The Roman merchant ship sail plan

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Abstract: Two papers about the introduction of the spritsail during the Roman-period in previous editions of *Buried History* are updated with additional references and hypotheses. A revised interpretation of Problem 7 in the Aristotelian corpus *Mekhanika* is given but the foregoing proposition that the introduction of spritsails made sailing to windward routine for Roman merchant sailing ships is retained. It is suggested that extremes of wind strength were the main inhibitors of windward sailing because it reduced boat speed, which in turn diminished lateral resistance and increased leeway.

Introduction

Recent issues of *Buried History* have included two papers by me discussing the significance of the spritsail, which first appeared in merchant sailing ships during the Roman-period (Davey 2015; 2016). Some of the material in those papers has been presented at public events, including a maritime conference in October 2017. The subsequent discussions have confirmed, modified and developed the original ideas leading to this paper, which also draws on the contents of the earlier papers.

In his discussion about the economic environment of ancient Rome, Hopkins suggested that maritime trade became a vital component of the economy of the Roman Empire partly as a result of advances in technology and practice, which involved 'increases in the sizes of ships and improvements in their handling' (2000: 260). This paper and the two before it explore the specifics of Hopkins' comment as it relates to the introduction of the spritsail.

It is argued that the spritsail was deployed on the bowsprits of merchant sailing ships from the Late Republican period and provided sailors with the necessary control to sail close-hauled and to go about routinely. The manoeuvrability it afforded also meant that sailing ship size could increase beyond that which was manageable with oars.

The small square-sail rigged on the bowsprit of sailing ships until the 19th century was called a spritsail and that is the term adopted in this paper (Figure 1; Davey 2015: fig. 1). The ancient Greek and Latin names for this sail were *artemon* and *artemo* respectively. It should not be confused with the fore-and-aft mainsail used on some coastal and river craft from the Roman-period onwards, which is also called a spritsail (Casson 1971: 243). A second term needing clarification is that of bowsprit, which is used in this paper to refer to an unstayed forward-raking mast extending beyond the bow on which the spritsail was rigged.

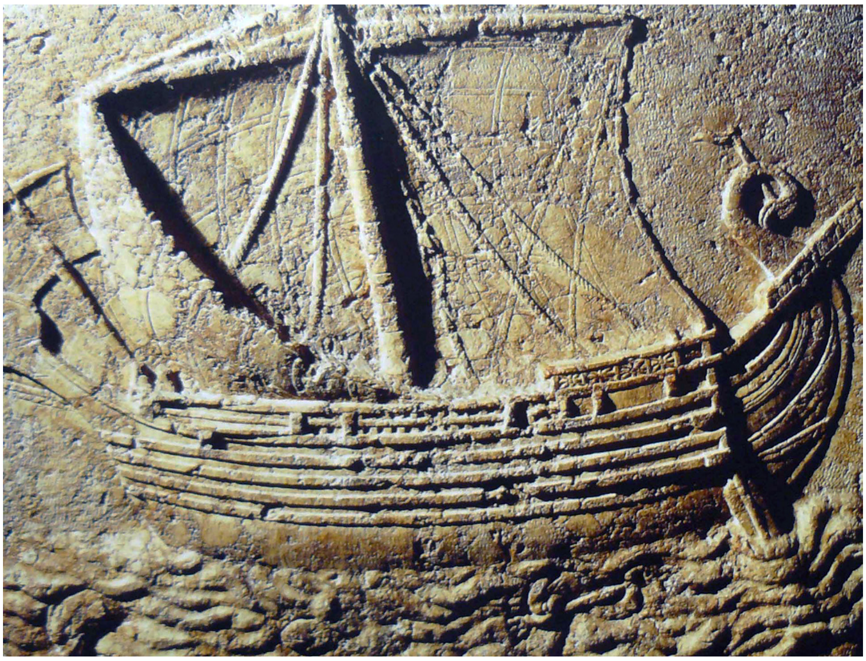

Figure 1: *Relief of a merchant ship on a sarcophagus from Sidon, 2nd century, National Museum, Beirut. The ship has sails typical of a Roman-period grain ship. The spritsail is the small sail at the bow.. Image: Wikicommons.*

Figure 2: *An Egyptian river boat under full sail from the Chapel of the 6th Dynasty Tomb of Mereruka c2300BC, Saqqara. (note the cat in the rigging) Photo: the author.*

Recently Dr Julian Whitewright published a paper entitled *Sailing and Sailing Rigs in the Ancient Mediterranean: implications of continuity, variation and change in propulsion technology*, tracing the early development of sails in the Mediterranean (2018a). Whitewright does not agree with two opinions expressed in the two previous papers. He maintains the view originally proposed by Casson that the use of the spritsail began in the mid-5th century BC because of the *Tomba della Nave* image of a ship with a foresail (Davey 2015: fig. 3). I have argued, and continue to do so in this paper, that there is currently no evidence for spritsails, which Whitewright calls *artemons,* prior to the 2nd century BC. The differentiation between foresails and spritsails may be at issue here: foresails were comparatively large and rigged on stayed masts while spritsails were small and rigged on unstayed spars protruding beyond the bow. Figure 6 illustrates the point. It is possible that some pre-Roman-period artists may not have been fully aware of the distinction.

Secondly, he does not agree that Roman-period merchant ships could sail to windward routinely. He believes that square-sailed ships could sail close-hauled, but that nothing we know about Roman-period sailing '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' (2018: 39). There are however, many other points on which this and my two previous papers have agreed with Whitewright.

Iconography

Depictions of ancient merchant ships were prolific during two periods, the Old and Middle Kingdoms of Egypt and post-Republican Rome. One room of the 6th Dynasty Tomb of Mereruka at Saqqara has over a dozen depictions of ships (Figure 2) and the 12th Dynasty tomb enclosure of Senwosret III has a room with more than 120 ship images (Wegner 2017). In the Roman-period the Square of the Corporations *(Piazzale delle Corporazioni*), Ostia, has black and white floor mosaics of at least 23 ships, of which only four do not have a second sail near the bow (Becatti 1961). Outside of these periods there are very few illustrations of non-military ships. Shipping in the Old and Middle Kingdoms of Egypt and the Roman-period appears to have had a significant status, which was probably the result of its economic importance, community awareness and technological achievement.

The iconography of Roman merchant sailing ships began with images at Pompeii and was discussed with numerous illustrations in Davey (2015: 31-7). In summary, Lucien Basch (1987) depicts about 46 Roman-period merchant ships without oars. Of these, ten have large foresails, while 28 have spritsails or bowsprits on which to rig spritsails. Of the eight ships depicted to have no sail at the bow, only three have square mainsails. There are also images of merchant ships with spritsails not included in Basch, especially on coins (Torr 1895: pl. 6 No. 27; Smith & Smith 1880: 201).

The graffiti of merchant ships with spritsails found throughout the Roman Empire are especially notable

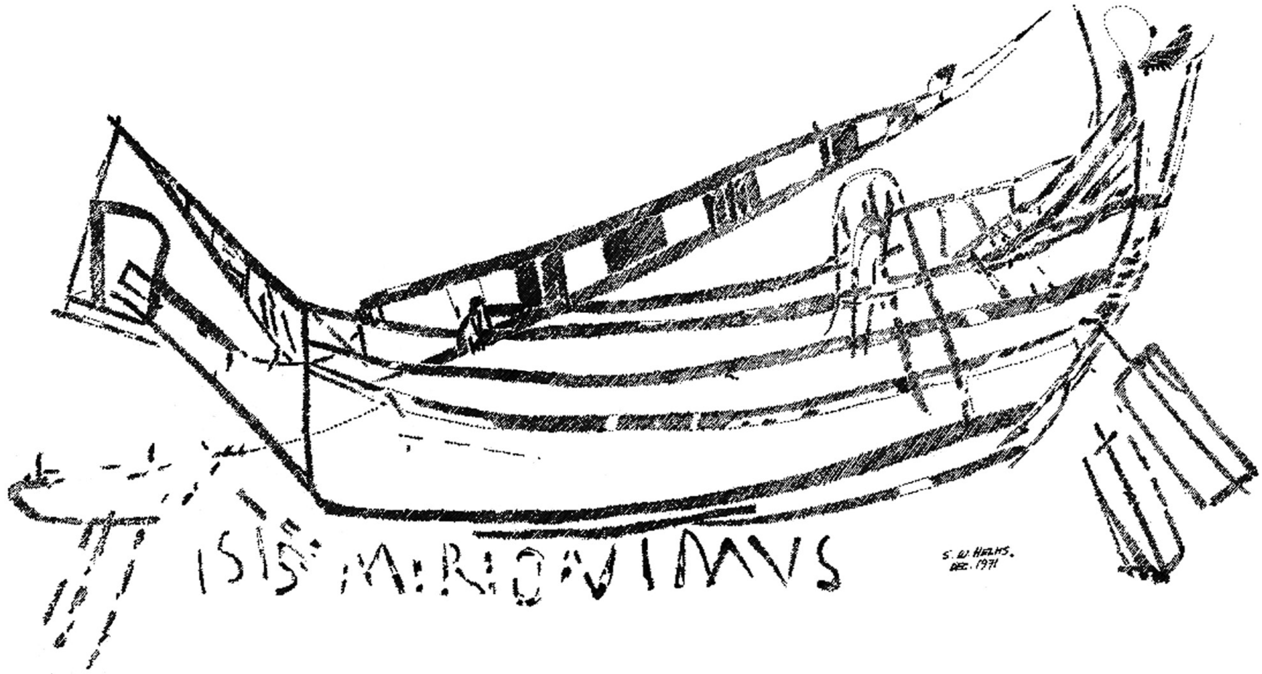

Figure 3: *Graffito from the Holy Sepulchre Church Jerusalem 4th century showing a ship with its mast lowered but the bowsprit still in place. Image from Basch (1987: fig. 1036) drawing by S. Helms 1971.*

because the people responsible for these many depictions were not part of an artistic tradition and could only have drawn what they had seen and knew about, ships with spritsails. These appear at Pompeii (Benoît 1961: fig. 73; Basch 1987: fig. 1051), Leptis Magna market (built c 8 BC) (Vergara Caffarelli & Caputo 1966: pl. 66A; Basch 1987: fig. 1102), the Palatino in Rome (Castrén & Lilius 1970: 109, 117; Basch 1987: figs 1025, 1096) and Sidi Khrebish (Berenike) near Benghazi (Pye 1974: pl. 4; Basch 1987: fig. 1103).

The graffiti reported to be from the quay at Utica (Moore 1911; Basch 1987: 234, fig. 483; Davey 2016: fig. 6) and in a Roman Villa at Cucuron (Vaucluse) occupied between the 1st and 4th centuries (Gassend et al 1986; Davey 2016: fig. 7) both depict spars raked forward of the bow and stepped into the keel of the ship in front of the main mast. Both authors conclude that the artist must have been a seaman because the detail shown was not apparent to the casual observer (Moore 1911: 280; Gassend et al. 1986: 30). Basch also depicts images of four ships that have the main-mast lowered to the deck but with an unstayed bowsprit still in place (1987: figs 1035, 1036, 1098 and 1108; Figure 3). It seems that the bowsprit was secured as an integral part of the hull and was not easily removed; it was not an afterthought.

Shipwreck evidence for Spritsails

Beltrame identified one shipwreck, the Saint Gervais 3, where there was a slot in the keelson near the bow that would secure a bowsprit, and three other shipwrecks where there may have been such a slot: the Punta Ala (Livorno), Torre Santa Sabina (Brindisi) and Torre Sagarrata (Puglia) (1996 & pers. comm.; Davey 2016: fig. 5). These ships all exceeded 17m in length and belonged to the period when spritsails were common.

It can be inferred, from the fact that the keelson of the Saint Gervais 3 was not reinforced to withstand vertical forces, that the spar was unlikely to have been held upright by tensioned stays. The slot in the keelson indicates that the inserted spar, with a spritsail rigged on it, acted as lever applying tangential forces to the hull.

Shipwrecks without evidence for bowsprits include the 2nd century BC Cavaliere (Charlin 1978), AD 300 Laurons 2 (Gassend et al. 1984) and the 5th century Dramont E (Santamaria 1995: Poveda 2012). These ships were all under 18m length overall and could be sailed close-hauled without a spritsail. Recent discoveries in the Black Sea have included three Roman-period ships 15-25m in length. One has a bowsprit visible and a second may have had one, which was lost when the bow section broke up (Whitewright 2018b).

It is therefore reasonable to believe from the iconography and archaeology that Roman-period large sea-going merchant ships were normally rigged with spritsails, while those shorter than 20m sometimes had spritsails. This has been generally recognised, but the implications of the extra sail have often been only partly appreciated.

Pre-Roman Experience

Mekhanika ('Mechanical Problems'), an Aristotelian treatise, is a short work on levers written by a Peripatetic. It was discussed in Davey (2015: 39). A further translation and comment are given here to explain its context. The Peripatetic School began in about 335BC and fell into decline by the mid-3rd century BC. It revived during the

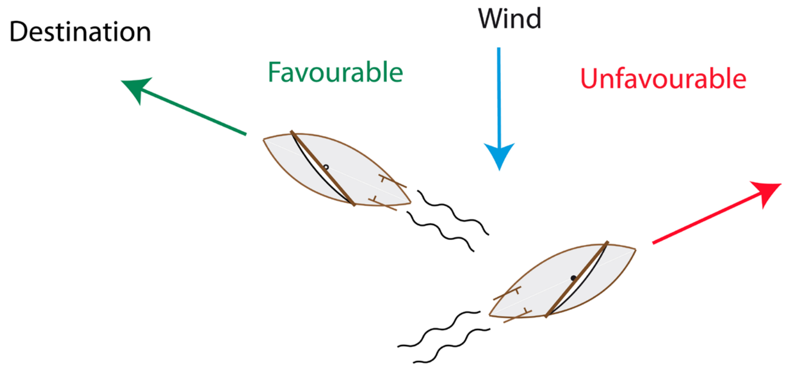

Figure 4: *A diagram illustrating* Mekhanika *Problem 7. While the ship sails close-hauled away from its destination the wind is deemed to be unfavourable, but after going about the ship sails toward its objective and the wind is regarded as favourable. Drawing by the author.*

Roman-period but the focus at that time was on the study of Aristotle's own works. *Mekhanika* was not written by Aristotle, and so it probably belongs to the earlier period. *Problem 7* therefore describes a situation faced by Classical period sailors:

> *Why, if the wind is not favourable when (sailors) wish to go about for a favourable breeze*, do they shorten/furl the section/part of the sail that is towards the helmsman, but loosen/slacken the forward (part of the) sail at the foot? Is it because the rudder cannot hold the vessel back against a strong wind, whereas they draw it up when it (the wind) is light. So, whereas the wind carries them forward, the rudder settles the boat into the *favourable* breeze, holding back and making the sea heave. As well, the sailors at the same time are struggling with the wind, for they lean against its opposite direction (Aristotle & Hett 1936: 361 amended).

This translation follows that of Hett, Loeb Classical Library, except for the two parts in italics. Hett's translation, 'Why is it that, when the wind is unfavorable and they wish to run before it…' does not make sense because a wind, which sailors wanted to run before, would not be unfavourable. Casson's translation (1971: 276 n.24), 'Why is it that sailors, after sailing with a favorable wind, when they wish to continue on their course even though the wind is not favourable…', is not much clearer. In the second instance Hett assumes that οὔριον, a fair or favourable wind, must be a 'following' breeze, which is not necessarily the case. In fact, a fair wind may be one that is steady and suitable for sailing to windward.

The context of the passage is a discussion about levers, which is relevant to the steering of a ship and going about. It is proposed that the text describes the situation illustrated in Figure 4, where a ship is close-hauled and finds itself heading away from the desired destination, so the wind is deemed unfavourable. By going about, the ship sails on a heading toward the desired destination and so the wind is considered favourable. This terminology may seem rather strange to non-sailors, but the idea of going about to get a 'good wind', that is a wind that will propel the boat quickly toward the desired destination, is still a common expression amongst sailors. Arnaud, drawing partly on Aristotle, discusses similar wind-based nautical terminology of orientation (2014: 52).

The text focuses on going about. Sailing boats with a properly balanced sail plan will comfortably go head to wind but as the wind strength increases, their ability to continue the manoeuvre by turning away from the wind to a new close-hauled heading is often problematic. The measures described in the text aim to turn the bow of the ship away from the wind. Applying the theoretical concepts explained by Davey (2015: 38), the sailors reefed or brailed up ('shorten/furl') the aft part of the sail to move the Centre of Effort forward, they loosened the forward part of the sail, so that it would catch the wind on the leeward side adding to the turning moment, and they moved their body-weight to counteract the heeling of the hull and to prevent the Centre of Lateral Resistance from moving forward.

Torr, who was writing when merchant sailing ships were still common, did not offer a translation of *Problem 7* but used it to describe going about: 'The passage shews that, when the yard was braced round, the sail was furled upon the arm that came aft, and left unfurled upon the arm that went forward' (1895: 96 n.206). The sequence of going about is thus: brail up (furl) the forward part of the sail so the ship rounds up into wind, as the ship goes head to wind the sheets are released and the yardarm is braced round so that the unfurled sail goes toward the bow, all the while leaning the boat away from the turn. This approach was discussed with Glafkos Cariolou, skipper of the *Kyrenia II*, who considered that 'it would work'.

Experience of the *Kyrenia II*

The 1986-7 sea journeys of the replica *Kyrenia II* between Piraeus and Paphos were documented by Katzev (1990) and were later commented upon by Cariolou, who was the skipper for the return voyage (1997). The ship carried ballast and supplies of about 10 tons out of a possible 30 tons to Paphos and 7 tons on the return. Cariolou reported that they went about twice in wind speeds of less than 16 knots, but that tacking in stronger winds was very dangerous for the integrity of the sail and was not practised (1997: 93). The voyage to Paphos was sailed mainly on reaches and runs, while the return journey involved a significant amount of close-hauled sailing and a couple of storms with winds reaching 8 Beaufort (34-40 knots). Breakages to the steering gear occurred during the return voyage, demonstrating that significant turning forces were generated when going to windward. Katzev concluded that the *Kyrenia II* voyages demonstrated a 'remarkable ability to sail into the wind' (1990: 255) but, without the capacity to go about comfortably, an overall course directly into the wind was not achieved.

There is currently a belief that to sail close-hauled, a boat's hull must have a wine-glass section. Such a shape appeared during the 5th century BC and is taken as an indication that ships were then sailing to windward (Steffy 1994: 40-49; Harris 2011: 16; Pomey 2011: 50; Wilson 2011: 217). Whitewright follows the conventional wisdom with respect to the 'wine-glass' hull shapes of the Kyrenia and Ma'agan Michael ships (2018a: 39). Neither ship had any evidence for a spritsail, and the *Mekhanika* quotation implies that such a sail was unknown at the time it was written. The experience of sailing the *Kyrenia II* highlights the limitations faced by Classical ships sailing to windward.

Recent spritsail experience

Contemporary illustrations of 17th and 18th century ships at sea nearly always show a spritsail to be set. The details associated with rigging a spritsail continue to be described in rigging manuals (Anderson 1955: 111-120; Lees 1984: 99-105; Marquardt 1992: 54-59, 186, 224f; Anderson 1994), but Harland's comprehensive study *Seamanship in the Age of Sail* states that 'it is difficult to get much information about how the [sprit-]sail was actually used' (1984: 86). He quotes sixteenth-century Dutch experience that the spritsail was never set at night, in rough weather or when approaching land or sailing in convoy.

The power of the spritsail to alter a ship's course is described by Alan Villiers (1903-1982), a Melbourne-born seaman and author, who gained experience with spritsails when he skippered the *Mayflower II* on its passage to America in 1957. He is quoted at length in Davey (2015: 40-1). In summary, he wrote, 'As for the spritsail, this was so good a manoeuvring sail that I could well understand how it had persisted down the centuries, even after the use of jibs, … had long been general' (1958: 253). However, its handling was not so straightforward, and he believed that this, more than anything else, led to its replacement by the jib (1958: 254). Villiers described the manoeuvrability of the *Mayflower II*: 'with the spritsail, the lateen mizzen, and the good positioning of the masts carrying the real driving sails, our *Mayflower* both tacked and wore quite well, swinging either across the wind or round before it very fast, with little loss of way…. She went to windward well in a good sailing breeze, and she could be made to lie up six points' (1958: 255), that is 67.5 degrees from the wind (*Points of sailing*, Dear & Kemp 2005).

Villiers viewed square sails, such as the spritsail, as 'real sails', an attitude that contrasts with many recent commentators, who regard the square sail in antiquity as inferior to fore-and-aft sails such as lateen rigs (Casson 1971: 243; Campbell 1995: 2). However, fore-and-aft sails never replaced square-rigged sails, which remained standard on merchant ships to the end of the Age of Sail. Whitewright has argued that the fore-and-aft lateen sail was not technically superior to the square-sail, and its adoption in the Late Roman-period was for more complex reasons (Whitewright 2008).

Modern scholars are inclined to deem the references to people such as Villiers as anecdotal. However, before any maritime archaeological university department was even contemplated, he had sailed on numerous working sailing ships and full-size replicas systematically documenting his experiences. He wrote 44 books and his archive (MS 6388) at the National Library of Australia runs to 25.05m (143 boxes + 2 phase boxes + 12 map folios) (http://nla.gov.au/nla.obj-234431689/findingaid, accessed 10.7.2019). His informed experience must be admitted as evidence for commercial sailing technology.

The relevance of comparatively recent ships such as the *Mayflower* to Roman merchant ships has also been questioned. Merchant sailing ships from at least the Classical period had full flat-bottomed sections amid-

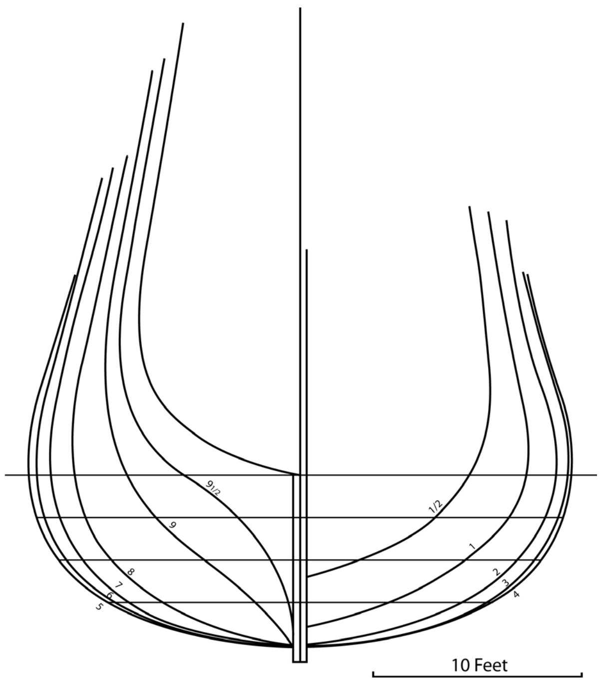

Figure 5: *The lines of the* Mayflower*, based on a model by R.C. Anderson. They show that the stern, drawn on the left, was above the waterline and that there was a wine-glass section near the stern. (Redrawn from Magoun 1987: Plan 5).*

ships, to increase their carrying capacity, and a keel protruding along the length of the hull. The reconstruction of the Ma'agan Michael shipwreck's hull shape illustrates the relationship between displacement and the fullness of the hull (Davey 2016: 35-8). Another notable feature is that, except for some medieval and non-European merchant ships, sea-going sailing ships from Classical times onward were generally double-ended below the waterline, that is, they came to a point at both ends, and many had fine or wine-glass sections near the bow and stern.

The lines of the *Mayflower* shown in Figure 5 were derived from a model at the Pilgrim Society, Plymouth, Mass. made by R.C. Anderson, a distinguished maritime historian, who obtained typical sections for 1600-1610 ships from the Samuel Pepys collection (Magdalene College, Cambridge) and the Scot collection of the Institution of Naval Architects (London) (Magoun 1987: 44, Plan 5). Judged on the criteria currently applied to ancient ships, that is the need for a deep wine-glass section, the *Mayflower* would be deemed unlikely to be able to sail to windward. However, we know that it could sail a course at 67.5 degrees from the wind (Villiers 1958: 255). Indeed, Villiers' experience of the *Mayflower* and 20th century clipper ships led him to suggest that all square-rigged ships with a balanced sail plan could achieve that point of sailing. At about 33m overall length and 180 tons, the *Mayflower* was comparable in size to many Roman-period merchant ships, which should be included in Villiers' suggestion.

Smith agreed that Roman ships could sail to windward (Smith & Smith 1880: 215), and his comments are discussed in Davey (2015: 41). The capability of ancient ships to sail to windward has also been discussed by Whitewright using modern replica data and ancient voyage records (2008; 2011; 2018a).

Most merchant ships in the Age of Sail are like modern sailing dinghies in that they had flat bottoms amidships and comparatively small area of underwater vertical surfaces. Merchant ships had keels while dinghies have foils and rudders. For these surfaces to provide effective lateral resistance, boat speed must be maintained. If wind speed drops causing the boat to slow, or the wind becomes strong causing the sails to stall aerodynamically, the boat will drift sideways or wallow. Moderate, steady breezes are ideal for sailing to windward.

Successful windward sailing by boats such as the *Mayflower* required good boat-speed, which is achieved by constantly adjusting the boat's angle to the wind direction. Sailing close-hauled is a skill involving a compromise between pointing (toward the wind) and boat-speed; point too close to the wind, the boat slows and its sideways movement increases; point away from the wind and the boat gathers speed, sideways movement reduces, but the boat's progress toward the wind also reduces. The application of this skill requires effective controls that can be easily and precisely manipulated, and indicators to guide those in charge. For Roman-period sailors, the controls were the braces and sheets of the spritsail, and the indicator was the maintenance of a full shape of the mainsail.

Commentators ancient and modern have described the function of the spritsail as an aid to steering ships (Augustine, *Enarratio in Psalmum* 32.4; Smith & Smith 1880: 201; Arnaud 2011: 153; Whitewright 2018a: 32). At a macro-scale, the spritsail enabled sailors to gain command of a ship that was 'in irons' (out of control head-to-wind), and at the micro-scale, it permitted fine adjustments to balance the sail setting to maintain boat speed when sailing a close-hauled course. Villiers' comments emphasise the importance of this purpose, and they lead to the conclusion that the spritsail made the sail plans of Roman-period ships comparatively complete and capable of efficiently sailing to windward in good sailing breezes. Wind strength was more of a limitation than wind direction because both light and strong winds made it difficult to sustain adequate boat speed.

Origin of the spritsail

The origin of the spritsail may never be known with certainty, but the evidence already referred to gives some indications. Casson deemed that all sails forward of the mainsail were called *artemon* and had substantially the same purpose even though some were large and others small. He argued that the reconstructed wall painting from the Tomba della Nave, Tarquinia, which is dated to the 5th century BC and depicts a ship with a second sail between the mainsail and the bow, reveals the origin of the *artemon* (Casson 1971: 70, 240, fig. 97; Basch 1987: fig. 880; 1976; Moretti 1961). The absence of additional evidence in the following few centuries has cast some doubt on his claim (Harris 2011: 19; Arnaud 2011: 152).

Arnaud has advocated a distinction between the unstayed bowsprit with a spritsail and the stayed, near-vertical foremast carrying a foresail (2011: 152-4). The purpose of these sails was substantially different; the spritsail was to help steer the ship, while the foresail was primarily for propulsion.

The situation described in *Mekhanika* Problem 7 could have been resolved with the application of a spritsail, which seems to have been unavailable at that time. Indeed, it is hard to identify a better example of a lever to manoeuvre a ship than the spritsail and bowsprit. Instead, Classical-era sailors tried to use the partial brailing of the mainsail to assist with steering of the ship, and they manipulated the forward section of the mainsail. It was not such a great leap of imagination to rig a small sail at the bow to do this work much more effectively. This sail had to be rigged on an unstayed spar or bowsprit, so it was not hindered by the standing rigging. This represents a logical development of the spritsail from the function of the mainsail.

When reviewing the progress of maritime technology, Harris used the dates of Roman ship images to argue for a 2nd century AD introduction of the spritsail, instead of accepting a 5th century BC date (Harris 2011). I have argued that the spritsail appeared in the Late Roman Republican period (2nd century BC), because of textual references to the *artemo,* which begin in about 100 BC: Lucilius, *apud Charisium*, 99; Labeo and Seneca, *Controversiae*, vii. i. 2; *The Pandects*, 1.16. 242 (Davey 2015: 37-8). This is a moderate position, which is compatible with the history of ship sizes.

Ship size

The experience of the *Kyrenia II* described above revealed that when sailing to windward, emergencies sometimes required the application of oars. This intervention may have been an option when sailing ships of 15m length displacing 30 tons or less, but it was not a reasonable possibility for larger merchant sailing ships. Merchant galleys on the other hand were narrower, had less freeboard, smaller displacement and were crewed by enough oarsmen to row the ship when necessary.

Wilson discusses the change in ship sizes in terms of displacement tons derived from shipwreck data between 600 BC and AD 1500 (2011). I did a similar analysis with respect to overall length (Davey 2016). Prior to mid-2nd century BC, ship displacements were 30 tons or less, with one exception, the Alonnisos wreck, which Hadjidaki determined to be a merchant galley (1996).

The economics of merchant galleys and sailing ships would have been substantially different. The cost of procuring, training and maintaining a large crew made merchant galleys a higher operating cost enterprise, so that cargoes of such ships needed to be strategically important or of high value. Merchant galleys would have been at a severe disadvantage when considered for long-range, large-volume, low unit value commodity trade.

Wilson's shipwreck data reveals that from the mid-2nd century BC ship displacements increased dramatically to as much as 600 tons (2011: 213, fig.14.1). He identified the Late Roman Republican trade of wine for slaves between Italy and Gaul, which ended with Caesar's capture of Gaul mid-1st century BC, as an intensive

Figure 6: *A mosaic of two ships from Station 23, Square of the Corporations, Ostia c AD 200. The ships have contrasting rigs and hull shapes. The ship on the right has a spritsail at the bow while the ship on the left has a foresail and may have a sail plan like the Madrague de Giens shipwreck. Image by Bill Storage and Laura Maish at http://www.ostia-antica.org/piazzale/corp.htm, accessed 20.7.2015, used with permission (Becatti 1961: 73, pl. 179).*

and highly profitable activity. Large merchant galleys may have been used for this trade. If they were, it would account some of the large ships built during that period, but it does explain the development of large grain ships.

Ancient authorities describe the Egyptian and Maghreb to Rome grain trade being conducted by large ships (Casson 1971: 183-190). According to Wilson, such vessels do not appear in the archaeological record because of the perishable nature of their cargoes; they did not leave heaps of amphora. He concluded that 'merchant ships of over 200 tons were not uncommon between 1st century BC and 4th century' (2011: 217; Casson 1971: 170-173).

It is proposed that it was the introduction of the spritsail that gave comparatively small crews the means to manoeuvre large merchant sailing ships, and that this made long-range, high-volume commodity trade technically feasible and economically viable. It is further proposed that it was the importance and ubiquity of this trade that prompted the large number of representations of ships with spritsails from the 1st century onwards.

Cutwater bow ships with foresails

Of the ten Roman merchant sailing ships with large foresails depicted in Basch, eight have cutwater bows. The images are from the 2nd century AD or later. The shipwreck at Madrague de Giens was the first ship with a cutwater bow to be excavated (Tchernia et al. 1978). Pomey discusses the sail plan and concludes, 'In any case, the convergences appear to be sufficiently numerous and important so that we can identify the vessel of La Madrague of Giens the great sailing ship of the mosaic of the Baths of Thémétra' (1982: 150; trans. CJD).

The Thémétra mosaic depiction specifically referred to is Basch (1987: fig. 1109), which has a foresail on a forward-raked mast. Pomey argues that, while the foresail provided power, it also helped to balance the sail plan. He considers that the proportions of the Madrague de Giens' hull were like the asymmetric ship depicted in the mosaic of Syllectains in the Square of the Corporations, Ostia (Figure 6; Basch 1987: fig. 1076). He suggests that the Madrague de Giens could also have been rigged with three masts and that this 'should significantly improve its stability, its sensitivity to the rudder and its capacity to go toward the wind' (1982: 151 trans. CJD).

The hydrodynamics of cutwater bows would have helped to balance large foresails because the Lateral Resistance was concentrated nearer the bow of such hulls. The Madrague de Giens wreck had a 1 metre deep wine-glass section, which may have given it the capacity to sail closer to the wind than six points.

As Pomey has argued, the foresail of the Thémétra-type boats provided power and control when sailing into the wind. However, the adjustment of such foresails would have been more physically demanding than the smaller spritsail; and it would have been much less discriminating. While the foresail may have helped balance the sail plan, it was not a sail that could be used for steering. The addition of a small mizzen sail may have overcome this situation, but such ships still needed larger crews than ships rigged with only a mainsail and spritsail. They consequentially also had higher operating costs and more logistical constraints.

The Madrague de Giens shipwreck reveals a complex development path for multi-masted vessels. While it may be tempting to suggest that the spritsail and foresail had similar origins and parallel histories, this would not explain the development of the cutwater bow to balance the foresail. It is also unnecessary because the spritsail appears to have a feasible technological development path from the way the mainsail was used when going about, according to *Mekhanika* Problem 7. The development of the unstayed bowsprit, on which the spritsail was rigged, is another component that does not relate directly to the stayed foremast on which the foresail was rigged.

Conclusions

This paper draws attention to the dynamics of sailing to windward and especially the importance of maintaining boat speed when so doing. A ship's ability to sail close-hauled is now generally thought to depend on its hull shape amidships, but it has been argued that sailing technique was also important. *Mekhanika* Problem 7 provides evidence that sailors of the Classical period were sailing to windward; and it illustrates how they used sail adjustment and hull inclination to try to control ships as they tacked, a manoeuvre essential for windward sailing.

Sailing to windward is a skill relying on the effective controls and indicators. Representations of merchant sailing ships during the Roman Empire were prolific, demonstrating their importance at that time. The greater portion of the ships depicted were rigged with spritsails, or with bowsprits on which to rig spritsails. This sail gave the crew the manoeuvrability they needed to handle windward sailing by maintaining boat speed while close-hauled, and providing a turning moment to assist with going about. Texts mention the *artemo* – spritsail from about 100 BC, revealing that it had been developed by that time. It continued in use until the last century of merchant ship sailing.

Shipwreck data reveals that from the time of the spritsail's introduction, ship sizes increased. The largest ships until then had been merchant galleys. It appears that the spritsail provided the means to command larger sailing ships overcoming the economic limitations of merchant galleys and achieving economies of scale to facilitate reliable long-range bulk-commodity seaborne trade.

The Roman-period ship depictions portray a variety of ship sizes and sail plans. This paper has focussed on the most common, those with spritsails. It is probable that smaller vessels plying river and coastal trade did not use spritsails as their itineraries were more flexible and they could set sail at the time of their choosing.

Scholars have often been reticent to accept the capability of Roman-period ships to sail to windward. Alan Villiers' experience sailing the *Mayflower II,* a ship with a spritsail and without a wine-glass section amidships, is a strong indication of the capabilities of comparably sized ships with spritsails. It may be time to set aside the longstanding scholarly approach and to adopt Villiers' suggestion, that all square-rigged ships with spritsails and balanced sail plans could sail to windward in good sailing breezes as a matter of routine, and that constraints were more likely to stem from extremes in wind strength rather than wind direction.

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