *dolia* transports (Hesnard *et al.*, 1988: 105–126) and those incorporating sewn construction (Charlin *et al.* 1978: 57–60). Finally, this variety of archaeological contexts spans an impressive chronological range from the 6th century BC to at least the 3rd century AD.

On the basis of the archaeological remains of the Mediterranean square sail it is therefore possible to postulate a common tradition of rigging, and by extension use of that technology. This is certainly comparable to the associated and similarly widely held method of ship construction, practised in the Mediterranean across the same period (see Pomey *et al.*, 2012). It seems possible that with time, and more importantly further archaeological discoveries, it will be possible to identify regional, cultural, chronological, and indeed functional variation in the rigging technology of the ancient world. This is likely to reflect the full spectrum of sailing activity in antiquity, and be sited alongside the wide-ranging and more readily observable hulls of such ships. It is also important to note that the archaeological evidence from the Roman Red Sea ports of Myos Hormos and Berenike indicates that the Mediterranean tradition of rigging and using the square sail also extended across the western Indian Ocean during the early 1st millennium AD, possibly encompassing non-Mediterranean cultures in that use (Whitewright, 2007: 290–291). Our understanding of this widespread use might therefore be pushed further by classifying it as a ‘shared maritime culture’ of seafaring activity that stretched across the Mediterranean and encompassed parts of the western Indian Ocean during antiquity.

An account of the Mediterranean square sail from the mid/late 1st millennium onwards is therefore one that addresses an increasing range of forms within the same overall approach to sailing, founded upon the square-sail rig: single-masted, *artemon*, mizzen, and two-masted. That such a wide degree of variation can occur within a single overall approach should not be surprising given our understanding of variation within other non-maritime technology during antiquity (for example Schneider, 2013). It is however important to draw attention to it here as a means to move our understanding of Mediterranean sail development to a narrative pathway that highlights such readily apparent technological variation. Some of the underlying discussion of this variation is continued below, but it may be emphasized here that such variation in forms is concurrent, and the development of one approach to using the square-sail rig does not appear to result in the abandonment of another. In this regard it is most striking that the longest-lived form of the sail is

seemingly the single-masted version, pictured in a graffito from northern Egypt dating to the 7th century AD (Fig. 8, top). The horizontal, symmetrical nature of the yard suggests that the sail, shown from the side, is a square sail. From the lines running from the mast, yard, and sail it is possible to interpret port and starboard braces, two sheets, forestay, backstay, and possibly lifts. The chronological story of the Mediterranean square-sail rig is therefore one of technological variation on a central theme (Fig. 5). But this sailing rig was not the only type in use in the ancient world, and it is to the other forms that we can now turn our attention.

Mediterranean fore-and-aft rigs

For a complete view of the sailing technologies available to the mariners of the ancient Mediterranean it is necessary to provide an account of the fore-and-aft sails that can be identified from the available, primarily iconographic, evidence. These comprise two main types of sail-form, firstly the spritsail and secondly the lateen/settee sail, which are located alongside the square sail in Figure 5, and which are now discussed.

The spritsail can be traced through a series of relatively unambiguous depictions between the 2nd century BC and the 3rd century AD. Specifically, a number of reliefs (see Fig. 9), mainly from the Aegean, Ostia, or Constantinople, illustrate sailing vessels carrying a single mast that is placed well-forward in the bow and with the sail supported by a diagonal spar running aft from the base of the mast (see Casson, 1956; 1960; cf Basch, 1987: figs 1078–9 and 1081–3; Polzer, 2008: 244–245). Such depictions are unequivocal in their depiction of a spritsail and for the most part the types of vessels shown are accepted as being support and service vessels, rather than larger merchantmen or warships. Although readily and strikingly apparent when observed in the iconographic record, depictions of the spritsail are not common, and literary descriptions of such sails are notable only through their absence, or at least their non-identification, thus far. Therefore, the abiding impression is of a sailing rig that was certainly used in antiquity, but which never achieved the ubiquitous acceptance within the maritime societies of the ancient Mediterranean, and their iconographic record, afforded to the square sail.

In keeping with the overall disparity in the evidence base for rigging technology, the sprit-rig is difficult to identify archaeologically, despite being present in the iconographic record. It occurs only from the end of the 1st millennium AD, well outside the period under consideration here, when the use of the spritsail can be noted in the archaeological remains of a small vessel (Yenikapı 6) excavated at Yenikapı in Istanbul (Kocabaş and Kocabaş, 2008: 103–12; Kocabaş, 2015: 11, fig. 6). Despite its rarity across all forms of evidence, its appearance at Yenikapı, in conjunction with the sporadic iconographic sightings just outlined, is enough to strongly suggest the continued use of the spritsail in the ancient Mediterranean, from the 2nd century BC onwards. But,

the limited nature of the evidence, when set against the wider extensive evidence for the square sail, suggests that the spritsail existed on the margins of Mediterranean maritime activity, at least from the perspective of the creators of iconography. From there it appears only fleetingly at the edges of our vision of ancient seafaring.

A further type of fore-and-aft sail, technologically unrelated to the spritsail, can be traced in the form of the lateen/settee sails. Such vessels carried a characteristic sail of generally triangular form with a high peak towards the stern of the vessel. In its lateen form this sail is a true triangle, while in its settee form, it has a short leading edge making it a quadrilateral if considered geometrically (Whitewright, 2009: 97–98). The two forms share a common use and their close relationship allows the use of the simpler term ‘lateen’ to cover both rigs. The earliest firmly dated depiction of the lateen rig is currently placed in the 2nd century AD with an example from Piraeus on a tombstone ascribed to ‘Alexander of Miletus’ (Casson, 1956; cf Basch 1987: fig. 1080; Whitewright, 2009: 102, fig. 5). Although the date of the earliest example might have been expected to be pushed backwards by new discoveries, no such thing has happened, at least not from a securely dated context, in the subsequent 60 years. The lateen rig then seems to become more widespread in late antiquity before eventually supplanting the square sail as the sailing rig of choice in the Mediterranean during the medieval period (Whitewright, 2009). Typical iconographic imagery (Fig. 8), often shows a triangular sail-form, which, with the heavily inclined yard, suggests the vessel is rigged with a lateen sail. In this example the mast is supported with a forestay and the artist has depicted a double halyard that runs from the yard through a prominent hook-shaped masthead before returning to a large block above the deck. The form of the hook-shaped masthead is repeated at the bow of the vessel, possibly suggesting the presence of a foremast. As with the spritsail, there is no firm archaeological evidence for the lateen sail until the end of the 1st millennium CE, when it is associated with the Serçe Limanı shipwreck (Mathews, 2004). Although some ambiguous, yet plausible, literary references exist, for example Procopius (*Vand. 1.13.3*) (Sottas, 1939: 229–230; Moore, 1957: 241; Kreutz, 1976: 83; Casson, 1995: 245, n.82), the iconographic material remains the primary source for understanding this significant shift in how the mariners of the ancient world rigged and used their sailing vessels from late antiquity onwards (discussion in Whitewright 2008; 2011a).

From the perspective of a wider narrative of Mediterranean sailing-rig development, the great contrast between the lateen and spritsail is that the former does become widely adopted in the Mediterranean, while the latter appears not to have been. The possible reasons for this are returned to below, but the adoption of the lateen rig, at the expense of the square sail represents the chronological end-point of the overview of Mediterranean sailing rigs in antiquity presented here. Throughout, there is notable continuity, variation and change from a maritime technological

perspective, involving all the sailing rigs of antiquity (square, sprit and lateen), which can now be considered further.

Discussion

The narrative outlined above allows a number of key points to be highlighted for discussion. Firstly the implications for our understanding of sailing in the ancient Mediterranean that arise from the advent of ships using a sailing rig as their only form of propulsion, distinct from the paddle/oar-sail combinations seen previously. Secondly, and interlinked with this trend, is the development of variations to the single-masted, square-sail rig, specifically the *artemon*, during the 1st millennium BC. Both of these might usefully be considered under a joint theme of ‘Specialization in Sailing’. The third point concerns the fore-and-aft sailing rigs visible in the iconography of antiquity. In particular, the spritsail and the lateen/settee sail allow the investigation of innovation within maritime technology, and consideration of why some new forms of technology are adopted, while others are not, despite offering seeming improvements in purely technical function.

In addition, several broader points can be made about the general trends observable across the entire chronology of rig development, from the Late Bronze Age to late antiquity. Most notable is the clear continuity demonstrated over the very long-term by the Mediterranean square sail. This is especially prevalent within the iconographic evidence, but can also be traced within the archaeological record left behind by a range of different cultures in different places at different times. These rigging components tell a story of a consistent overall approach to creating the functional core of the Mediterranean square sail, from which it is reasonable to imply an equally consistent approach to the use of such a rig. It is therefore possible to paint a picture of a shared tradition of rigging and sailing that spans the Mediterranean and stretches into the western Indian Ocean during antiquity.

Within the notion of such a tradition it would be easy to assume that the single-masted sailing rig was simply a precursor to subsequent developments. But, while it is certainly the main trunk from which other variation stems, for large parts of Mediterranean maritime society it was clearly also their sailing rig of choice, as reflected in its continued depiction in the iconographic record until the early 7th century AD. Despite this, the considerable technological variation visible within the Mediterranean square sail, both iconographically and archaeologically, should not be forgotten. From an iconographic perspective, it is possible to trace the variation in sail-plan exhibited through the development of the *artemon*, mizzen sail, fully two-masted, and also three-masted rigs (main, *artemon*, and mizzen). Meanwhile, archaeological remains indicate that at a component level the function of the excavated rigging components is certainly compatible and directly comparable, but the detailed outward form and/or material of many of the components such

as brail rings or pulley blocks is different. This highlights considerable potential future research into the extent to which such material variation is reflective of regional and/or cultural traditions within the overall square-sail rig. There seems no reason to doubt that such quantifiable variation is just as likely to exist in rigging components as in amphora forms, but gathering the required corpus of evidence of this most perishable and disposable of maritime artefacts may ultimately prevent such an approach from bearing fruit.

Specialization in sailing

The development of specialist sailing vessels during the early 1st millennium BC can be seen as a highly significant moment within the wider trajectory of Mediterranean sailing. For the first time sailing vessels could operate without the need for a secondary form of propulsion, allowing ships to carry more cargo, to operate with fewer crew, and to potentially sail for longer without the need to re-provision. But, such a fundamental alteration in seafaring mind-set, enabled by freeing ships of the need for auxiliary propulsion, has not necessarily received the attention that it might have done. By contrast, the change in mind-set, and associated material elements such as ship construction, required by the initial adoption of the sail in the Mediterranean during the 3rd and 2nd millennium BC has been highlighted by Broodbank (2013: 327) in addressing the seeming slow spread of sailing technology westward. One way of assessing the significance of this change is by comparing it with the adoption of auxiliary deck machinery and propulsion in shipping during the 19th and early 20th century. The former allowed a dramatic increase in the tonnage per man that could be carried, while the latter ultimately led to sail-trimmers being superseded by boiler stokers (Gould, 2001). Both are recognizable as resulting in seafarers themselves having a fundamentally different outlook on seafaring.

Within the overall chronological development set out above, a clear question therefore revolves around the extent to which this change in seafaring mind-set came about as an immediate result of the development of the loose-footed, brailed, square sail during the Late Bronze Age, or through the subsequent refinement in the use of that technology sometime after its adoption. Unpicking the distinction between these two interpretations is currently difficult because of the incompleteness and chronological inaccuracy of the iconographic material that is necessarily the main evidence base. It is therefore only possible to speculate that while the rigging components of the Mediterranean square sail in the early/mid 1st millennium BC appear to be much the same as at the end of the Bronze Age, the technical practice and associated knowledge used to operate the square sail had changed significantly. Perhaps driven by an expansion in seafaring routes, the mariners of the 1st millennium BC refined their use of existing technology as a reaction to a

changed operational context. In doing so, this may have created a set of skills and knowledge that allowed auxiliary power to be dispensed with, if the situation required it.

Focusing on the development of pure sailing vessels allows discussion to return to the *artemon* and the implications arising from its use. In particular, the nature of the *artemon* dictates that its primary functional purpose is in balancing the hull and rig of a vessel and in aiding tacking/wearing ship (Davey, 2015: 39–40). It follows that such technology is only required when sailing is already regularly being undertaken on courses across the wind, and higher still, on an upwind course. In this regard, the development of the *artemon* indicates that ancient mariners were attempting to sail on courses to windward and reacting to the problems that they encountered when doing this. To consider this further, we must return to the point at which sailing expertise allowed oars to be abandoned on certain types of vessel. An implicit trade-off must have been a willingness to accept that voyages would be made as weather conditions and seasonal or daily wind patterns allowed, including very calm conditions. The level of sailing performance that was reached before mariners felt able to dispense with oar power as an auxiliary form of propulsion can only be speculated upon, but an ability to at least maintain a course at 90 degrees to the wind would seem to be a sensible minimum. This places our understanding of ancient sailing in a situation where the rise of specialist sailing vessels can be linked to consistent sailing in crosswind and upwind conditions, because of the subsequent development of the *artemon* as a balancing/steering aid to sailing under such conditions. The presence of hull forms exhibiting ‘wine-glass’ shapes, for example Kyrenia or Ma‘agan Michael, seemingly suited for sailing on such courses from the mid 1st millennium BC is probably not a coincidence. This allows a further suggestion to be made; that in contrast to the seemingly limited performance of Late Bronze Age vessels, sailing performance in the early 1st millennium BC was far more akin to the potential estimations that can be arrived at for the Greco-Roman world in general, including a capacity for upwind sailing in optimum conditions (Whitewright, 2011b).

It is therefore useful to begin to trace the potential sequence of technological processes that eventually led to the development of the *artemon*, interlinked with the development of specialized sailing vessels, and in turn seemingly stemming from the advent of the loose-footed, square sail in the Late Bronze Age. In this regard, it is significant that there is no mention of the *artemon* in the various descriptions of sailing vessels, sailing rigs, and sailing practices across either the *Iliad* or the *Odyssey*. Yet many other elements relating to ships, shipping, seamanship and navigation are described and included in significant detail (for examples see McGrail, 1996). If Homer’s work dates to the mid 8th century as is widely accepted (Lane-Fox, 2009: 381–384), then the *artemon* seems unlikely to have been in use, at least within a Greek context, at that date. But, Homer does make the distinction between pure merchant ships and other ships (*Od.* IX, 323), although such

merchant ships still carry a limited number of oars. From this, it might be concluded that the Homeric-era sailing rig could increasingly be deployed in such a manner as to allow its users to become less reliant upon oar power in the interest of cargo capacity. This implies that the establishment and integration of pan-Mediterranean routes by the early 1st millennium BC (Broodbank, 2013: 445–505) was therefore undertaken with the existing Late Bronze Age maritime technology, notably specialist sailing vessels carrying single-masted, loose-footed, brailed, square sails. Such technology allowed auxiliary oar power to be dispensed with, but also exposed Mediterranean mariners to life without the safety net of an alternative form of propulsion and in doing so introduced them to new challenges and problems associated with balancing their sailing vessel when sailing across and into the wind.

The rationale for the adoption of the *artemon* might therefore be seen as one of problem solving within the context of ancient seamanship. In this instance, it is one of solving some of the very practical issues of vessel-handling when sailing on upwind and crosswind courses, and when changing from sailing on one tack, to sailing on the other tack. The development of the *artemon* should very much be seen as a continuation of the technological trajectories of earlier centuries, stemming from changes to the wider context of sailing. As such, it is a technological variation that sits within a wider tradition of existing seafaring practice, but one that is geared towards the refinement of sailing performance and cementing in place the extended maritime connections of the early 1st millennium BC. In that light, the development and use of the *artemon* forms part of the seafaring knowledge and skill-set developed by Mediterranean mariners in the wake of their earlier adoption of the loose-footed sail. The very nature and function of the *artemon* necessitates that it is a technological development derived from the deck of the ship, that is driven by its users, rather than from external merchants or ship-owners seeking factors such as additional capacity. The complexity of untangling such developments from the available evidence base is further illustrated by the fact that the *artemon* does not become ubiquitous in later centuries. Moreover, there are numerous vessels, attested both iconographically and archaeologically, that did not use an *artemon* sail, either because the nature of the seafaring undertaken by the crews of such vessels did not require the refinement that it offered, or because their use of the single-masted square sail was sufficiently developed that they did not require the *artemon*.

Finally, in the light of the above discussion it is critical to clarify that the *artemon* did not cause cross/upwind sailing to commence, by its very nature it simply facilitated the continuation of such courses in a more effective and controlled manner. Likewise, neither the development of the loose-footed, brailed sail, nor the subsequent refinement offered by the *artemon*, allowed concerted long-distance upwind sailing to become a normal part of seafaring activity, in the sense of a crew deliberately setting out from harbour with the intent to sail continuously to windward until their

destination was reached. As has been demonstrated elsewhere (Whitewright, 2011b), although the Mediterranean square sail had some ability to sail to windward in good conditions, such a capability seems highly unlikely to have facilitated continuous upwind sailing on extended voyages.

Fore and aft

The fore-and-aft sailing rigs described previously, the sprit and the lateen, offer insight into some of the rationale for the adoption of maritime technology in antiquity. The spritsail in particular is of interest because its conception and manner of use as a sailing rig bears no resemblance to the Mediterranean square sail, based on current understanding of rigging and sail handling. Its development offers an example of an original and completely formed invention within the context of sailing-rig technology. This can be placed more widely alongside other ancient technological invention/innovation in, for example, olive presses (Mattingly, 1994) or military technology (Cuomo, 2007: 41–76), and further helps to normalize sailing rigs within the wider suite of technologies in use in the Greco-Roman world. This provides a meaningful contrast to the long-term continuity exhibited by the single-masted square sail and the variation-based innovation associated with the range of forms of that rig known to have been used in antiquity.

Although the existence and long-term use of the spritsail in antiquity is not in doubt, its marginal visibility in the available evidence probably indicates that it did not become widely adopted following its invention. Such an incident of invention followed by limited adoption is of particular interest because the spritsail offers excellent all-around performance, including on upwind courses, when measured in modern testing (Palmer, 1984: 1390; 1986: 188–193; 1990: 82–86; Marchaj, 1996: 161, figs 144–145). The failure of the spritsail to become more popular among mariners in antiquity indicates that upwind performance, in a general sense, was not a dominant factor in the selection of sail-form by those mariners in the late Roman Republican and Imperial period (cf Whitewright, 2011b), contrary to much commonly stated academic opinion (recent examples include McCormick, 2001: 458; Makris, 2002: 96; Castro *et al.*, 2008: 347–348, 351; Polzer, 2008: 242).

This theme can be explored a little further, because at first glance it perhaps seems at odds with the previous discussion regarding the loose-footed sail in the Late Bronze Age and the *artemon* in the 1st millennium BC. However, those two examples, especially the *artemon*, took place within an existing set of long-held maritime traditions of conceiving and using technology. The latter is highly significant because it emphasizes the fact that such traditions involve the daily use, and associated seafaring knowledge and practice, of a particular maritime technology. Knowledge and practice are inextricably interlinked, as practice develops to make best use of the available knowledge, knowledge is cemented on the basis of practice, and is subsequently developed, varied,

defined, and refined. Any widespread adoption of the spritsail would therefore have meant the abandonment of around a millennia—in some places—of square-sail tradition, performance, practice, and knowledge. The performance advantage offered by the spritsail was clearly not sufficient to undertake such as step, except in a limited number of areas of maritime activity. So, why was it invented, and why did it not become more widespread?

Despite the clear differences between the sprit-rig and the square-sail tradition, it can be suggested that the invention of the spritsail may have resulted from the same set of wider circumstances playing out in the Roman period that had given rise to the *artemon* in earlier centuries. Specifically, as mariners continued to grapple with the challenges faced by sailing courses closer to the wind their ability to innovate, illustrated through the development of the *artemon* and mizzen sails, gave rise to a genuinely novel invention from the perspective of sail-form and use, the spritsail. Regarding its limited adoption, it is possible to speculate that although the spritsail offered advantages in upwind performance, at least in a modern sense, ancient sailing routes, patterns of trade, methods for designing and constructing hulls—for example mast-step placement and integration into hull structure—were already optimized for crosswind and downwind sailing, at which the square-sail rig excelled. Once developed, the *artemon* and mizzen continued in use because they fitted directly into this system, offering a refinement, rather than an alternative. In that sense, both were pre-optimized for existing sailing routes and maritime conditions and could be operated within an existing set of seafaring knowledge and practice. By contrast, although the seafaring package offered by the spritsail was relatively effective in an upwind direction, its practical application may have been limited because the Mediterranean square sail and the maritime activity that it served were in a state of equilibrium with a focus on crosswind and downwind sailing, and with seemingly settled approaches to crew structure. As a result, the spritsail may have been marginalized to the small craft and river vessels that the iconographic depictions suggest used it. Such vessels required operation in variable, often confined space where an increase in windward performance is bound to have been useful. The spritsail therefore offers a valuable example in the importance of context of use for ancient technology, and illustrates the point that functional improvement does not automatically equal widespread social acceptance of a given technological system.

This theme can be returned to when considering the lateen sail, which unlike the spritsail does become widely adopted from late antiquity onwards, to the extent that it supplants the square sail as the primary sailing rig of the Mediterranean (for an extended account and interpretation see Whitewright, 2008). This process is reflected in the consistent depiction of lateen-rigged vessels across a range of iconographic media and cultural contexts (Whitewright, 2009). This itself indicates adoption in the mind-sets of the wider society consuming such iconography, as well as by

mariners actually using it. In the context of this paper, our interest in the lateen sail lies in the fact that unlike the spritsail, it seemingly offered no definable improvement in sailing performance, yet became widely adopted. Comparative performance analysis of the lateen and single-masted square sail (Whitewright, 2011b) challenges the standard view of sail development that was driven by a ‘need’ for improved windward performance, provided by the lateen sail when compared to the square sail (for example Kreutz, 1976: 81–82; Meijer and Van Nijf, 1992: 224–225; Pryor, 1992: 33; Campbell, 1995: 2; Casson, 1995: 243; Basch, 2001: 72; McCormick, 2001: 458; Makris, 2002: 96; Castro *et al.*, 2008: 347–348, 351; Polzer, 2008: 242). Instead, the lateen sail provided the same general performance levels, within existing hull parameters, as the already existing square sail, while providing the opportunity for cost reduction from the perspective of construction requirements and ongoing maintenance costs (Whitewright, 2011a: 98–102). In both cases, the lateen sail simply required less component parts, both blocks and cordage, than the square sail to set up the rig and make it function effectively. The rearrangement and alteration of rigging components, including sail-form, that afforded such economies was in turn reflected in the changed iconographic record of Mediterranean vessels produced by society from the Late Antique period.

Although adoption of the lateen sail would have required alteration to the technical practice used for its operation, such alteration could have taken place within the bounds of existing seamanship and navigational knowledge because its overall performance parameters were broadly similar. Likewise, the adoption of the lateen rig did not require alteration of existing sailing routes, seasonal timings, or shipbuilding practice. Consequently the lateen sail, once conceived, could operate comfortably on a range of vessel types, from fishing boats to freighters, with a broadly similar operational practice. As a result, the lateen sail could function within the existing *status quo* of Late Antique maritime activity in a way that the spritsail could not do in earlier or later centuries. That the lateen sail could supplant the millennia-long technological continuity of the square sail, seemingly across all vessel types, further indicates its compatibility with the context of maritime activity in the Late Antique and Early Medieval Mediterranean. There, construction and/or maintenance costs seem to have been the driving factors, within a set of sailing routes and timings that remained optimized for crosswind and downwind performance. This, to some extent, serves to reinforce the conclusion offered above, that the spritsail did not become widely adopted because it did not adequately fit the existing maritime systems of the Mediterranean. Or put another way, for the spritsail to become widely adopted, such Mediterranean-wide systems would themselves have had to alter to accommodate it. That they did not, perhaps tells us much about the extent to which technology does, or in that case did not, drive wider developments. Such an observation should serve to identify sailing rigs as material culture that can be highly indicative of wider motivations for technological selection and expression within ancient society. Although clearly worth studying

in its own right, the maritime technology of antiquity should also be examined because of the insight it can provide into the ancient world in general, aside from directly maritime affairs.

Conclusion: continuity, variation, change

The aim of presenting and discussing the sailing rigs of the Greco-Roman world was first and foremost to bring the technology underpinning all maritime connections in the ancient Mediterranean more fully into view. To do this, it was first necessary to address the longer view of sailing-rig development within the Mediterranean, from which the great continuity in technology and technical practice exhibited by the Mediterranean square sail became clear. Although subject to considerable and at times highly sophisticated variation, it is possible to identify a consistent Mediterranean-wide tradition of conceiving, creating, and using sailing rigs stretching nearly two millennia. The use of ceramic vessels as the primary form of maritime transport container across a broadly similar time-frame also hints at how associated aspects of antiquity can be considered in relation to one another.

A clear future challenge lies in trying to understand the regional and cultural nuances within this tradition of sailing that undoubtedly exist, but may remain hidden to us by the vagaries of archaeological preservation. Most strikingly, this continuity seemingly spans a wide range of cultural contexts and geographical areas, even extending outside the Mediterranean and into the western Indian Ocean. At a broad level, it is therefore possible to postulate a shared maritime culture of rigging and sailing with the Mediterranean square sail that transcended political, geographic, and cultural boundaries. In this sense, sailing and seamanship using the Mediterranean square sail can perhaps be seen as a way of defining Mediterranean-ness across geographical space. This might be a useful supplement to existing perspectives, such as annual rainfall or the distribution of olive culture (Horden and Purcell, 2000: map 1; Broodbank, 2013: map 2.1). The implicit association of such a defining technology with the sea makes such an application both more striking and appealing from a maritime archaeological point of view.

The longer view also proves critical in beginning to explain some of the more notable variation visible within the Mediterranean square sail, particularly the development of the *artemon*. Its emergence, following the wider adoption of the loose-footed, brailed, square sail illustrates a variation of maritime technology against the backdrop of wider changes within maritime activity. In this case, the expansion of eastern Mediterranean maritime routes into the central and western Mediterranean, with a corresponding increase in the nature and variety of sailing routes and sailing conditions encountered by peoples from all areas, can be highlighted. At the heart of this technological variation lies an intuitive awareness of practical seamanship concerns and especially of the complex technological forces at play when sailing across and towards the wind. Given the

extent of maritime connections in antiquity such a statement is perhaps unnecessary. Still, ancient mariners were clearly willing to modify their existing technology and technical practice as a consequence of wider changes to how societies used and deployed sailing vessels. This theme is not unique to the *artemon* in the 1st millennium BC, but is a recurring one, witnessed again through further square-sail variations such as the two-masted rig and the use of the mizzen sail in later centuries. From a modern maritime perspective, all such variations can perhaps be seen to result in an increase in the flexibility and reliability of sailing vessels, operating within the same overall systems as their predecessors or contemporaries.

Having highlighted technological continuity and variation, attention must finally be turned to change. The spritsail in particular provides a fascinating example of novel invention that results in a demonstrable functional improvement, but which does not become widely adopted by Mediterranean maritime societies. This, despite its apparent advantages in upwind performance, more than anything may serve to indicate how deeply embedded Mediterranean shipping routes were by *c.*200 BC. The routes themselves, the networks that they served and the construction and use of the vessels that sailed them appear to have been optimized for an existing level of performance, based on the square sail, against which the spritsail, for all its qualities, was unable to make headway. By contrast, the lateen seems to offer functional continuity, at a reduced investment and maintenance cost, which seems, in the context of the Late Antique/Early Medieval world, to be enough to allow it to supplant the square sail. Be that as it may, even within that example, it should be remembered that the widespread adoption of the lateen is seemingly limited for several centuries until it and the maritime system that it must operate within are fully compatible from an economic perspective. It should be clear that the development of sailing-rig technology in the ancient world does not follow a progressive linear pathway. Earlier technology does not automatically fall out of use as a result of later developments, or those with apparently superior functional performance.

A suitable point with which to conclude may be to emphasize that across the range of material presented and considered here, in all its forms, capabilities, and potential, there is no ‘best’ or ‘most efficient’ sailing rig. There is simply a range of technological options, traced through the sometimes patchy evidence, that are available for use in a range of different social, political, and economic contexts. The same can be said to be true of ancient hull forms, which at different times, or at the same time, exhibit deep-keeled vessels seemingly suited for crosswind and upwind work, as well as hulls with flatter floors and limited draught.

The popularity of any particular piece of maritime technology is arguably reflected in its appearance in the archaeological, iconographic, and literary record that survives for us to interpret. The uptake, or not, of these different options at different times is a greater reflection of the maritime outlook and/or requirements of the societies that utilize them, rather than the functional qualities of

the technology itself. The latter are important for our modern study in defining and differentiating between rig types, but bigger factors are clearly at play in dictating what was used on the waters of the Mediterranean in antiquity. The themes of continuity, variation, and change are paralleled by notions of the acceptance, adaption, and abandonment that sailing technology underwent in antiquity. All of these should be seen as a critical part to any understanding of the maritime connectivity that is such a recurring and enduring central theme of Mediterranean studies. It is hoped that material presented and discussed in this paper serves to emphasize this. At the same time, it should remind us of the people that lay at the heart of the technological developments, and who were ultimately responsible for making the technological choices that we now seek to understand.

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Tables

Table 1. Selected archaeological examples of the primary rigging components that comprised the Mediterranean square sail.

Rigging Component	Example Site	Site Type	Period	Reference
Brail Rings	Naukratis	Port site - Nile	Egyptian late period	Thomas, 2014: fig. 5
	Giglio	Shipwreck	Etruscan	Bound, 1985: 60
	Grand Congloué	Shipwreck	Roman: Republic	Benoit, 1961: 178–9, pl. 30
	Grand Ribaud D	Shipwreck – Dolia transport	Roman: Imperial	Hesnard <i>et al.</i> , 1988: 105–26
	Straton’s Tower	Shipwreck	Roman: Imperial	Fitzgerald, 1994: 169
	Myos Hormos	Port site – Red Sea	Roman: Imperial	Whitewright, 2007: 285-6; Blue <i>et al.</i> , 2011
	Berenike	Port site – Red Sea	Roman: Imperial	Wild and Wild, 2001: 214
Cylindrical Pulley Sheaves	Kyrenia	Shipwreck	Hellenistic	Swiny and Katzev, 1973: 351, fig. 12
	Cap del Vol	Shipwreck	Roman: Imperial	Foerster, 1980: fig. 5
	Caesarea Maritima	Port site	Roman: Imperial	Oleson 1983
Deadeyes	Laurons 2	Shipwreck	Roman: Imperial	Ximénès and Moerman, 1990: 7
	Grado	Shipwreck	Roman: Imperial	Beltrame and Gaddi,

				2005: 80
Sailcloth	Edfu	Recycled in burial	Roman: Republic	Rougé, 1987; Black, 1996
	Myos Hormos	Port site	Roman: Imperial	Whitewright, 2007: 285-6; Blue <i>et al.</i> , 2011
	Berenike	Port site	Roman: Imperial	Wild and Wild, 2001

Figures/Captions



Figure 1. Map of the Mediterranean indicating the location of places and sources of evidence mentioned in the text (basemap licensed under CC BY-SA 4.0 from Flappiefh, Graphic Lab, France).



Figure 2. Two examples of Minoan intaglio sealstones (1700–1450 BC), carrying depictions of ships propelled by both oars and sail, with associated circular rings shown on the sails. The artefact is shown on the left, with its impression on the right. Top: BM Cat No. 1947,0926.28; Bottom: BM Cat No. 1884,0628.9; (Image copyright: Trustees of the British Museum, CC BY-NC-SA 4.0 licence).



Figure 3. Cypriot bichrome ware jug (750–600 BC) showing a sailing vessel carrying a single-masted, loose-footed sail (British Museum Cat. No. 1926,0628.9, Image copyright: Trustees of the British Museum, CC BY-NC-SA 4.0 licence).



Figure 4. Black-figured *kylix* (520–500 BC), made in Attica and excavated in central Italy, carrying a depiction of two ships (British Museum Cat. No. 1867,0508.963. diameter: 203mm, height: 89mm, Image copyright: Trustees of the British Museum, CC BY-NC-SA 4.0 licence).

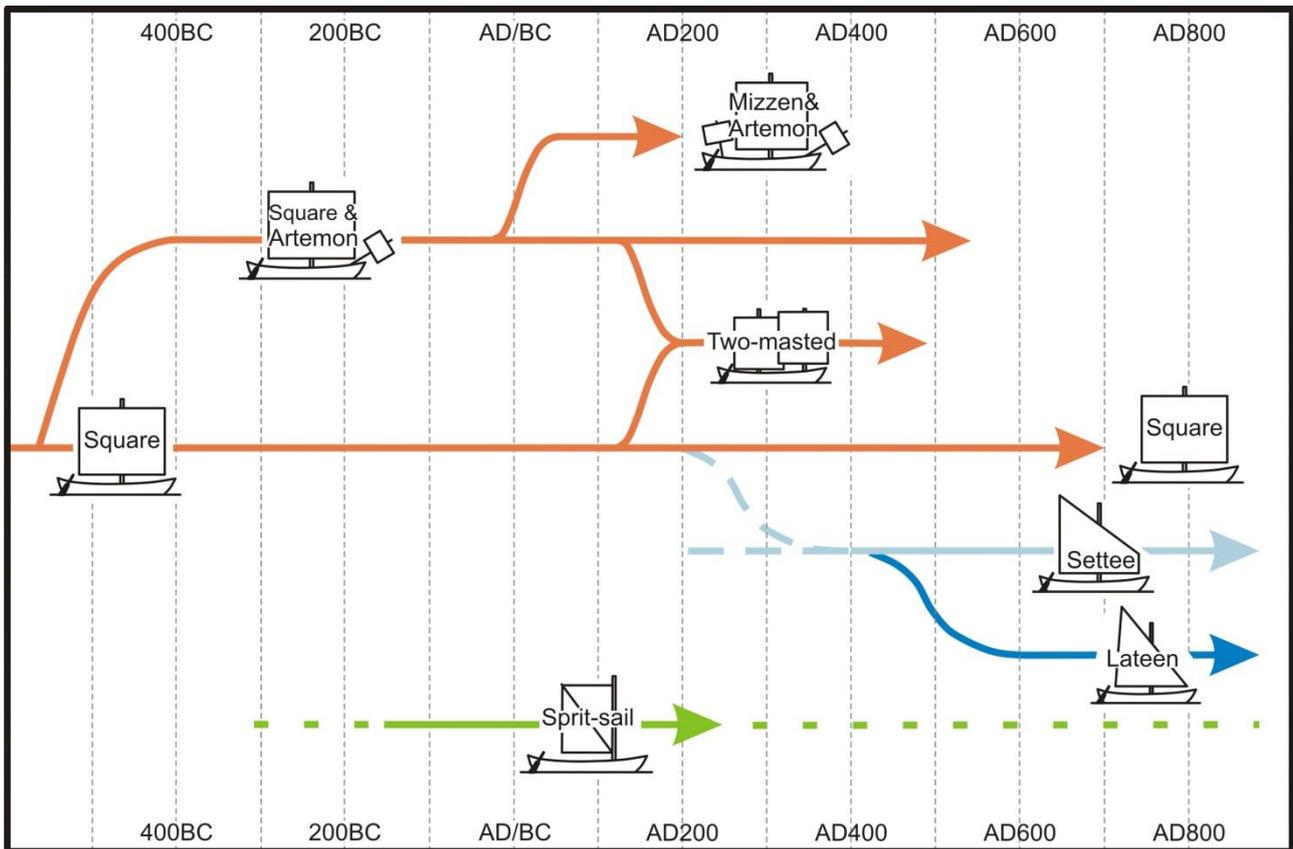


Figure 5. Long-term developmental trends in the rigging of ancient and early medieval Mediterranean sailing vessels based primarily upon the interpretation of iconography in conjunction with archaeological and literary evidence where required. Families or traditions of rigging are differentiated by different line styles. The single-masted, loose-footed, brailed, square sail can be considered to have originated in the Late Bronze Age, but for ease of illustration the full extent of that chronology has been omitted.



Figure 6. Marble relief from Carthage (c.AD200) showing a two-masted sailing vessel (British Museum Cat. No. 1850,0304.32. height: 228mm, Image copyright: Trustees of the British Museum, CC BY-NC-SA 4.0 license).

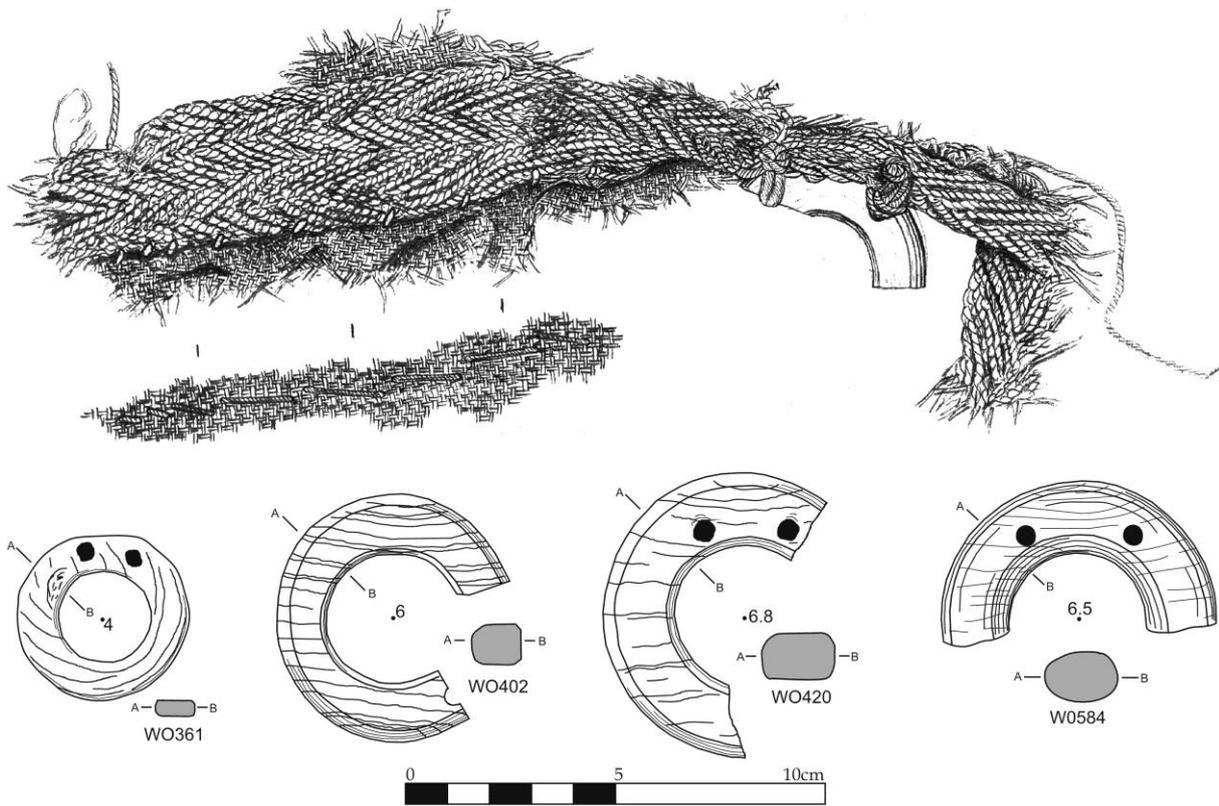


Figure 7. Wooden brail rings and sail fragment from the Roman Red Sea port of Myos Hormos (1st and early 3rd centuries AD). Top: cotton sail fragment in which the brail ring is attached to a horizontally set herringbone reinforcement strip that spans the seam between two horizontally set pieces of regular cotton cloth. Bottom: four wooden brail rings of varying diameter and cross-sectional form. The former indicating their likely use on differently sized sails and the latter their different individual makers, or regions of manufacture.

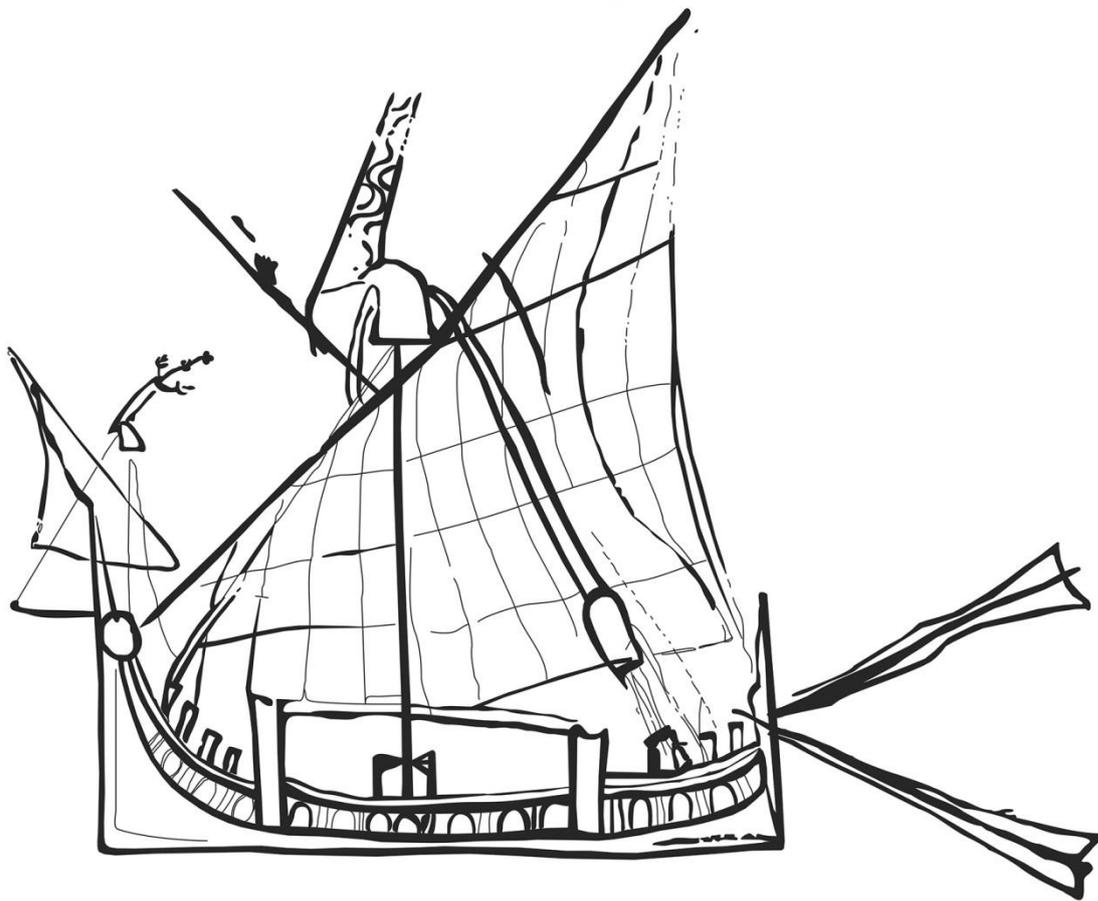
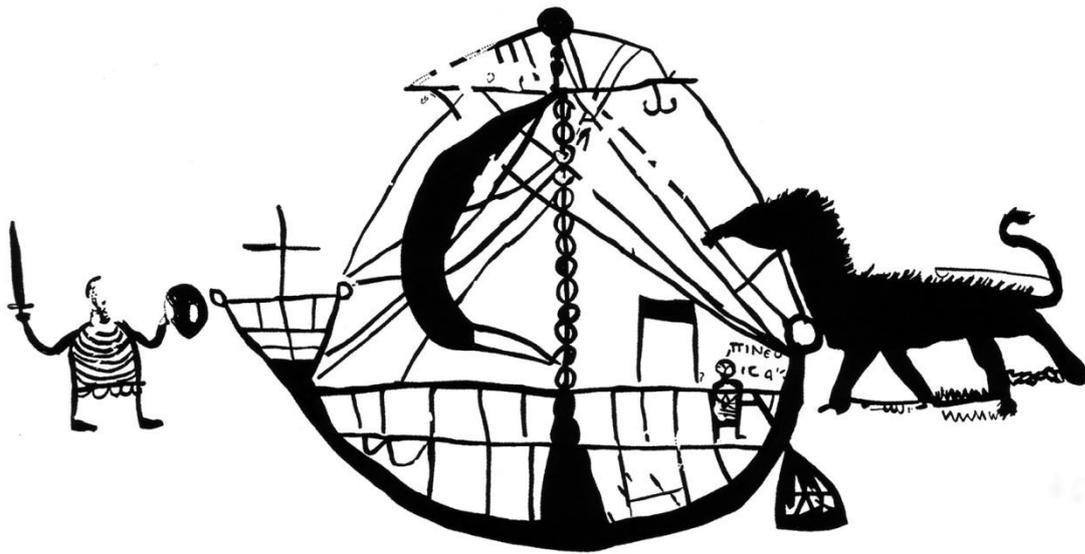


Figure 8. Two ship graffiti from the monastic site of Kellia, northern Egypt (early 7th century AD).
Top: Single-masted square-sail rig (after Kasser, 1978: fig. 156). Bottom: Lateen rig (after Basch, 1991: fig. 1).



Figure 9. Sprit-rigged vessel (2nd century BC), Archaeological Museum, Thasos. The characteristic diagonal 'sprit' is shown in the process of being set, with the mast itself located in the very bow of the vessel (Casson, 1960, frontispiece).