UNIVERSITY OF SOUTHAMPTON

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Maritime Technological Change in the Ancient Mediterranean: The invention of the lateen sail

Two Volumes, Volume One

by

Richard Julian Whitewright

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ABSTRACT

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MARITIME TECHNOLOGICAL CHANGE IN THE ANCIENT MEDITERRANEAN: THE INVENTION OF THE LATEEN SAIL

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The earliest evidence for sails in the Mediterranean dates to c. 3100 BC and indicates that vessels were rigged with a square-sail. From this point until the late-antique period the square-sail remained the principal sailing rig of the Mediterranean. A new form of sailing rig, the lateen, began to be utilised amongst Mediterranean mariners from at least the 2nd century AD and became widespread from the 5th century AD. The lateen sailing rig proved so popular that the square-sail was eventually abandoned in the Mediterranean during the medieval period.

The rapid pace of technological change during the late-antique period followed a long period of relative technological stability and has traditionally been explained via a logical progression of technology. This has imposed a ‘need’ to improve the windward performance of ancient sailing vessels upon their users. Such a progression has also been seen as providing the mechanism, viewed through changes to geometric sail shape, for the unilinear evolution of the modern, western sailing rig.

This explanation of maritime technological change is now outdated and unsustainable, both in terms of modern theories of technological change and the available evidence on the specific subject of the lateen sail. Despite this, it is still widely accepted within maritime studies of the ancient world. By investigating the fine detail of all of the constituent parts of a sailing rig, rather than simply the sail shape, it is possible to view sailing rigs as a series of related, component parts. Acknowledgement of the importance of the technical practice used to operate a sailing rig underlines the importance of the ancient mariner in determining the nature of maritime technology. By relating a detailed understanding of maritime technology to the broader context of the ancient world, this study sets out to challenge, dismantle and replace outdated theories regarding the introduction and adoption of the lateen sail in the ancient Mediterranean.

Contents

Volume Two

Page

List of Figures

Part Three

Part Four

List of Tables

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Abbreviations and definitions used in the text

A number of conventions have been used throughout the text for the purpose of cross-referencing, both to other chapters or sections and also to information contained in the Appendices.

The text is divided into four parts, where another part is referred to it is simply referenced, e.g. Part Two. Chapters within these parts are labeled numerically and cross-referenced according to their number, e.g. (ch. 2.1) would refer to the chapter on the 'Mediterranean Square-sail' within Part Two. Sections within these chapters are cross-referenced in a similar way, e.g. (ch. 2.1.4), which would refer to the section on 'running rigging' in chapter 2.1. Figures have been labeled in numerical order within each Part of the text. Hence Figure 1-2 is the second figure in Part One, while Figure 2-1 is the first figure in Part Two.

Appendix One contains details of the archaeological sites and evidence referred to in the text, these are arranged alphabetically and numbered from Site 001 to Site 048. They are cross-referenced in the text by their Site Number, e.g. S024.

Appendix Three contains details and interpretation of the iconographic evidence included in this study. The depictions of these vessels have been ordered by rig type and chronologically within each rig-type. Their Vessel ID numbers run continuously throughout the catalogue and are referred to in the text, e.g. V01.

Appendix Four contains a series of information relating to the historical voyages used for evidence in chapter 2.3. These voyages are numbered continuously and are simply referred to as Voyage 01, Voyage 02 etc.

Introduction

During the late 5th century AD a mosaic was laid at the port town of Kelenderis in southern Turkey, a portion of the mosaic depicted a sailing vessel entering the harbour of the town. Such depiction of a sailing vessel was common practice in a variety of different iconographic forms and contexts. However, the creator of the Kelenderis mosaic did not depict a vessel rigged with a square-sail, as Mediterranean people had done for thousands of years. Instead they chose to show a vessel carrying a quadrilateral shaped sail in which one side was much longer than the other. Other features of the vessel indicate that this was not because a mistake was made depicting a square-sail, but because a sail with unequal sides was meant to be depicted. The Kelenderis mosaic is significant because it represents the earliest currently identified, unequivocal depiction of a type of sail known as a *settee* sail. The settee sail, along with the closely related, triangular *lateen* sail came to replace the square-sail and become the most common sailing rig in use in the Mediterranean until the 14th century AD. The inclusion of this type of sail, rather than a square-sail, by the creator of the mosaic indicates that they were familiar with the settee rig. The mosaic symbolised their interpretation of the features which represented a sailing vessel during the late 5th century AD. Contemporary iconography in other areas of the Mediterranean was still being created in which square-sails, rather than settee or lateen sails were depicted.

The following study aims to investigate and understand the processes of technological change which led to the invention and adoption of the lateen/settee sailing rig by Mediterranean mariners. This process has been the subject of study, debate and comment by maritime archaeologists and historians since the early 20th century (e.g. Adam 1976; Basch 1989; 1991; 2001; Brindley 1926; Campbell 1995; Casson 1956; 1966; 1995: 244-5 & 276-8; Castro *et al* 2008; Facey 1991; Friedman & Zoroglu 2006; Hourani 1951: 100-105; Kingsley 2004a: 78-79; Kreutz 1976; Le Baron-Bowen 1953b; 1956; Makris 2002: 96; Pomey 2006; Pryor 1992: 27; 1994: 67-9; Sottas 1939; Ward & Ballard 2004: 12). Such study has included the common theory that the lateen/settee rig originated in the Indian Ocean before being transferred to the Mediterranean via the Arab invasions of the 7th century AD. The publication (Basch 1991) of unequivocal iconographic evidence predating the Arab invasion has rendered that theory of transmission redundant and the Kelenderis mosaic provides further, earlier confirmation of this. The Indian Ocean is still identified as the origin of the lateen/settee sail by some scholars (Kingsley 2004a: 78-79; Ward & Ballard 2004: 12). This brief background sets the temporal and spatial parameters of the present study. In chronological terms, the primary focus is upon the Roman Imperial and late-antique period leading up the depiction of the vessel in the

Kelenderis mosaic. Geographically, study covers the Mediterranean world and the western Indian Ocean where the lateen/settee sail is often assumed to have originated. However, meaningful evidence is necessarily considered from the wider antique, late-antique and early-medieval periods.

The invention and adoption of the lateen/settee rig in the Mediterranean has commonly been described with phrases such as;

"Lateen-rigged ships were probably faster, and achieved better sailing angles to the wind [than square-rigged ships]. Could speed and manoeuvrability be two of the main reasons that made lateen sails apparently so popular in the early-medieval Mediterranean?" - Castro et al 2008: 348.

The quote encapsulates the assumptions and ideas which have underpinned the existing study of this example of maritime technological change in the ancient Mediterranean. Sailing rig development has been based on the notion that observable change must have occurred for an explainable, logical reason. In this case the need for better windward performance. This 'need' is commonly cited as having been met by the development of the lateen sail when compared by to the square-sail that preceded it (e.g. Basch 2001: 72; Campbell 1995: 2; Casson 1995: 243; Castro *et al* 2008: 348; Kreutz 1976: 81-2; Makris 2002: 96; McCormick 2001: 408; Meijer & Van Nijf 1992: 224-5; Pryor 1992: 33). The development of the lateen sail and its superiority over the square-sail allows the establishment of a unilinear progression of sailing rig technology which finishes with the modern sailing yacht rig. Each step in the process allows a further leap in windward performance to be made. The logical, predictable nature of progression, rendered in technologically deterministic terms dictates that 'older, simpler' technologies must become redundant once 'newer, better' ones are developed. A generic example of this progression is illustrated below.

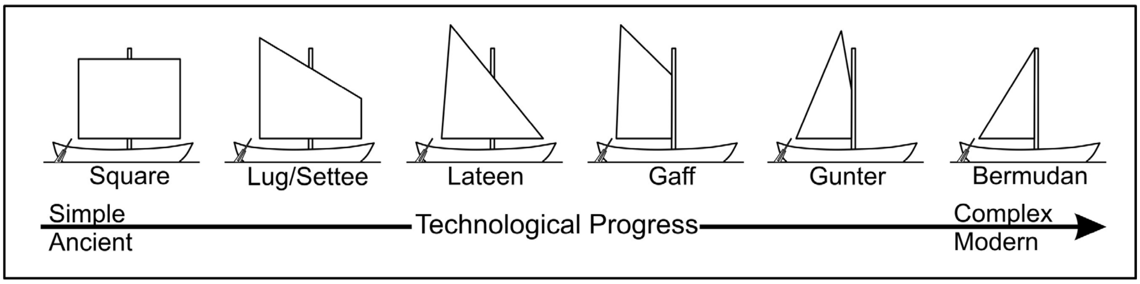

Figure 0-1. A generic model of the unilinear progression of sail development, viewed through sail-plan.

The main investigative methodology which has been utilised in order to understand sailing rig development has been to document visible changes in the geometric shape of sails (e.g. Facey 1991; Hourani 1951: 100-105; Le Baron-Bowen 1953b). This has been conducted along a logical pathway in which geometrically similar forms must precede and succeed one another. The unilinear, determinist approach to sailing rig development, in conjunction with analysis of geometric shape, has acted in tandem. This has produced a scheme in which logical changes in technology produce obviously desirable improvements to mankind's ability to travel over water. The reverse has also been upheld by the approach; that an understandable desire to improve the performance of sailing ships has led to logical improvements in rigging technology.

It is the contention of this study that the theories and methodologies which have been used to study the historical development of sailing rigs in general and the specific case of the development of the lateen/settee sail are flawed. In particular, the explanation of the introduction of the lateen/settee rig in the Mediterranean has lacked consideration of the available evidence. Meanwhile, the use of sail-plan as a means to illustrate change has unduly privileged that area of all sailing rigs. Existing studies have overlooked the information contained in other rigging elements and in techniques used to handle sails and sailing vessels. This study maintains that only by investigating every area of the sailing rig, including its manner of operation, can a sailing rig be understood and any observable technological change or stasis fully assessed.

The concept of technological determinism and views of technological development which rely on a unilinear model of progression have been the subject of strong critique and criticism within the fields of archaeology and anthropology (Loney 2000: 647; Pfaffenberger 1992; van der Leeuw & Torrence 1989: 1-2). Recent work concerned with the study of specific examples of technological development in antique (Cuomo 2007; Mattingly 1994) or maritime (Adams 2003; Gould 2001; Schiffer 2005) contexts has demonstrated that both of these areas of study can be approached afresh and with recent theoretical developments in mind. It is the intention of this study to reappraise the terms on which archaeology has considered and investigated maritime technological change in the ancient world and specifically the invention and adoption of the lateen/settee sail in the Mediterranean. Finally, the development of the lateen/settee sailing rig must also be viewed in the wider context of the ancient Mediterranean. Continuity or changes to the structures of Mediterranean society, economic systems and related areas of maritime technology, such as shipbuilding, are likely to have had an impact on how ancient mariners visualised, created and utilised sailing rigs.

It is these aims which structure what follows. Part One sets out to contextualise the study from a variety of angles. Chapter 1.1 addresses wider theories of technological change in conjunction with outlining the approaches taken by scholars to the subject of the lateen/settee rig. An original methodology for elucidating the introduction of the lateen/settee sail into the Mediterranean can then be set out. This methodology is unique in focusing upon ancient sailing rigs and their technical use as a way of understanding any visible technological change, rather than simply analysing sail-form alone. Previous studies, based on the latter approach, have traditionally relied upon iconographic imagery as a way of identifying when important changes to sail-form occurred. Some recourse has also been made to the literary sources. Both of these traditionally accessed sources, in conjunction with the archaeological record which is central to the present study, are set out in Chapter 1.2. Finally Chapter 1.3 provides the wider context in which mariners operated in the ancient world.

In contrast to the broader picture covered in Part One, Part Two is directly focused upon understanding the fine detail of the two sailing rigs which are central to this study; the square-sail and lateen/settee rig of the ancient and late-antique world. These two sailing rigs are comprehensively characterised in chapters 2.1 and 2.2 respectively. As well as the rigging components used, these chapters also clarify and describe the techniques of sail handling used to operate ancient sailing rigs. An assessment of the comparable potential performance of these sailing rigs is conducted in chapter 2.3. Following this, Part Three sets out and analyses the whole spectrum of maritime technological change/stasis which falls within the scope of this study.

Having conducted a detailed investigation into the characteristics, use and technological change/stasis visible in the square-sail and lateen/settee rigs of the ancient world, Part Four draws these themes together and relates them to the wider picture observed in Part One. In doing this, an alternative, more holistic methodology for the investigation of sailing rigs, ancient and modern is proposed. The unilinear model of technological change upheld by the current literature can be replaced with a scheme which acknowledges the full technological variation visible in the maritime technology of the ancient Mediterranean. Finally, a considered pathway for the invention and subsequent adoption of the lateen/settee rig is developed and a described. Unlike earlier explanations, this explanation is contextualised alongside other maritime technological development, as well as against the wider social, economic and environmental background in which the lateen/settee rig was invented and adopted.

Part One: Contextualisation

1.1 Technological change in a maritime context.

1.1.1 Theories of technological change

Technology and technological processes are central to both human existence, behaviour and to the way that humans experience and make sense of the world (Dobres & Hoffman 1999: 1; Schiffer 2004: 579). Consequently technology and technological change has been a subject of interest and importance in the social sciences which have emerged as disciplines from the 19th century onwards (Geselowitz 1993: 231; Roux 2003: 1; Schiffer 2001: 215). Technology and technological change has also been acknowledged as being one of the central concerns within archaeology (Ucko 1989: x), a discipline acknowledged as enabling investigators to discern long-term patterns of technological change (Schiffer 2001: 215). Archaeologists initially investigated innovation by borrowing models from other disciplines (Adams 2003: 37-8; Geselowitz 1993: 233). Early archaeological approaches drew heavily upon Darwin's evolutionary approach (Basalla 1988: 15) and applied this to artefact typologies in developing concepts relating to the evolution of technology (Schiffer 2001: 215). These theories relied upon the imposition of a unilinear progression upon technological change in which each invention builds upon the previous one and technology moves from the simple to the complex, hence the digging stick had to precede the plough (Harris 1968: 232). This approach has been categorised by Pfaffenberger as the *standard view* of technology (1992: 494) in which 'necessity is the mother of invention' (c.f. Fitzhugh 2001: 126) and form is secondary to function. New Archaeology put forward a view of technology and artefacts which was largely in accordance with Pfaffenberger's definition of the *standard view* and a presumption of a need-driven technological evolution (Pfaffenberger 1992: 495). This approach has also tended to emphasise the effect of the physical environment in shaping technology and its function.

The first of the two assumptions outlined in the *standard view*, that 'necessity is the mother of invention', has been the subject of reassessment by both Pfaffenberger (1992) and Basalla (1988) who note that necessity is very much a relative term. What may seem an incontrovertible need for one people, generation or social class may be of no value or be a superficial luxury for another (Basalla 1988: 12) or even more simply, merely a need generated by our own cultural fixations (Pfaffenberger 1992: 496).

Implicit to the *standard view* and its evolutionary concepts is the idea of *technological determinism* (Pfaffenberger 1992: 510) in which technology evolves according to its own autonomous logic (Dobres & Hoffman 1999: 10; Pfaffenberger 1988: 243). This logic has developed from the typological approach (above), dictated by the notion that technology must always develop along a unilinear progression from simple to complex. It follows that if a technological change can be demonstrated to have happened, then it must have done so for an explainable, functionalist reason which improved the technology in some way. The tacit assumption within this view is that once a superior technology has been invented, its antecedent will become redundant and disappear (c.f. Cuomo 2007: 49; Schiffer 2001: 216). Although the notion of technological determinism is currently viewed as largely untenable (e.g. Arnold 1995: 733), specific examples can be identified with regard to modern information technology (e.g. Ceruzzi 2005). The polar opposite of this deterministic approach is one of *technological somnambulism* (Pfaffenberger 1988: 236) which denies a causal link between technology and social formations (*ibid*). Instead, technology is simply viewed as a product of society but has no influence upon society. Both viewpoints inhibit a balanced understanding of the social choices and social relations which occur in any technological system (*ibid*) because of the extreme points of view which they represent. Neither of these approaches therefore are really an ideal way to assess technology or technological change in particular. One approach virtually denies the role which technology plays in shaping a society while the other over emphasises it to the point of ignoring any other factor which might have an impact upon society. Consequently an alternative, more balanced, approach to the study of technology is required.

There is usually more than one technology or solution to any given need or task. The choice of one technology (and resulting artefact type) over another may be strongly influenced by the beliefs, social structure and prior choices of the society in question (Killick 2004: 571; Lemonnier 1993: 16). This idea forms the basis of the *social constructionist* approach to technological change. No explanation of an observed technological change is complete unless it relates the observed technology to its wider social context (*ibid*). This concept of technology as a social construct developed out of a combination of ideas hailing from the sociology of science and the history of technology in the early 1980's. The classic work on the subject remains that of Bijker, Hughes and Pinch (1989) *The Social Construction of Technological Systems*. The development of a technological artefact is more than simple technological achievement, embedded within the artefact are social, political and economic considerations which form a 'seamless web' of which the technology is part (Pinch 1996: 23). As Eglash (2006: 332) notes 'technological forms and histories of innovation are far more contingent on social factors than the technological determinist position indicates.' In a sense this draws upon *somnambulism* in denying the role of inevitable processes and unseen forces at work and places the responsibility for technology and any change squarely on the shoulders of the society. However, Killick (2004: 572) notes that technological practices are obviously constrained by the laws of physics and chemistry and by their geological, ecological and historical setting. Even operating within these constraints there is still usually more than one way of accomplishing a given task and the solution which is adopted depends on the choices made by each individual or group. It is this acknowledgement of the variety of factors, active during the process of technological selection which sets the *social constructionist* view apart from that of *somnambulism* as a more realistic approach.

The 'social construction of technology' (often termed SCOT (Pinch & Bijker 1989: 28)) conceptualises and links society to technological artefacts via relevant social groups (Pinch 1996: 23). These are identifiable social groups which play a role in the development and meaning of an artefact. This meaning can subsequently be used to explain why an artefact is developed along certain paths and not others (Pinch 1996: 24). SCOT also uses the twin concepts of the *stabilisation* and *closure* of technology to explain why some technologies become adopted by societies and others do not. Stabilisation examines the processes which dictate how the initial form of an artefact develops and changes dependent on the societal influences which are brought to bear on the artefact (Law 1989: 111; Pinch & Bijker 1989: 44-46; Pinch 1996: 24-5). Closure occurs once the processes dictating the form of an artefact have diminished (*ibid*). These concepts in turn acknowledge that alternative technologies do not automatically vanish, once a specific technology has been widely adopted. Two different technologies, fulfilling the same role in a society, may exist side by side. Equally, the process of closure or stabilisation may not be final, new factors or considerations can emerge and technology may undergo further change (Pinch 1996: 25).

The ideas behind SCOT have been developed further by Dobres and Hoffman (1999: 1-19), who put forward an alternative *constructionist* view which stress the relationships which are formed between material, social and symbolic factors. In particular, they focus upon the role of people and human agency in the social construction of technology, a factor which is claimed had long been absent from most archaeological consideration and from many socio-cultural studies (Dobres & Hoffman 1999: 7; c.f. Fox 1996: 13). While accounts of systems that overlook or discount practice and agency as major factors are seen as untenable, it is stressed that these factors should not be removed from their social communities or systems as a result of any attempt to focus more closely upon them (Dobres & Hoffman 1999: 7). Even when addressing individual artefacts or technical activities, context must be retained. In doing this Dobres and Hoffman attempt to include all the factors which influence technology and evaluate them from a position of equality. While they accept (1999: 3) that this may considerably complicate matters, it is seen as being preferable to limiting our definition of technology in order to make it more accessible.

A further variation has been developed by scholars such as Law (1989). This assumes that the social aspect of technological selection is not raised above other factors and should be considered as equal to them. While the social factor may still be an important one and in some cases even the dominant one, other factors (natural, economic, etc) may be more resistive to the efforts of the system builder (society) to reshape them (Law 1989: 113) and so must be acknowledged as having an impact upon any resulting technology or artefacts. This last approach is far less restrictive with regard to non-social factors which can be identified as influencing technology and its application, and as such must be seen to be less restrictive on the interpreting archaeologist. Roland (1992: 88) sees the systems approach to technology as dealing with 'aggregations of technology' each of which acquires contextual meaning only when viewed as a component of the overall system. Like Law, he cites the sailing ship as being the prime pre-industrial example of this, comprising as it does an almost endless list of interlocking constituent parts (c.f. Schiffer 2001: 215-6).

Discussion

Differing approaches to technology inevitably address differing factors depending on the outlook of the approach in question. One might emphasise the social aspect of technological selection while another may concentrate on more functional or environmental factors. With regard to societal change in general, McGlade and van der Leeuw (1997: 3) have noted that a variety of theoretical approaches have attempted to address the issue. The result has been that each one in turn has obscured the complexity of the problem by superimposing a single theoretical lens through which to view the data (*ibid*). Killick (2004: 575) goes as far as to say there is not "any single theoretical approach that is optimal across the whole 2 ½ million years of the human technological career" there is no reason why there should be a conflict between materialist or idealist approaches to the subject, they can actually compliment one another (*ibid*). Dobres and Hoffman (1999: 12) back this up by emphasising that because technology is a multifaceted cultural practice it should be studied from a variety of perspectives. Meanwhile, Fox (1996: 8-9) warns against the use of a 'universal prescription' as a way of explaining technological change. He further notes (*ibid*) that the selection of a theoretical approach must be a pragmatic one, based upon immediate efficacy and suitability to a particular problem.

The interpreting archaeologist may be unconsciously dictated to in their selection of theoretical approach by the nature of the evidence available for study. An idea of the subsequent contrast in interpretation can be gained from two maritime examples. Seafaring in the Late Bronze Age of the Mediterranean has been widely studied by maritime scholars (e.g. Landstrom 1970; Nelson 1943; Wachsmann 1981) who have relied heavily on iconographic and literary sources. Perhaps as a consequence of this, analysis has been restricted to cataloguing functional changes in vessel and sail shape based on such subjective interpretative nature of the available sources (see ch. 1.2) (e.g. Jones 1995; Vinson 1994). It has remained outside the scope of maritime archaeology to relate this period to contemporary theoretical concerns. In contrast to this is the subject of hull construction in North West Europe during the medieval and early-modern period. A wealth of evidence from many sources; archaeological, iconographic, historical and ethnographic have allowed a far more developed understanding of the technological change occurring in this region at this time (e.g. Adams 2003). Consequently, this particular example of technological change has recently been assessed in theoretical terms consistent with those of the wider discipline of archaeology.

This point of view, questioning the suitability of applying one single theory to the question of change has been applied to some studies of technology (e.g. Law 1989; Roland 1992). These reject any one specific approach (e.g. McGlade & van der Leeuw 1997: 7-9), but instead attempt to construct an alternative based on what they perceive to be the most relevant elements to their particular field and body of evidence (Adams 2003: 37). Even when investigation is conducted under the guidance of a particular theoretical standpoint, for example the Social Constructionist perspective, there is likely to be modification or addition to suit the specific case study (Pinch 1996: 29). There is no reason to confine the formulation of a methodological approach to the maritime technological change of antiquity within the bounds of a single theoretical standpoint. If scholars admit that there is more than one technological solution to any perceived problem, then it seems likely that there must be more than one theoretical approach which can be used to address a single example of technological change. What is perhaps more important is a number of key considerations which must be borne in mind when carrying out any study into technology and which can be said to transcend any boundaries put in place by the adoption of a given theoretical basis.

Necessity is almost certainly not the ‘mother of invention’, merely a need which is perceived and imposed from the point of view of our own society on to another. If technology must be evaluated from this point of view then it must be done so in terms of the specific cultural context and attitudes at a given point in time (Basalla 1988: 212-3). Care must be taken to identify and separate out our own specific cultural needs and biases in order to prevent them from being applied out of context. Having (if possible) acknowledged our own cultural bias, it is then imperative that we at least try to understand “the ideological component of the technology from the perspective of the society that used it” (Geselowitz 1993: 235). Loney (2000: 660) with reference to ceramic production, has noted that this not only entails viewing technology from the perspective of the potter, but from the perspective of a person bound within the rules and ideology of the society to which they belong. Technology may alter and develop on a logical trajectory, but logically only from within the local cultural parameters and in a manner that is internally consistent (Loney 2000: 660-1).

In order to do this, Geselowitz (1993: 235) considers that "it is first necessary to know, as a baseline, the actual physical parameters of the techniques involved." In other words it is essential that theoretical views are backed up by a thorough knowledge of how the things and process concerned actually work (Lemonnier 1993: 7-8; c.f. Cuomo 2007: 43). This is the *microscale* sought by Dobres and Hoffman (1999: 8) at which fundamental social, material and antecedent contexts form, it is within these that technology acquires its physical shape and social value (*ibid*). Understanding of technology at this scale can only be achieved through the material culture of the archaeological record. The level of detail contained within the physical record of a technology can allow us to move beyond the general conclusions often derived from textual or iconographic sources (Whitewright 2007b: 282). Fulfilment of this can allow a fuller appreciation of ecological, social, economic and political factors or circumstances which obviously affect technology on a wider level. It is impossible to fully understand the impact of these factors upon the development of technology, or indeed to assess any subsequent change in these factors as a result of technological development, if the technology itself remains poorly understood. Appreciation of these wider factors can be seen to make up the final consideration regarding technological change and adaptation.

Identification of the physical changes which technology undergoes over time or indeed space is only one aspect of this study. The observation and recording of such change is likely to be relatively straightforward, based upon similarities and differences within the material culture of the technology coupled with the general conclusions derived from other sources. An example of this type of observed technological change can be seen in the development of the bowsprit and its associated fittings on full-rigged sailing ships since the 15th century AD (Moore 1925: 70-73 & figs 62-70). In this particular example (Figure 1-1), technological change is recorded within a single cultural context over a period of time and changes to the form of rigging are clearly visible, although its general function remains the same. Far more complex is the rationalisation of this observed change with the broader factors which various scholars have identified as being relevant to technological change (e.g. McGlade & van der Leeuw 1997: 3-4). As Adams (2003: 45) observes *"to show that change has occurred is one thing. To explain it is quite another."* It is this last point which represents the principle challenge of the current study.

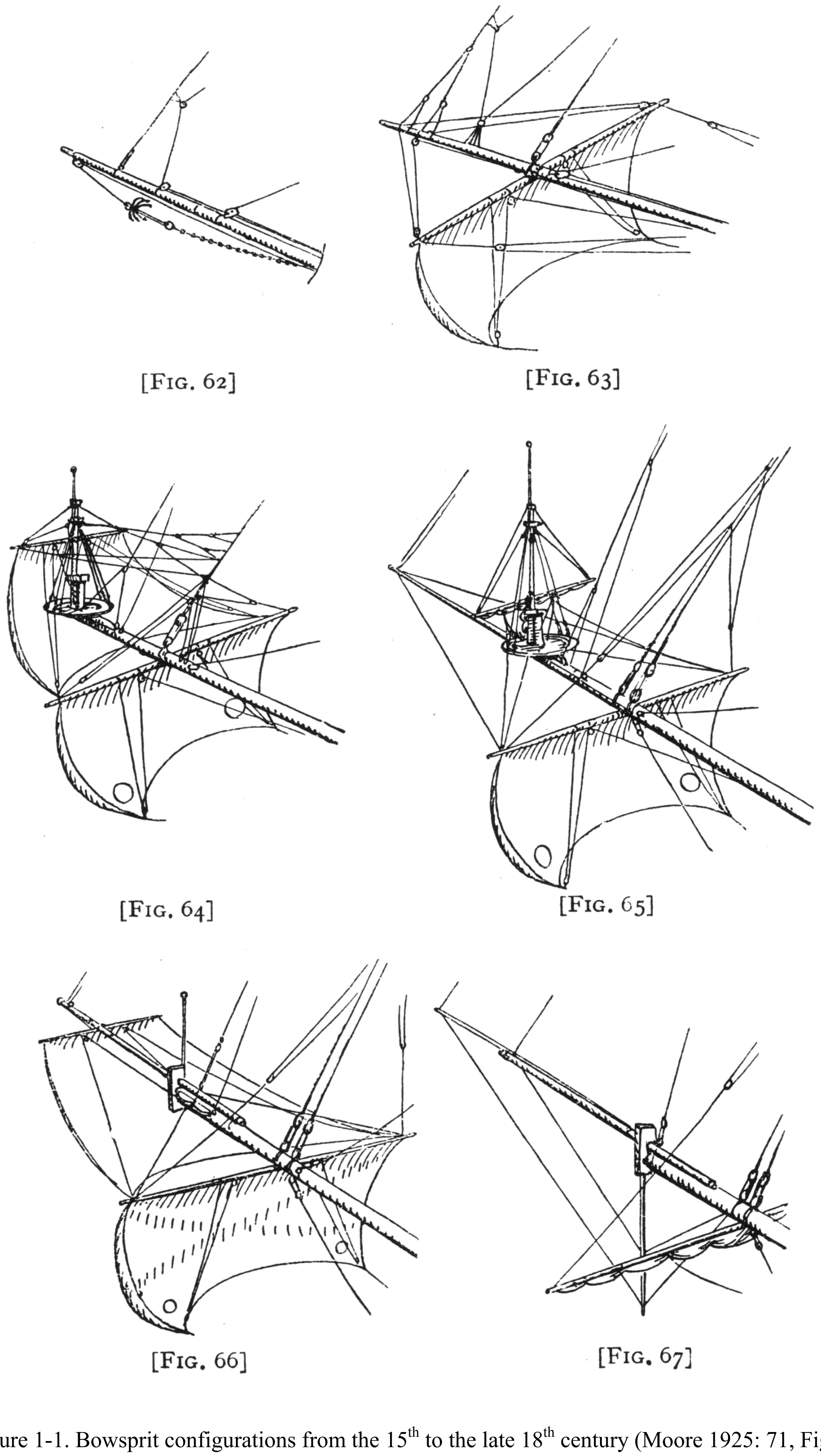

Figure 1-1. Bowsprit configurations from the 15th to the late 18th century (Moore 1925: 71, Fig. 62-7).

1.1.2 Technology in the ancient world

Mediterranean technology during the Roman period has traditionally been considered stagnant and exhibiting little technological change (Cuomo 2007: 2-4; Mattingly 1994: 577; Wilson 2002: 1-2), even being described as 'backward' by some authors (e.g. Garnsey & Saller 1987: 52; Reece 1969: 32). This viewpoint resulted from the analysis of Greek and Roman technology put forward by Finlay (1965) which has been reiterated many times since (Greene 2000: 29, 53) that "the Greek and Romans together added little to the world's store of technical knowledge and equipment" (Finley 1965: 29). A full summary of the development of approaches to ancient technology and the various influencing factors which led to this viewpoint is provided by Greene (2008). Themes traditionally cited to explain the apparent technological stagnation in the ancient world have included; the abundance of cheap slave labour, a bias against manual labour, a conservative, antichange outlook, deficiencies in energy sources and an animistic conception of nature (Greene 2008; Houston 1989: 78). Furthermore the stagnation of the ancient world contrasts unfavourably with the medieval period, which has traditionally been identified as a period of technological innovation and progress by historians (Greene 2000: 53; Wilson 2002: 2). Where technological change has been observed, the preference has been for unique, 'progressive' inventions which lead to an improvement in the efficiency of the technology in question (Horden & Purcell 2000: 288; Mattingly 1994: 577). Such an approach has lead to technological change being expressed in linear terms in which simpler/earlier technologies are rendered obsolete by more complex/later ones (Cuomo 2007: 42, 47 & 49; Greene 1990: 212; Mattingly 1994: 586 & Fig. 4; for an example see White 1984: 67-72 & Appendix 5).

The traditional view of Roman technology has come about, in part, because of a reliance on literary sources as a way of detailing technology and its spread around the Mediterranean. Horden and Purcell (2000: 288) have noted the inadequacy of such sources for the task of recording technological change because such changes are likely to have happened at a social level below the attention of ancient writers. Increasing attention to the archaeological, literary and iconographic material relating to Mediterranean technology is allowing an ongoing reassessment of the nature of technological change in the ancient Mediterranean (Greene 1992: 101). This has been particularly valuable with regard to specific examples of technology, for example water-mills (Wikander 1985; Wilson 2002), catapults (Cuomo 2007: 41-76) olive presses (Mattingly 1994), water-pumps (Stein 2004) and weaving practices (Wild 1987). Technological developments previously attributed to the medieval period, or viewed as under-developed in the Roman world are now being acknowledged as existing across the Roman world (Greene 1994: 27; Holt 1996: 106). These studies have demonstrated that technological change in the ancient Mediterranean was neither retarded by social conventions, linear in development nor stagnant in comparison with later periods (c.f. Greene 2000: 55-56). The gap between the 'backward' Roman period and the 'innovative' medieval period has been closed. Finally it is important to note the observation by Greene (1990: 211) that;

"There was never really any such thing as Roman technology, but rather technology of Roman date. Like other aspects of Roman civilization, it incorporated non-Roman elements, some with a Greek background, and others derived from indigenous 'barbarian' peoples brought under Roman rule. Likewise, 'Roman' solutions to technical problems were not applied evenly over the empire as part of the process of Romanisation."

In the context of the maritime technology of the Roman Mediterranean, much of the technology in use in the Roman period can be found in earlier, pre-Roman periods throughout the Mediterranean. With this in mind it is preferable to refer to maritime technology from the Roman world as being 'Mediterranean' rather the purely 'Roman' in origin.

1.1.3 Approaches to maritime technology

The traditional view of maritime technology

Ancient ships and boats and their associated technology have been the subject of study for at least a century (e.g. Rice Holmes 1909; Torr 1895). For much of this time the evidence available, particularly direct archaeological evidence, has been limited (ch. 1.2). This has lead to a heavy reliance upon iconographic and textual sources when studying ancient ships and boats, although the situation has improved immeasurably in recent years with regard to the published evidence for the rigging and sails of antiquity (e.g. Beltrame and Gaddi 2005; Black 1996; Whitewright 2007; Ximénès & Moerman 1990). Throughout this period theoretical approaches to maritime archaeology have remained firmly based upon the *standard view* of technology identified by Pfaffenberger (1992). This has drawn upon the beliefs embedded within Western European thought, that technology drives history (Loney 2000: 659) and that 'old' technology will inevitably be replaced by 'new and better' technology (Schiffer 2001: 216). In keeping with this maritime archaeologists have relied upon the twin notions of technological determinism and unilinear progression outlined above (c.f. Adams 2003: 44; Dolwick 2008: 16; Gould 2001: 195).

The development/invention/introduction of the lateen/settee sailing rig in antiquity perfectly exemplifies this point with regard to maritime technological change. The majority of the scholars who have written about ancient seafaring, have at one time or another felt the need to put forward a theory on how, why or when the lateen/settee sail came into being (e.g. Adam 1976; Basch 1989; 1991a; 2001; Brindley 1926; Campbell 1995; Casson 1966; Facey 1991; Hornell 1942; Hourani 1951; Le Baron-Bowen 1953b; 1956; Sottas 1939) and how it fits within the overall development of the sail (Facey 1991; Hourani 1951; Le Baron-Bowen 1953b). This very quickly resolved itself into a standard sequence which moves logically from the ancient square-rig to the modern Bermudian sail. Such evolutionary sequences are inevitably founded on a geometric plan-view of the sail of the particular rig-type in question. Presentation and definition of rigs in this way is probably the result of the preponderance of iconographic evidence (which lends itself easily to such analysis), in combination with the standard way in which sail-plans are illustrated at the design stage by modern naval architects and designers.

The classic example of this form of developmental scheme, based solely upon sail-plan, is published by Le Baron-Bowen (1953b: fig. 18) which focuses on the intermediary stages between the square-sail and the lateen (Figure 1-2). The square-sail is placed at the beginning (left-hand) and the lateen at the end (right-hand). A further point worth noting is the removal of context which this kind of analysis based on plan-form alone entails. Little consideration is given to the physical use of the sails, the environment within which they were used or the society which produced and used them. As in this example, scholars have been happy to further decontextualise sails in order to fit examples from different regions, periods and cultures into a uniform and generalised scheme. This contrasts with the change observed by Moore (Figure 1-1) where the examples are all derived from a single cultural context.

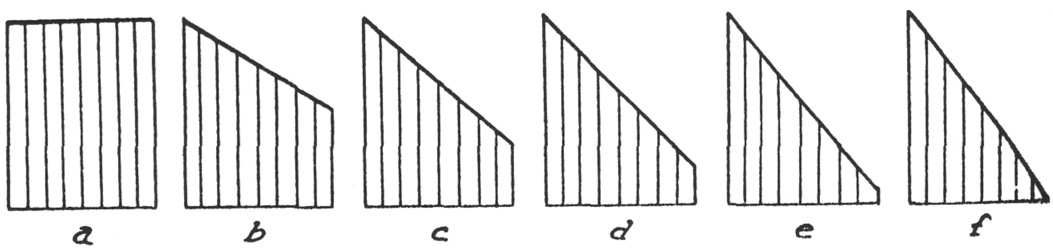

Fig. 18. The evolution of the Arab and the Mediterranean lateen sails. *a,* square sail; *b,* dipping lug of India and Arabia; *c,* present day sails of Oman; *d,* present day sails of the Persian Gulf; *e,* present day sails of Aden and the Red Sea; *f,* triangular sails of the Mediterranean. None of these sails have booms at the foot of the sail. *(Original.)*

Figure 1-2. Sail evolution as seen by Le Baron-Bowen (1953: Fig. 18).

It is unfair to criticise scholars who were working within the constraints of the limited evidence then available to them. However, subsequent scholars have failed to integrate contemporary theoretical thinking and new evidence into studies of maritime technology, arguments and theories first aired half a century ago have been repeated and assimilated into a relatively static body of literature without question (e.g. Basch 2001: 64; Castro *et al* 2008: 348; Kingsley 2004a: 78; Makris 2002: 96; Pryor 1994: 67-9; Ward & Ballard 2004: 12). The implicit assumption behind all of these arguments remains that of technological determinism. The square-sail is viewed as inherently limited, inefficient and primitive in comparison to the lateen, simply because it predates it.

Need-driven technology

In accordance with the *standard view* of technology outlined above, there must be a 'need' which underpins the evolutionary model which has been utilised thus far. The antique nature of the square-sail provides this twice over. Firstly, because it is ancient and therefore at the beginning of the linear progression towards modernity. Secondly, as a development of this first agenda it is perceived as being technologically inferior in terms of its ability to perform to windward. In maritime contexts, the quest for improved windward performance is western society's 'need' which has continually defined the discussion of sails and their development within the modern world (c.f. Marchaj 1996: 23-26). As a consequence of this it has also defined the modern world's study of the ancient world. The importance of windward performance results from it being the dominating deciding factor in most yacht races (Marchaj 1996: Fig. 18). Since its inception and development in the 19th century AD, organised yacht racing and its associated industry has dictated many of the technological development in modern sailing rigs (c.f. Marchaj 1996: 152 & 161). The decline of sail-powered commercial cargo ships has meant that the contributory factors influencing how societies have constructed maritime technology have been radically altered. Factors such as seaworthiness, material durability or economic viability which may arguably have been equally important to seafarers or shipbuilders from all periods have been replaced with a different set of factors geared to the constraints of a yacht race. In this regard, the influences on hull and rig design resulting from a set of racing rules or sailing instructions may represent the ultimate example of society constructing maritime technology.

The over-riding importance given to the windward performance of a rig-type or sail-plan may therefore be a relevant factor when discussing the outcome of a modern sailing regatta. However, its application to the ancient world, usually at the expense of other contributory factors, is very much in keeping with the observation by Pfaffenberger (1992: 496) that the perceived 'needs' of an ancient society are often simply a construct of our own cultural fixation. Basalla and Lemonnier (cited by Loney 2000: 650) sound almost clichéd when they observe that from our perspective as scholars, changes in technology over time appear to be the result of goal-directed problem solving. However, this view is precisely that which maritime archaeologists and maritime historians have generally subscribed to; that every change in the sailing rig of the ancient, medieval and early modern world was a step towards the goal of optimum windward performance manifested in the modern racing yacht. Such a view of ancient maritime technology sits comfortably with the traditional views of ancient technology in general. That it represents a relatively slow stage of the continuum from ancient to modern and simple to complex.

Deconstructing the unilinear progression

In upholding this viewpoint, maritime archaeologists and historians have retained the notion that technological change can only occur along a unilinear route. The allegedly superior upwind performance of the lateen/settee sail, based on its fore & aft configuration, has been assumed to be the motive for this transition (e.g. Basch 2001: 72; Casson 1995: 243; Castro *et al* 2008: 348; Hourani 1951: 101; Kingsley 2004a: 78; Kreutz 1976: 81-2, 98 & 108; Le Baron-Bowen 1949: 95; Makris 2002: 96; Polzer 2008: 242; Pryor 1994: 67-9; White 1984: 143-4). By its very nature this assumption places technological determinism at the centre of any attempt to explain the transition from square sail to fore-and-aft sail in the ancient Mediterranean and by definition also assumes that any transition is both logical and linear in nature. The unsuitability of this approach can be easily demonstrated, using published evidence, by reference to the sailing vessels of the ancient world, particularly those of the Mediterranean in the Roman period (Part Three) (c.f. Whitewright In Press-a).

The lateen sail is not the only fore & aft sail known to us through the evidence. Published iconographic examples of sprit-sails from Ostia and the Aegean (Casson 1960: 241; Le Baron-Bowen 1957), indicates that this type of fore-and-aft sail develops, seemingly independently, within the Mediterranean as early as the 2nd century BC and continues in use until at least the 3rd century AD. This sail-form was previously held to have been first developed and used by the Dutch in the late medieval and early modern period (Brindley 1914; Casson 1956: 3-4; Moore 1925: 147). Reliefs presented by Casson (1956: Pl 1 & 2), clearly demonstrated that the sprit-sail was in use in the Mediterranean by the 2nd century BC (V27, c.f. V28, 29 & 30). If the same assumptions noted above, with regard to the lateen, are applied to the sprit-sail then it should surely feature at some point in the progression from simple to complex. However, the sprit-sail is technically distinct, in its rigging and manner of operation, from contemporary square-sail and lateen/settee rigs, as such it has never been assimilated into recent, deterministic schemes of sail development. The sprit-sail emphasises the fact that sails of the ancient world were by no means uniform in their nature and should not simply be categorized according to criteria such as sail-form. The sprit-sail also serves to highlight the capacity for unique or alternative solutions to problems within maritime contexts. As such it is the first indicator that a unilinear determinist approach to ancient rigging and sail technology will remain untenable as increasing amounts of new evidence are uncovered.

The development of the sprit-sail is just one such variant which occurs in the sail-form of the ancient world. Other, equally visible variations also occur in the maritime technology of the ancient world, for example in the rig-plans of square-sail vessels. The extensive iconographic record of the classical and late-antique period, although fraught with some interpretive problems (ch. 1.2.1), allows an understanding of the general characteristics of Mediterranean square-sail vessels and reveals considerable variation in the rigs of those vessels. As well as single-masted vessels, there are also two and three-masted ships and other vessels rigged with a mainsail and auxiliary sails. The significant point here is the great variation in the rig of the vessels which are depicted and were operating simultaneously. Furthermore, even after a 'technically improved' rig is depicted, the 'outdated' rig which it should logically have replaced continues in use, often for a relatively long period of time. The single-masted, square-sail rig of antiquity is the prime example of this, it continues to be depicted in the iconography, alongside other, apparently more 'technically superior' rigs until at least the early 7th century AD. Indeed, single-masted square-sail rigs are still used in parts of the world today. The technological variation which is visibly apparent in the sailing rigs of the ancient Mediterranean renders the notion of a unilinear progression of technology obsolete in that context (Whitewright In Press-a).

The redundancy of the unilinear progression in explaining sailing rig development bears comparison with the recent reassessments of ancient technological change in the terrestrial contexts of catapults (Cuomo 2007: 41-76) and olive presses (Mattingly 1994). Mattingly highlights the contemporary variation in olive press technology and its non-linear/logical development. Previous studies into olive presses had viewed technological change acting along a logical unilinear pathway with the screw-press being viewed as the ultimate development of this technology (e.g. Mattingly 1994: Fig. 4; White 1984: 67-70). Mattingly (1994: 588-595) has observed that the screw-press is contemporary with other 'simpler' types of press and may have had a specific function pressing more refined types of oil, rather than bulk consignments. In the context of ancient siege weapons, Cuomo (2007: 41-76) has presented evidence which rejects the linear development of catapult technology. She replaces this with a 'scatter' model of technology, whereby different types and stages of catapult technology co-exist and continue to be produced and utilised at the same time and alongside one another (Cuomo 2007: 55).

New approaches to maritime technology

The unsuitability of unilinear evolutionary models to explain technological change is now largely accepted (Loney 2000: 647; McGlade & van der Leeuw 1997: 8; van der Leeuw & Torrence 1989: 1-2). The theoretical approach utilised to explain maritime technological change in the ancient Mediterranean is therefore outdated (c.f. Gould 2001: 195-6 & 211). McGrail, writing from a maritime perspective, has noted that;

"Preoccupation with the idea of tracing the 'evolution' or 'development' of the various types of boats has bedevilled many otherwise objective studies"

- McGrail (1998: 1).

Maritime archaeology is perhaps still suffering the teething problems of being a relatively new area of archaeological study. Muckelroy (1978: 10) noted that after 25 years of systematic excavation the maritime archaeological data-base was only just becoming sufficiently extensive enough to allow the first efforts at defining the discipline to begin. It may be that a further 25 years down the road, the discipline is now ready to begin to develop its own theoretical models and to address the evidence in the light of wider concerns than simple technical observations (Adams 2006; Gibbins & Adams 2001: 286).

Ancient hull construction

It is perhaps no surprise that in the context of the ancient maritime world, the topic of study which is the most well-established has been the first to begin such a reassessment. The study of ancient hull-construction has seen a shift in theoretical emphasis in the last decade, based around the study of the transition from shell-first to frame-first hull construction methods. This important transition was previously viewed from an overtly linear and determinist standpoint by most of its exponents, for example;

"The demise of edge joinery and the introduction of standing frames were fruits of that progression. And they did not evolve suddenly in the medieval period; they were in the making since the first human pushed away from shore"

"Thus the seventh-century Yassi-Ada ship is yet another example of that steady transition from logs and thick planks to modern steel freighters."

- Steffy (1994: 85).

Recently excavated hull remains from the eastern Mediterranean (Barkai & Kahanov 2007; Harpster 2005; Kahanov 1997; Kahanov & Royal 2001; Kingsley & Raveh 1996; Mor & Kahanov 2006; Royal & Kahanov 2005) have shed new light on this transitional phase of construction and have lead to a reassessment of the processes involved. This can be seen as indicative of a wider rejection within maritime archaeology, of the linear, evolutionary framework which has largely underpinned shipwreck archaeology since its inception (Adams 2003; Breen & Lane 2003; Gould 2001; Harpster 2005: 88; Maarleveld 1995: 4; Royal & Kahanov 2005: 312). In this case it is only recently that direct archaeological evidence regarding hull construction has been excavated which has allowed both the refinement of our understanding of the technology and the beginning of a more modern theoretical approach to studying it. A reassessment of the discipline's approach to the technology of rigging and sails need not have waited so long, even the briefest glance at the published evidence available from the last thirty years reveals that the approaches to this subject, outlined above, are deeply flawed (Whitewright In Press-a). A key criticism of this area of maritime archaeology is that until now, even with the evidence necessary to conduct a reappraisal of the technology and processes of change which drive it, no such study has yet been carried out.

A specific maritime approach

It was noted above that maritime archaeology has now developed enough for an increase in the complexity of the theoretical models used to interpret the available excavated evidence to occur. Although not yet achieved with regard to the subject of ancient rigging and sail technology, such approaches have begun to gather momentum with respect to ancient hull construction (above). Recent theoretical development in the field of medieval and early modern ship technology and construction offers a potential model of how technological change can be approached within a maritime context. The work done in this area by Adams (2001; 2003) may well serve as the basis for a broad methodology for the rest of the discipline.

Adams (2003: 38) notes that maritime archaeology is archaeology first and ‘maritime’ only in the sense of the environment, context and methodology. He further observes that the challenge for maritime archaeology is to develop theoretical perspectives which capitalise on the strengths of the classes of information and levels of preservation common in maritime contexts. This is seen as leading towards an enhanced perspective of archaeological material in general, rather than in the sense of developing a separate maritime theory (*ibid*). However, Adams (2003: 39) goes on to point out that the very nature of ships and boats means that they resist confinement within either end of the current theoretical spectrum, being neither materialist nor idealist in their position. Maritime technology is certainly quantifiable and testable, but at the same time it is subject to symbolism, ideology, ritual and tradition (Adams 2003: 39). A ‘total’ maritime theory is probably unnecessary (and very likely unobtainable given the diversity of the subject), an approach to maritime technology which acknowledges and addresses the various factors which are involved in its construction is probably long overdue. There is no reason why such an approach should not sit alongside other theories designed to explain specific areas of archaeology such as ceramic production (e.g. Roux 2003) or urbanisation (e.g. van der Leeuw & McGlade 1997).

Adams (2001: 300) suggests that ships can be viewed as a manifestation of the maritime needs and aspirations of a society. However, these needs and aspirations are produced within a series of constraints which are both physical and metaphysical. This acknowledges the fact that culture and society, rather than nature or the environment, has the ultimate say on the physical form of technology (c.f. van der Leeuw 1993: 241). This approach is very much in keeping with the social constructionist approach set out above. Adams differs in his setting out of the constraints which influence the society in its creation of technology (2001: 300-4). Rather than general constraints (economic, environmental, social), he identifies seven different interrelated constraints which equally impact upon the form, structural characteristics, appearance and use of watercraft. These can be considered variously as economic, social or environmental factors, or indeed combinations of the three. The most important point is that they are all equally interrelated and so one is not privileged above the other (Figure 1-3). These constraints are, in no particular order; ideology, technology, tradition, economics, purpose, environment and materials (*ibid*). Ships, boats and the maritime technology associated with them represent the resolution of the dialectic relationship between these infinitely variable factors (Adams 2001: 303). Change must occur if one or more of these constraints begin to operate in different ways or at a different intensity. Changes can be read in the materiality of watercraft that allows us to relate observed technological change to the causes outlined above (Adams 2003: 29).

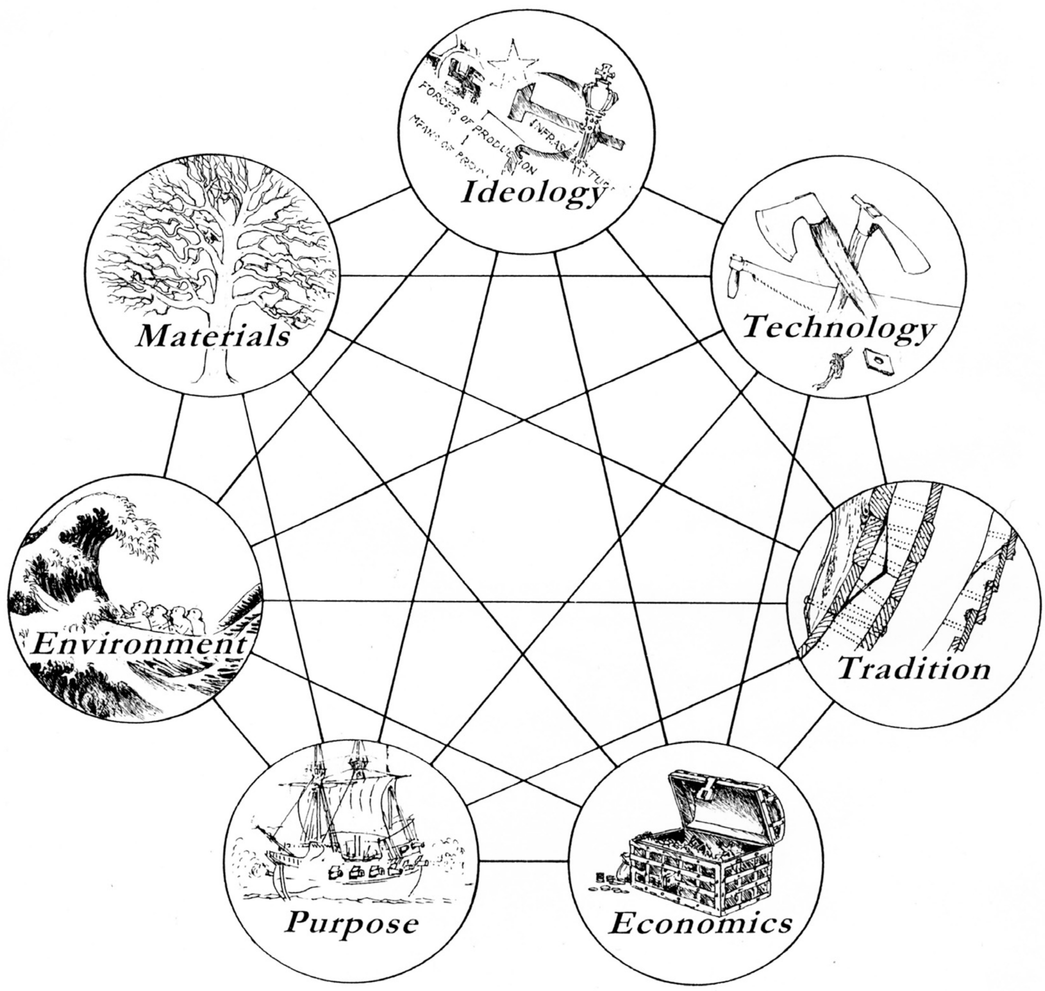

Figure 1-3. Interrelated constraints on the form, structural characteristics, appearance and use of watercraft (Adams 2003: Fig. 2.1).

Adams' rendering of the factors which contribute to changes in technology achieves two things. Firstly, it associates the causal factors of change without privileging one above any of the others and in doing this acknowledges the relationship which exists between all of them. This succeeds in satisfying many of the demands set out by the various theoretical approaches noted above. Secondly and perhaps more importantly, it represents an approach to maritime technological change developed explicitly with a view to an application within maritime contexts, rather than an approach borrowed from another branch of archaeology. As such, it may be better suited to elucidating the unique nature of ancient watercraft than theories intended for purely terrestrial contexts.

1.1.3 Toward a methodology

The current theoretical shortcomings in the approach of maritime archaeology towards maritime technological change in the ancient world have been briefly outlined above (c.f. Whitewright In Press-a). This has highlighted the failure of the existing methodological approach to satisfactorily answer the questions relating to the emergence of the lateen/settee sailing rig which have been posed by the evidence, both now and in the past. This study is concerned with answering the same questions through the construction of a fresh methodological approach geared specifically to this particular example of technological change. Continued deconstruction of existing, outdated theories, will not achieve this aim (c.f. Fox 1996: 8-9).

The first part of this methodology must be to identify, in general terms, the technological change with which this study is concerned. This must include an investigation into the technical detail and characteristics of the principle technological forms in question; the Mediterranean square-sail rig and the lateen/settee rig which replaces it. This sets up the parameters and scope of the study while providing the focus for more detailed investigation. Such an investigation must encompass both physical properties and practical usage within the wider cultural context concerned. Finally both observable technological change and continuity should be considered on an equal footing (c.f. Mokr 1996: 83). Although this study is focused upon changes to Mediterranean maritime technology, principally the introduction of the lateen/settee rig, observable continuity of technology may also provide an indication of the factors influencing how a society constructs its technology. Ideally, these trends will be visible within the archaeological record, reality may dictate recourse to alternative sources of evidence, outlined fully below (ch. 1.2).

Defining the sailing-rig

The pre-eminence of geometric sail-form as a way of characterising and categorizing sailing rigs was noted above. Such an approach privileges this area of the sailing rig as a way of defining or identifying a specific rig-type. The significance of changes to other areas of a given sailing rig, such as the standing/running rigging and associated technical practice is therefore relegated to a less important position.

A further aim of this study is therefore to establish the importance of the technical practice or 'use' of a sailing-rig as a way of defining rig-type. Such an approach is thus far unique in published studies of maritime technological change but offers two clear recommendations. Firstly, it provides a methodological break with previous schema, concerned with sail-form alone. Secondly, addressing the use of the sailing rig focuses attention on the point of interaction between the technology and its users. Previous studies have divorced maritime technology from the people who created and used such technology on an everyday basis by focusing on sail-form alone. While such an approach fits easily with a view of technological change based firmly on the concept of technological determinism it is ill-fitting for an approach which acknowledges the over-riding role of society in constructing technological systems. Giving primary status to the technical practice which underpins the successful use of a sailing-rig re-engages the technology under study with seafarers and their wider society. Implicit in this is the acknowledgment of the role of seafarers in the creation of a sailing rig. Their arrangement of rigging components and the relationship of these components during use creates the outward appearance of the sailing-rig, it is this outward appearance which is subsequently recorded by other people in the form of the iconographic or textual record. It follows that any change to rigging components, their arrangement or technical use will result in an alteration to the outward appearance of the sailing rig.

A brief illustration of the value of defining a sailing rig based upon its use, rather than its sail-form, can be seen in a comparison between the settee sail and the dipping lug-sail. Both of these sails are set fore-and-aft and both are formed from a quadrilateral shape in which the luff of the sail is shorter than the leech. As a consequence of this both sails are set upon a yard which is inclined upwards from the bow of the vessel. Both rigs are usually supported with a system of running stays rather than a recognisable system of standing rigging. The defining feature of the two rigs is in the technical practice used when bringing the sail onto a new tack. The yard and sail of the dipping lug-sail is brought about to the opposite side of the vessel by lowering the yard and dipping (passing) it aft of the mast. In contrast to this, the settee sail is tacked by taking both yard and sail around the front of the mast. This difference in practice has further implications for the use of sailing vessels rigged with either rig. Whereas a dipping-lug rig may be tacked head-to-wind without difficulty, the practice associated with the settee sail dictates that the vessel is invariably worn about before the wind (c.f. 2.2.6). This represents two contrasting approaches to sailing, resulting from a differing technical use of the rig in either case. Failure to define rigs according to their use has led to some commentators mistakenly identifying examples of modern settee sails as dipping-lug rigged vessels (e.g. Le Baron-Bowen 1956: 241-2). Likewise, the linear evolution of sails illustrated in Figure 1-2 includes both lug-sail and settee sails when they should be differentiated by their associated technical practices.

By rejecting sail-form as the principle means of defining a given rig-type, our perception of what constitutes a sailing rig can be further shifted. Rather than simply observing a sailing rig as a geometric form, this study proposes viewing the sailing rig as a technological system (c.f. Law 1989; Marchaj 1996: 23; Roland 1992: 88). As noted above, technological systems can be viewed as aggregations of technology, each of which only acquire contextual meaning when viewed as a component in an overall system (Roland 1992: 88). The sailing rig can be defined as comprising several constituent parts (e.g. mast, yard and sail) which are in turn comprised of other component parts (e.g. halyards, shrouds and stays) and so on. As well as this, the sailing rig itself is one part of the overall system which can be said to constitute a sailing vessel. Only when it is viewed in the context of the hull upon which it is mounted and the crew which operates it does the form of the sailing rig acquire its full meaning. Similarly, only when the smallest rigging component is viewed in the context of the overall system of which it is part can its significance be fully understood. This aggregation of technology is bounded and enclosed by the technical practice utilised by people in order to successfully operate it. If the rigging components which comprise the rig are rearranged, then the rig will have a different outward appearance. How noticeable this difference is depends largely on how extensive the variation and alteration of rigging components is.

Instead of approaching sailing rigs from the perspective of sail-form it is preferable to define a sailing rig with regard to the technical practice used to operate the rig by the crew of the vessel. Associated with this is a conscious attempt to visualise sailing rigs as a system of interlocking component parts, rather than a simple geometric form. The use of such an approach can still allow the diagrammatic expression of a sailing rig to be used (Figure 2-1 & Figure 2-15) without unduly privileging any one area of the sailing rig. Such a combined approach re-establishes the link between the ancient sailor and any technological change which might result in alterations to the outward form of the sailing rig. In conjunction with this, viewing the sailing rig as a technological system provides the potential for much greater insight into the inter-relationship between component parts than simply describing the shape of the sail.

Explaining maritime technological change

Throughout this chapter, emphasis has been placed on the importance of addressing and understanding technology in the most detailed manner available. Interpretation of rigging components at the 'micro-scale' defines and characterises a sailing rig by associated technical practice, rather than by simple classification according to sail-form. It remains important to address technological difference and its implications from the perspective of the seafarer. They after all, represent the user of the technology, often in a dangerous or hostile environment. As such they must have had some impact upon the final nature of the maritime technology upon which their lives, as well as livelihoods depended. Although outwardly functionalist, such analysis is important if the role of the individual mariner is to be acknowledged and maintained in the construction of a maritime technology.

Building upon such investigation into the sailing rigs involved in this study must be a full investigation into any technological continuity or change exhibited by such sailing vessels during the same period. Once the technology itself is fully understood and any observed stasis/change documented, focus can be shifted to explaining why change occurred and to address the issue of how the process of technological change might have operated. In keeping with the theoretical stance outlined above, explanation will involve the rationalisation of the observed technological change with the influences (as identified by Adams) acting upon the society during the construction of technology. This will enable a more developed explanation than has been allowed by the unilinear deterministic models previously applied to this example of maritime technological change.

1.1.4 Conclusion

The Mediterranean witnesses a profound shift in the maritime technology being utilised by sailors and seafarers during late-antiquity. As well as the development of new shipbuilding traditions, the region witnesses the adoption of an alternative form of sailing rig - the lateen/settee rig - which begins to operate alongside and eventually supersedes the established Mediterranean square-sail rig. Maritime archaeology has noticeably matured as an approach to understanding the archaeological record, during the 50 years since its inception (Adams 2006). In some areas of research this has enabled the development of theoretical approaches to understanding past societies in keeping with those adopted in the wider discipline of archaeology. Scholars working in the field of ancient Mediterranean ship construction have recently begun to follow this trend by abandoning a deterministic approach in the face of fresh archaeological evidence. However, despite evidence to the contrary, ancient sailing rigs are still largely conceived as being part of a unilinear progression towards modernity. The aim of this study is to investigate and explain the adoption of the lateen/settee rig in the Mediterranean. The outdated theoretical nature of existing approaches and assumptions to the subject dictates that an alternative theoretical methodology must be developed and adopted. This approach will reflect wider trends currently used to interpret technological change, but will also be geared specifically to understanding the example of maritime technological change described above. Such an approach entails:

- The development of a complete and thorough understanding of the technology concerned and its associated material culture. In this case being the square-sail and lateen/settee rig of the ancient Mediterranean. Integral to this is the development of an understanding of the technical practice required to use/operate a given sailing rig on an everyday basis.
- Defining different sailing rigs on the basis of differences in technical practice as well as differences in the form of the rigging components that comprise them. These areas represent the point of interaction between mariners and maritime technology.
- Viewing a sailing rig as a technological system within the overall system that is the sailing ship. A sailing rig can be further visualised as ‘aggregations of technology’. Individual rigging components can be defined by their contextual relationship to one another within the overall system.
- Establishing a technical appreciation of the differences between ‘old’ and ‘new’ maritime technology. What is actually changing in the material nature and physical use of the technology in question during the period under study and what stays the same. Previously this has been simply based on sail-form alone. However, any assessment should also include changes to the form, function and use of rigging components.
- Rationalising technological change with the broader constraints which have been identified as acting upon society during the creation and adoption of a piece of technology. In the context of maritime technological change in the ancient Mediterranean this will allow the reasons and processes behind the introduction and adoption of the lateen/settee rig to be more fully explained and understood than previous studies have allowed.

Adherence to these main themes will enable a considered conclusion regarding the maritime technological change concerned. This conclusion will be concerned with identification of the motives for change and an identification of the origin of this change. A detailed working knowledge of the technology, its accompanying ideology and its associated material culture, are key to both of these. Understanding the technology in question at the level at which it operates can inform us of the reaction of people in a society, expressed through and by their material culture, to more general over-arching factors and constraints.

1.2 Sources of evidence

The study of maritime technological change introduced above must draw upon the maximum amount of evidence available if it is to be considered comprehensive. As well as direct archaeological evidence it is also important to consider iconographic, textual and ethnographic sources. This chapter outlines the scope of these four sources and highlights some specific examples which are relevant to this study.

1.2.1 Considerations

Archaeological Evidence

Direct archaeological evidence is of prime importance to any study of the ancient world. It can furnish us with information about the physical properties of the material culture of past societies and place this material culture within its wider social context. Muckelroy (1978: 215) emphasises the advantages which archaeological evidence has over other sources as being twofold. Firstly, that the archaeological record is only subject to one act of interpretation within a methodological framework, that of the archaeologist. Other sources, as will be seen below, are subject to interpretation by their contemporary recorder as well by the modern viewer. Secondly, that archaeological remains, although often incomplete, show what actually existed, rather than what was thought to have been there or should have been there. This last point is of especial importance with regard to studies of technology and technological change. The presence of an artefact or class of artefact in the archaeological record can often confirm the type, form and use of a technology which previously could only be speculated upon, based on other sources. In other words, archaeological evidence can inform of the fine detail of any given technology which is often lacking when other sources are relied upon.

It is only relatively recently that studies of the maritime aspects of the ancient world have been able to draw upon systematically excavated archaeological material. Although textual and iconographic sources have been available for some time, systematic underwater excavation has had to wait until the latter half of the last century. Since the first tentative forays using early SCUBA equipment by Cousteau at Grand Congloué in 1952 (Benoit 1961), the corpus of available material has rapidly grown. Ancient shipwrecks discovered up to January 1992 are documented in the seminal work by Parker (1992) and number 1259 entries or find spots (Parker 1992: ii). Discovery, excavation and documentation have not stopped and shipwrecks have continued to be uncovered from all areas of the Mediterranean. Regrettably they are yet to be assimilated into a volume which updates Parker's initial work.

The boundaries of underwater archaeology in the Mediterranean have also shifted since its initial forays in the mid-20th century. The availability of modern technology has allowed the survey of previously inaccessible areas of seafloor, with the discovery of well preserved wrecks still in situ (Ballard*, et al.* 2000; Ballard*, et al.* 2001; Ballard*, et al.* 2002; Ward & Ballard 2004). At the same time other maritime archaeologists have left the water to concentrate on the growing corpus of material being uncovered on the shores of the Mediterranean. Discoveries of well-preserved ships in terrestrial contexts have been made at Comacchio (Berti 1990), Fiumicino (Boetto 2006 & NAVIS I), Marseille (Gassend 1982; Pomey 1999), Naples (Boetto Forthcoming), Olbia (Riccardi 2001; 2002), Pisa (Bruni 2000) and Ravenna (Medas 2003). These remains have been characterised by their high level of preservation and survival of finds, including rigging components, which are rare in more conventional shipwrecks.

While the Mediterranean is a fertile ground for maritime archaeological discoveries, the Indian Ocean is relatively barren. Despite having been a theatre of maritime activity for several millennia, little or no remains of the ships and boats of this region have been discovered thus far (Deloche 1996: 199; Flecker 2000: 213). On-going work suggests that the Indian Ocean still has the potential to preserve the archaeological remains of shipping yet to be discovered (see Gaur*, et al.* 2006; Gaur*, et al.* 2001; Tomalin*, et al.* 2004; Tripati 1999; Tripati*, et al.* 2001). The relative scarcity of maritime archaeological evidence has led Indian Ocean shipping to continue to be studied from the perspective of other sources of evidence; literary, iconographic, ethnographic, historical or a combination of all four. The focus of Indian Ocean maritime archaeology has been largely concerned with studies of trade, especially long-distance or luxury trade. Social or technological aspects relating to this activity have remained largely overlooked (Ray 2002: 64). This imbalance in the focus of study has come about because of the imbalance in the evidence available to study. As will be seen below, it is difficult to infer precise technical or physical detail from textual or iconographic sources. While Indian Ocean shipping continues to remain absent from the archaeological record it will be impossible to understand the fine detail of these vessels with absolute certainty.

It is not through lack of evidence that rigging elements have been largely ignored in the analysis of the shipping of the ancient world. Rather it is simply that the importance of a detailed knowledge of this area has been overlooked in favour of a focus on hull-construction and cargoes. This last point may also be coupled with a tacit assumption that the iconographic and textual sources furnish us with an already adequate view of this area of the ancient ship, because that is all that has been utilised thus far. Throckmorton (1964: 205) noted that study up until that time had been limited to the study of rigs and general characteristics because the evidence was limited to iconographic sources. To accept this situation is to deny the level of detailed information which direct archaeological evidence can provide at both a technical and wider social level. Yet the potential of the archaeological record to produce an informed, detailed picture of rig and sail technology, over and above the more general nature of textual or iconographic sources, is still largely overlooked.

Iconographic Evidence

Although the iconography of ancient shipping is undoubtedly full of valuable information it is not without its problems as a source of evidence. Many of the problems and criticisms of the use of iconography from other periods and regions hold true to the ancient Mediterranean and Indian Ocean and vice-versa. Rarely is iconographic evidence unequivocal in its meaning, consequently, interpretation can often be difficult (Calcagno 2006; Farrell 1979: 227), subjective or indeed both. The nature and therefore interpretation, of any single representation may be influenced by its overall context; the medium, shape, size and location of the overall piece can have an important bearing on the shape, detail and meaning of the representation in question (Deloche 1996: 205; Farrell 1979: 227; Greene 1996: 18; Ulrich 2008a: 36; Villain-Gandosi 1994: 169 & 173). Vessels can suffer from being misproportioned, stylised and schematised, all of which hinders their interpretation (Villain-Gandosi 1994: 174). Images were rarely created as records of technological detail, their intended message could be conveyed without a high degree of accuracy. It is also wrong to view vessels in isolation from their depicted surroundings. Ships may be depicted with other pictorial elements such as humans, animals or other forms of vehicle. The presence of these can alter the interpretation of the representation based upon the overall context of the piece (Ballard*, et al.* 2003: 388). Likewise the geographical location of a depiction does not directly indicate the use in that area of what has been depicted. In some cases carvings may be imported from elsewhere and a representation may appear some distance from its original place of inspiration. The Roman ships depicted at Low Ham villa in Somerset are an example of this. It has been argued that the design was based upon a contemporary Mediterranean manuscript (Smith 1970: 91), while the similarity between it and a mosaic from Tripolitania have raised the possibility that it was laid by an artist from that area (Liversidge 1973: 284). Either way it seems inaccurate to state that the depictions are representative of British shipping simply because they were found in Britain (e.g. Marsden 1974b: 115-6 & fig. 20).

Relevant iconographic depictions occur in the form of stone-carvings, graffiti, frescoes, manuscripts, mosaics, ceramic decoration and coins. The nature of the medium involved can have important implications for any subsequent interpretation. For example, it is a commonly held view that graffitos of ships contain more technical accuracy than formal carvings, paintings or mosaics (Farrell 1979: 230; Tzalas 1990: 323; Villain-Gandosi 1994: 170). This is based on the notion that the latter were executed by artists who may not have been fully familiar with their subject material. In contrast to this graffiti is often considered to be the product of mariners or sailors who are more technically informed about their subject and not constrained by artistic convention (Le Bon 1995: 172). Le Bon also notes that graffiti is not as simple to interpret as is often assumed. Just like other visual imagery it is subject to a range of factors which may affect its accuracy or content (Le Bon 1995: 173). The removal of detail may occur because of the conscious choice of the artist to represent a subject symbolically rather than literally (Le Bon 1995: 175). Because these types of informal conventions are likely to be unique to a single artist at a single point in time they can significantly alter the ease with which some graffiti can be interpreted. Graffiti should in fact be treated with the same caution and considerations as other more formal representations.

One of the best examples of the overall problematic nature of iconography comes from Cyprus in a study of a modern representation of the replica vessel *Kyrenia II* (Tzalas 1990). The depiction of *Kyrenia II* was included in a new fresco at the church of the “Holy Cross” at Pedoula. The artist, who was highly skilled, sought no technical advice on the ship and was not influenced in any way during his work (Tzalas 1990: 323). He also kept secret the fact that he planned to incorporate the ship into the fresco, meaning that no voluntary advice was offered. The artist had seen the ship many times and also had photographs to work from. Based on this it would seem likely that the *Kyrenia II* would have been depicted in an accurate way. This was not the case and there were in fact numerous discrepancies. Tzalas (1990: 324) divides these into three categories;

- Errors made because of a lack of understanding of ships, unintentional errors. E.g. Braces are missing; yard shown as a single piece when the reality was a three-piece yard fished together; proportions of hull and sail are shown incorrectly
- Intentional abstractions and simplifications considered necessary in order to incorporate a ship into the Byzantine style of fresco. E.g. Small levels of detail such as the seam of the sail are omitted.
- Additions and omissions considered indispensable for a ship of the ‘gentiles’ to enter a Christian shrine. E.g. a cross has been added to the masthead and an image of the Virgin Mary incorporated into the sail.

All of the problems and considerations regarding iconographic interpretation are manifested in the representation of *Kyrenia II*. Despite the level of information available, the artist still wilfully altered the vessel in question in order to make it fit into the medium and cultural context in which they were working. Unfamiliarity with the technical detail of the vessel led to errors in this area despite the availability of photographs. In most cases artists are concerned more with the overall impression of their work than with the minutiae of technical detail (Farrell 1979: 244; Humphreys 1978: 79; Villain-Gandosi 1994: 169).

Maritime iconography has been used extensively to date technical developments in the sailing vessels of the ancient world. Accurate dating via iconography is however difficult for two reasons. Firstly, the representational nature of ship depictions means that some technical details may continue to appear after they have fallen out of use. Secondly, a long period of time can elapse between the introduction of a technical detail and its initial appearance in the iconographic record. The appearance of a technical feature in the depiction of a ship or boat simply indicates that the feature has been utilised at some point previously, it may not be contemporary with the creation of the depiction. Dating the introduction of technological details via the iconographic record is therefore difficult and imprecise, it is probably only suited for the most general purposes. It is enough to assume that if a detail is consistently depicted then it is probably still, or has become, commonly used.

Interpretation of iconographic evidence is not a straightforward procedure. It is subjective, both in its creation and its interpretation (Calcagno 2006: 226) and there are many factors at play which the modern viewer cannot ever fully comprehend. There may be a bias in iconographic depictions, with smaller-scale local vessels being ignored in favour of larger, more impressive or more novel ships (Basch 1989: 332; Calcagno 2006: 232). Elements of vessels may be copied from other pieces of work and so may be removed, both in space and time from the vessel which inspired the original piece of work. Humphreys (1978: 79) is of the opinion that artists often included all the attributes of a vessel regardless of the practicalities of their use. She cites a vessel depicted with sails and oars as merely showing that the vessel possessed both forms of propulsion, not that it used both in combination. However, there is no satisfactory way of proving or disproving this particular viewpoint. Various elements of ships are often misrepresented or shown out of proportion. Basch (1987a: 102) has observed that a common error is for vessels to sit too high in the water. In the modern representation of the Kyrenia ship the proportions of the hull, mast and sail are all incorrect, as is the shape of the underwater hull as represented by the modern artist (Tzalas 1990: 324). This modern study yet again reinforcing some of the observations made about iconography created in antiquity.

A more critical analysis of the iconographic resource becomes possible with an increased understanding of the physical working of what is being depicted. For example, a square-sail vessel cannot be sailed without braces, yet this element is often missing from depictions of such sails, not because they were absent in reality, just because the artist chose not to show them. An artist who is unfamiliar with their subject will incorporate what *they* feel to be significant, not what actually is significant (the modern example of *Kyrenia II* bears this out). This further emphasises the importance of understanding the fine detail of the technology in question. The problems associated with iconographic evidence are clear. The extent to which iconography can be used as a reliable source of evidence less so. The reality of the situation is probably that usefulness varies from example to example. Consequently, Basch (1987b: 38) has suggested an approach to iconographic analysis in which each particular interpretation is affected by the circumstances surrounding the depiction; its function, medium and dimensions. Each example of iconography must be individually addressed and interpreted, taking all of these points into account. Then it may be placed into a wider corpus of evidence which has the ability to inform on factors such as technological change.

Literary Evidence

Literary sources available for the study of ancient maritime technology are numerous and encompass both the Mediterranean and Indian Ocean regions. As with the iconographic resource they vary in both their ease of interpretation, their level of ambiguity and consequently in their usefulness to this particular study. One point worth noting is that the number of interpretative filters is increased when dealing with literary sources. Archaeological evidence is subject only to the interpretation of the archaeologist while iconographic evidence is subject to both the interpretation of the artist and the viewer. Literary sources, especially when dealing with technology and technological practice are often subject to three or more interpretative filters. Firstly the ancient author, secondly the modern translator of the text and thirdly the investigating archaeologist. In many cases the original text does not survive, only medieval copies, or copies of copies are still in existence. Furthermore, in many cases several medieval copies of the original ancient text may exist, each of which might have ambiguities, relative to the others. This adds a further level of interpretation, between ancient and modern. Any of the people in this process are capable of misinterpretation, either through accident or design.

Although some maritime scholars (e.g. Casson) are suitably skilled to carry out their own translation, there are very few who are skilled enough in linguistics to be able to do this satisfactorily. As a consequence of this there is an inevitable reliance upon the use of translated works as a source of evidence rather than the original script (if it survives). This adds a further problem when textual sources are being used to address specific aspects of a writer's work; Namely that a reliance is placed upon the correct translation of a body of text, by an individual who may have little or no knowledge of maritime affairs and its nomenclature in the language or culture in question. A further problem at this stage may be the imposition of western words into a text, during translation, which in reality had no parallel within the language and culture used by the original author.

The caveats relating to the application of literary or documentary evidence to the study of ancient maritime technology are broadly similar to those appertaining to the iconographic record. Sources may be subjective in both their creation and interpretation, especially where translation is required. When dealing with texts of a broad theme, care should be taken not to assume that the author records everything which they have seen. Only the unique or the unusual may be recorded, with more familiar sights and practices left un-remarked upon (Houston 1988: 553; Muckelroy 1978: 233). Like iconographic depictions, care must be taken to place textual sources within their wider context and to take into account any standard literary conventions or previous sources which an author may have used (e.g. Houston 1987). In a similar way to the iconographic source material, the complexity of the textual source material demands that each example must be treated differently and on its own terms.

Literary sources do have the capacity to carry a great deal of information regarding ancient technology. An author might record the material used to build a boat or to manufacture pieces of rigging, likewise they may record the length of time a voyage takes between two points and whether or not conditions were favourable. In these scenarios ancient authors can be taken at face value, unless there is an obvious reason for fabrication. The situation becomes more difficult once the content of the texts becomes more complex. If it is accepted that artists misrepresent shipping due to a lack of knowledge on the subject then there is no reason for writers to be any different. The recording of technology and techniques are probably the most vulnerable in this respect.

The use and application of literary sources from the ancient world to inform our study is therefore not as straightforward as is sometimes perceived. However, these problems and considerations do not prohibit the use of textual sources in the study of the ancient world, they merely describe the limitations of such evidence for the interpreting archaeologist. This brief outline further highlights the point made by Muckelroy (1978: 215-6) regarding the relationship between archaeological evidence and other sources, such as texts or iconography. The relative directness of the archaeological evidence dictates that it should form the primary source material for addressing maritime antiquity, with other sources providing complimentary evidence over and above the archaeological record.

Ethnographic Evidence

Ethnographic material and data has become increasingly used by archaeologists as an aid to the interpretation and explanation of the archaeological record (Stiles 1977: 87). ‘Analogous applications of ethnography to archaeology allow us to breach temporal and spatial gaps by using information derived from one context (the present) to help explain data found in another context (the past)' (Johnson 1999: 48). Its use has been increasingly recognised by maritime archaeologists in the study of ancient water transport (Hasslöf 1963: 164; 1966: 128-130; McGrail 1998: xxiii; Muckelroy 1978: 234) as a way of gaining an insight into areas of the discipline where the archaeological record is lacking. McGrail (1997: 75) notes that the use of carefully selected ethnographic analogies can enable archaeologists to propose 'hypothetical reconstructions of incomplete objects or structures or to suggest the function of enigmatic elements.' While this latter aim is possible, it should be remembered that such interpretation may be taken out of the social and cultural contexts from which the artefact originated (Stiles 1977: 94). Hodder (1992: 99) has warned against the application of cross-cultural generalisations which have been removed from their cultural backdrop.

Blue (2003) has addressed the use of ethnography by maritime archaeologists at a more fundamental level, attempting to draw upon maritime ethnographically derived data to answer over-riding maritime archaeologically derived questions. Underpinning this is the notion that by identifying the variables that determine certain features of vessels in an ethnographic context, a more comprehensive set of criteria with which to address the interpretation of archaeological remains can then be provided (Blue 2003: 334). The obvious advantage of this approach to the interpretation of archaeological evidence is that due to the ethnographic origin of the data, the people who build and use the vessel are implicit in the evidence regarding it. Consequently the social and cultural aspect of boat design and use is less likely to be overlooked at the expense of more traditional maritime archaeological pursuits of function or evolution. For the same reasons, because behaviour and actions are observed, not inferred, the opportunities for speculations to multiply are more limited (Trigger 1989: 363). Although any subsequent interpretation is still carried out from the inevitably subjective perspective of the archaeologist, this is probably unavoidable.

Hasslöf (1963: 164) Muckelroy (1978: 234-5) and McGrail (1998: xxiv) all see a further benefit of ethnoarchaeological studies as encouraging the maritime archaeologist to escape the mental bounds of their own culture in order to become familiar with technology beyond their immediate experience. This has echoes of the call by Geselowitz (1993: 235) for archaeologists to attempt to understand the ideological component of a given technology from the point of view of the society which created and used it. Neither of these aims must be taken too literally. To *attempt* to understand another culture's ideology or technology is perfectly acceptable. To claim to have shaken off the preconceptions of your own society and to have replaced them with another, is far less realistic.

Discussion

The limitations and advantages of the available sources of evidence are clear. This includes the iconographic, literary and ethnographic sources which can be used in addition to direct archaeological sources. Muckelroy (1978: 216) has highlighted the complimentary nature of the disciplines involved in the interpretation of each source of evidence. However, archaeological evidence still has some advantages over the other sources which should not be set aside lightly. The principle benefit of the archaeological record is its directness. This is clearly seen in Figure 1-4 which expresses the interpretative filters, imposed by society, which are in place between antiquity and the present day for archaeological, iconographic and literary sources. Archaeological sites do undergo initial depositional and subsequent site-formation processes. However, such processes can often be identified during excavation and should not exert an overly subjective influence on our interpretation of the past. This contrasts with iconographic and literary sources which can suffer from a range of factors including being copied, moved, mis-translated or re-used. All of which can greatly alter their subsequent interpretation.

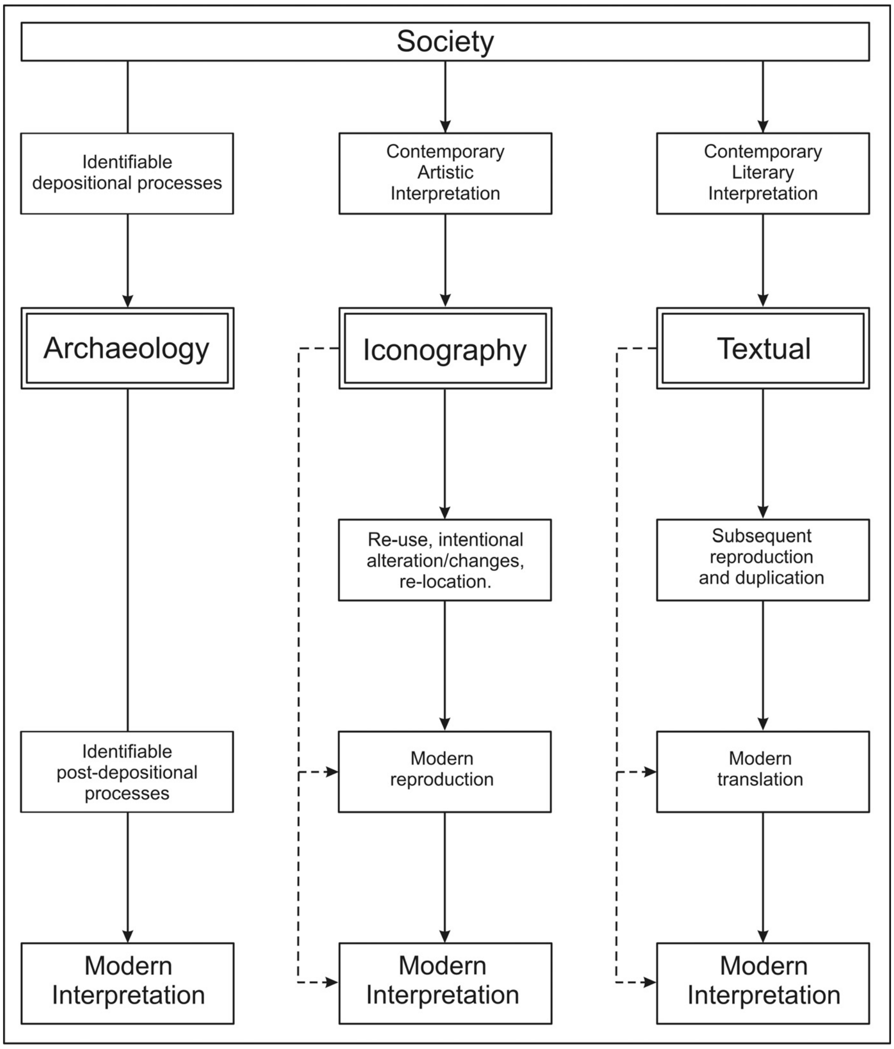

Figure 1-4. Diagram illustrating the cultural transformations which act upon a source of evidence between its creation/deposition and our eventual interpretation as archaeologists.

Because of the sometimes sparse extent of the archaeological record (ancient rigging is a good example of this), archaeological interpretation can be limited by trying to generalize from a limited dataset (Muckelroy 1978: 236). It is at this point that the other sources described above can be complimentary. Careful use of applied analogy can allow ethnographic sources to inform us of practical considerations and limitations of related or similar technology. Meanwhile, the extensive iconographic record of ships and boats in the Mediterranean allows for easy analysis of the general nature of shipping (e.g. number of masts, sail shape) and can often give a reasonable idea of the date during which such general technological forms are in use. However, the problems of iconographic interpretation outlined above means that in many cases fine details cannot be extracted from the image. Literary evidence is similar in its limitations. While it can provide details with regard to construction materials or sailing times it can also suffer from interpretative problems. Evidence drawn from these classes of evidence must be interpreted on its own merits and with its broader context in mind if they are to be used to produce a general impression of the nature of maritime technology in the ancient Mediterranean.

1.2.2 Sources of evidence for ancient maritime technology

Archaeological Evidence

The basic record of maritime archaeological evidence for the Mediterranean world is contained in Parker's (1992) seminal work on Mediterranean shipwrecks. This volume catalogues each vessel and gives a brief summary of their characteristics. Parker's great achievement is in being able to relate the data derived from over 1200 shipwrecks to an understanding of trade and exchange in the ancient world (c.f. Parker 1990). This had only otherwise been attempted on the basis of one or two shipwrecks for any given system or route at certain points in time (e.g. Pulak 1998: 214-220). Analysis of this quantity of wrecks has also been able to further inform on the average size of vessels and change in size over time, based upon their actual remains rather than on inferences derived from literary or iconographic sources. It is on this archaeologically based overview of Mediterranean shipping that our understanding of the detailed nature of such ships can be built. Regrettably, no project has yet got underway which is charged with incorporating the evidence that has subsequently emerged into a study similar to Parker's. Such evidence has taken the form of completely new sites and shipwrecks as well as excavation, re-analysis or publication of new material from existing sites. A complementary source on ancient shipwrecks is the European Commission funded NAVIS I database[1] which although a valuable resource is not nearly as comprehensive or uniform in its coverage as Parker's earlier work.

[1] The database can be freely viewed and accessed at http://www2.rgzm.de/Navis/home/frames.htm

Hull Construction

The principal focus of investigation over and above the general backdrop provided by Parker has been to address detailed questions regarding the construction techniques of ancient ships. The survival of several relatively intact hulls, for example the Kyrenia ship (Site 024) or the Laurons 2 vessel (Site 026), has provided the opportunity to study this aspect of maritime technology in some detail. Within this area of study, much of the focus has been on explaining how ancient ships were constructed and observing and explaining changes to construction techniques. Particular attention has been paid to the transition from shell-first to frame-first construction. The archaeological analysis of hull remains has identified this as happening during the first millennia AD. The perceived linear development of such a transition, had been postulated based largely on the evidence of four wrecks; Kyrenia, Yassi Ada I, Yassi Ada II and Serçe Limani (summarised by Steffy 1994: 83-91). Recent discoveries have forced a reassessment of this theoretical model which had previously directed most approaches to understanding shipwreck archaeology and in particular ship construction during antiquity.

Perhaps the most notable of these discoveries are the ship remains which have been excavated in the Mediterranean at the sites of Bozburum in Turkey (Harpster 2005), Dor (Tantura) in Israel (Barkai & Kahanov 2007; Kahanov 1997; Kahanov & Royal 2001; Kahanov*, et al.* 2004; Kingsley & Raveh 1996; Mor & Kahanov 2006; Royal & Kahanov 2005), St Gervais in southern France (Jézégou 1989), Ravenna in Italy (Medas 2003) and Yassi Ada in Turkey (Bass & van Doorninck 1982). These vessels have been dated to the late-antique and early-medieval period and have shed new light on the transition from shell-first to frame-first construction of ships and boats in the ancient Mediterranean (ch. 3.4). The reassessment which such discoveries have provoked are indicative of a growing rejection of the theoretical framework which has largely underpinned shipwreck archaeology since its inception (e.g. Breen & Lane 2003: 469; Harpster 2005: 88; Maarleveld 1995: 4; Royal & Kahanov 2005: 312). Further variation in the approaches taken to hull construction in antiquity can be seen from the growing corpus of sewn vessels (e.g. Beltrame 2000; Brusic & Domjan 1985; Pomey 1999) which are now starting to be acknowledged as forming another distinct building tradition within the ancient Mediterranean (ch. 3.4).

Rigging Elements

The rigging of ancient vessels has fared less well than the hulls to which they were attached. Although there have been several studies based on iconographic or textual sources (below) little work has been undertaken which has focused specifically on the archaeological remains of rigging. Some aspects of ancient rigging, e.g. sails, are poorly represented in the archaeological record (c.f. Black 1996). However, recourse to Parker's work reveals that 5% of the 945 catalogued wrecks which date between the 9th century BC and the 10th century AD had some form of rigging present when they were surveyed or excavated. Although limited in quantity in the context of individual shipwrecks, taken as a whole, the remains of rigging and fittings (including mast-steps) from the ancient Mediterranean do constitute a useful source of evidence. Significantly, from this corpus of evidence not even a general study, specifically concerned with the manufacture and use of ancient rigging has developed. Maritime scholars have continued to rely on the traditional iconographic and literary sources. These sources, particularly the iconography, have been well-suited to the theoretical approaches, based around geometric sail-plan, which have been used to understand ancient sailing rigs (ch. 1.1.2). Scholarly aims and objectives have been satisfactorily served by continued reference to the iconographic and documentary resource from which the original models of change have been drawn.

Despite this problem with wider interpretation, rigging has begun to gain increased archaeological attention in recent years in wider maritime literature (e.g. Gianfrotta & Pomey 1981: 285-296; Gianfrotta 1997: 108) although its general coverage and discussion in the academic literature remains sparse. Most notably, the work of Carre (1983) has assembled much of the excavated evidence recovered from the French Mediterranean coast. Beltrame and Gaddi (2005) have published the rigging elements recovered from the site of the Grado shipwreck (S020) at Gorizia in Italy. As well as representing a fully published corpus of rigging material it is also significant because the entry in Parker's publication (1992: No. 464) records no mention of any rigging material. This further illustrates the problem of rigging surviving in the archaeological record but being overlooked or ignored by the excavating archaeologists. As well as the Grado wreck several other sites are of particular interest to this study due to the large quantity and/or high quality of rigging material excavated. These include the Grand Ribaud D (S022) (Hesnard, *et al.* 1988), Kyrenia (S024) (Swiny & Katzev 1973), Laurons 2 (S026) (Ximénès & Moerman 1990) and Madrague de Giens (S029) (Carre 1983) shipwrecks and the Roman Red Sea ports of Berenike (S002) (e.g. Wild & Wild 2001) and Myos Hormos (S034) (Whitewright 2007b). Many other shipwreck/terrestrial sites have also witnessed the recovery of small numbers of rigging artefacts of various types and these are included, along with the sites mentioned above, in Appendix One. Although seemingly insignificant within the context of a single site, the contribution to the overall dataset on ancient rigging which each find represents is significant. The impression of the Roman sailing rig set out in chapter 2.1 illustrates that it is possible, using currently published evidence, to construct an understanding of ancient rigging based on archaeological evidence, complimented by other sources.

Iconographic Evidence

In the absence of substantial archaeological remains, iconographic evidence has become one of the mainstays of maritime archaeological study (Calcagno 2006; Farrell 1979: 227; McGrail & Farrell 1979: 162; Tzalas 1990: 323). The ancient Mediterranean is no exception to this and much of the scholarly discussion of the first half of the 20th century was based largely upon the iconographic sources. Even with the advent of systematic underwater archaeology (above), the incomplete nature of the finds has meant that iconography has retained its place as one of the main sources of evidence. This is particularly true with regard to rig and sail technology where the archaeological record is still largely incomplete in many areas (above).

Existing sources

Iconographic evidence relevant to this study comes from the Mediterranean and Indian Ocean regions. It is drawn primarily from the first half of the first millennium AD, although several relevant examples have been selected which are either slightly earlier or later. The current principle work on maritime iconography in the ancient Mediterranean is that carried out by Basch (1987b) who assesses an extensive catalogue of examples. The work of Casson (1995) draws upon and presents less examples than Basch but does relate the iconography to other sources of evidence. While no other author has attempted to publish a large corpus of imagery in print since Casson, advances in information technology are providing alternative sources. The European Commission funded NAVIS II database[2] contains over 1500 depictions of ships of which over 600 are relevant to the time frame of this study. The freely accessible and searchable nature of this database, in conjunction with the work of Basch, means that it is unnecessary to present all of these images within the covers of this volume. An approach similar to that taken by Casson is subscribed to, whereby only examples of specific relevance have been included in the catalogue of vessels attached here (Appendix Three). As such, only those examples which are deemed to be representative of a particular type of vessel, rig technology or instance of technological change/stasis need to be included. This recognises the fact that this study is based on several sources of evidence and is concerned with analysing iconographic data rather than re-compiling it.

As well as the wide-ranging publications of Basch and Casson there are a number of individual papers presenting maritime iconography which merit discussion in the context of this study. These are generally papers which are presenting a significant new piece of relevant iconography to the wider maritime community for the first time or dealing with a corpus of images so far overlooked. Such publication generally post-dates the volumes published by Basch and/or

[2] The database can be freely viewed and accessed at http://www2.rgzm.de/Navis2/Home/Frames.htm

Casson. A series of recently published depictions of lateen/settee rigged vessels dating to the late 5th/early 6th century AD from southern Turkey (V32) (Friedman 2007; Friedman & Zoroglu 2006; Pomey 2006; In Press) and Corinth (V33) (Basch 1991b) and from early 7th century AD Egypt (V34) (Basch 1991a) should be cited because of their importance in firmly establishing the existence of the lateen/settee rig in the Mediterranean prior to the 7th century AD. Western scholars focusing on Mediterranean maritime iconography following the Arab expansion have tended towards vessels depicted in European rather than Islamic contexts. The work of Nicolle (1989) provides a useful counter to this, focusing as it does on shipping in Islamic art from the 6th century AD onwards. In particular, some of the early examples which Nicolle highlights are important because of the relative scarcity of evidence from this cultural context. Likewise the work of Deloche (1996) is important because it addresses the limited iconographic resource of the Indian Ocean. The nature of the evidence from this region is broadly similar to the Mediterranean, although there are no examples of mosaics. One small, but significant group of depictions from Andhra in SE India occur on coins and as graffito on pots (V43-46) which may well give the best indication, at least from an iconographic perspective, of the nature and variation of Indian shipping in this area.

Iconographic evidence will play a large part in this study. To ignore such a potentially rich and widespread source of information is inconceivable. However, the use and application of such evidence must be carefully considered bearing in mind the problems and considerations outlined earlier. Images must be addressed within their wider context, whether it is artistic, cultural or just the comparative iconographic sources. Similarly, it is important not to fall into the trap of attempting to extract too much information from a single iconographic example. For example, accurate observations of hull shape or vessel size would seem to be well beyond the bounds of iconographic interpretation. The corpus of material is large enough, for the Mediterranean at least, to allow the extraction of general observations and trends regarding any change/stasis to the maritime technology. This approach has been paralleled for the archaeological evidence with the work of Parker (1990; 1992) which has identified important general trends within the shipping of the ancient world based upon recorded shipwreck evidence. Where the iconographic evidence is less abundant it is likely that only the most general conclusions will be able to be drawn. In some rare cases, where the evidence is truly unequivocal, observations of technical details and practice may be made, however, this is not to be widely expected.

Literary Evidence

Literary sources have long provided evidence for the use and potential use of ships and boats in the ancient world (e.g. Rice Holmes 1909). Perhaps the most notable recent use of the ancient literary sources is that carried out by Casson (1991; 1995) who has used the Mediterranean sources to inform in many areas of maritime life. It is in many ways comparable to the publications of Parker and Basch which have been cited previously when dealing with archaeological and iconographic evidence respectively. The majority of Casson's work (based upon his own translation) is widely accepted, however, certain pieces have been questioned and serve to underline some of the problems associated with the use of textual sources as a form of evidence. The best example is the giant grain ship *Isis*, which is at the centre of Lucian's *Navigium* (tr. Kilburn 1959) and which has formed the basis of Casson's analysis of the upper size of ancient merchant ships (Casson 1950; 1995: 183-190). The discrepancy between the tonnage suggested by Casson and that suggested by Houston (1987; 1988) and Parker (1990: 340; 1992: 26) on the basis of literary/ethnographic and archaeological evidence respectively is returned to in chapter 1.3.4.

The Indian Ocean

The Indian Ocean region in antiquity is served by literary evidence distinct from that of the Mediterranean world. Although some ancient authors such as Strabo, Pliny and Ptolomy mention the Indian Ocean, it is generally as part of a wider commentary on the world as they see it, from a Mediterranean perspective. Several alternative ancient sources are written entirely from an Indian Ocean perspective and although limited in the technical detail of vessels, have allowed the development of an understanding of the economic systems within which Indian Ocean shipping operated. The most notable of these texts is probably the *Periplus of the Erythraean Sea*, an account by a 1st century AD Greek merchant of the ports and markets of trade of the Red Sea and Indian Ocean and how to reach them.[3] As well as economic information the *Periplus* also gives brief accounts of some of the indigenous vessels of the region and details of some of the ports of trade. The *Periplus* is obviously written from the perspective of a Mediterranean merchant/sailor in the Indian Ocean. A useful balance to this is the Tamil literature from southern India; the *Purananuru* (tr. Hart & Heifetz 2002), an anthology of 400 poems written in Old Tamil between the 1st and 3rd centuries AD. Both of these sources serve to present a view of the maritime networks of the Indian Ocean from an Indian Ocean perspective, rather than simply a view from the Mediterranean.

Islamic Period Sources

The continued use of the lateen/settee rig in the Indian Ocean until the present day means that reference to Islamic literature regarding sailing practices is both helpful and necessary. This serves two purposes. Firstly, addressing the Islamic literature regarding sailing and navigation during the medieval period provides a comparable insight into the use and potential performance of the lateen/settee rig which can be addressed in conjunction with ethnographic

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[3] See Schoff (1912) and Casson (1989a) for translation and discussion of the text.

sources (below). Secondly, it may provide an insight into the more general maritime conditions which may influence sailing practices in this region. The scarcity of archaeological and iconographic sources means that such alternative sources are increasingly important and provide something of a bridge between the inferred practice of antiquity and the ethnographically observed practices of our modern period. It should be noted however, that the problems of interpreting ancient texts outlined above still hold true, even with a language as commonly spoken as Arabic there are words and phrases whose exact meaning remains unclear (e.g. Tibbets 1971: 310).

The principle Islamic work is that of the navigator Ibn Mājid (written in c.1490), of whom Tibbets (1961; 1971) provides the principle translation. Ibn Mājid himself was a *mu'allim* (navigator) sailing principally on the Red Sea and the Arabian Sea whose father and grandfather were also navigators. He had a reputation for his expertise in the field of navigation as well as a reputation derived from his writing on that subject (Tibbets 1971: 7-8). The work of Ibn Mājid builds upon a body of literature stretching back roughly 500 years (Tibbets 1961: 1-7) prior to the arrival of the Portuguese on the Indian Ocean. It is the presence of such a body of literature which has, in part established the assumption that Arab shipping has remained largely unchanged since at least the early medieval period (e.g. Hourani 1951: 100-101). The work of Ibn Mājid and his forerunners are written as navigational treatises rather than commentaries on trade or geography and subsequently include detailed information about navigation, sailing practices and techniques. While no comparable work exists for the Islamic cultures of the Mediterranean, the writing of Ibn Jubayr (tr. Broadhurst 1952) provides a valuable and considered account of sailing practices there. Finally, information from the Cairo Geniza (Goitien 1967) can be utilised to partially illustrate the extent of Mediterranean voyages with lateen/settee rigs in the 11th and 12th centuries AD (ch 2.3 and Appendix Four).

Summary

The literary sources available to this study are probably more evenly distributed than the archaeological or iconographic evidence. Although there is a predominance of material from the Mediterranean, the Indian Ocean remains well-served by the sources which have survived. Because of its often general nature, it is unlikely that a more detailed understanding of technological characteristics can be derived from literary rather than archaeological sources. Only occasionally, as with the work of Ibn Mājid, can the textual sources inform us of the details of technical practice. However, in both the Mediterranean and the Indian Ocean the textual evidence serves to formulate a general impression of the context in which maritime activity occurred. This serves to compliment the information derived from purely archaeological sources.

Ethnographic Evidence

Ethnographic sources

There are a number of sources from which archaeologically relevant, ethnographic information can be derived (Stiles 1977: 91). These include;

- The published literature of conventional ethnographic studies.
- Early accounts of people travelling outside their own culture, e.g. Marco Polo.
- Museum collections of material culture.
- Experimental studies.
- Explicit ethnoarchaeological studies.

The sparse nature of archaeological, iconographic and textual sources for the Indian Ocean relative to the situation in the Mediterranean has been noted above. With regard to ethnographic evidence the situation is reversed. The Indian Ocean and specifically the study of its shipping has been well served by ethnography, most notably in the first half and middle of the last century (e.g. Greenhill 1956; 1957; Hornell 1946a; Prins 1965; Villiers 1940). The subsequent decline of the traditional patterns of trade in the region leaves these studies and its associated body of literature, as the last real opportunity to observe such vessels and the people who sailed them in their original context. To conduct comparative studies today would be virtually impossible. In contrast to the rich ethnographic resource of the Indian Ocean, relevant ethnographic study in the Mediterranean is scarce (e.g. Moore 1925; Throckmorton 1964), fortunately it is well covered by the other three sources dealt with in this chapter.

One assumption underpins the successful application of ethnographical material from the Indian Ocean to solve archaeologically posed questions regarding ancient shipping of the region. Specifically that there is continuity between the maritime material culture of the ancient and modern world, allowing us to apply a continuous analogy between the two. Changes to ship design and construction have occurred since the arrival of European vessels in the region in the fifteenth and sixteenth centuries (Johnstone & Muir 1962). However, designs considered to be older and more traditional have also continued in use (*ibid*). Likewise the trading patterns of indigenous vessels seem to have remained largely unchanged and uninterrupted until the most recent times (Ray 2003: 279; Thapar 1997: 12). Although there are examples where technology and its associated social practice have remained constant from older accounts to those observed recently, a note of caution should still be sounded. As well as continuity, there have also been significant changes to the technological make-up of shipping in the Indian Ocean (c.f. Johnstone & Muir 1962). One obvious example would be the incorporation of staysail jibs into the lateen/settee rig of the Indian Ocean, a feature probably derived from observation of western shipping. Consequently some ethnographic parallels may be invalid due to outside influence and care must be taken to evaluate this before such parallels are applied.

The assumption of continuity is reinforced by literary works such as that by Ibn Mājid (above) which describe practices bearing a strong correlation to those recently in use in the region. A continuation of certain technical practices is perhaps borne out by the appearance of sewn vessels in reference to the Indian Ocean. Sewn vessels are mentioned by the author of the *Periplus*, by Medieval European travellers and by Arab writers[4]. They also appear in iconographic depictions from the region as far back as the 2nd century BC (Deloche 1996: Fig. 1d) and archaeological examples have now been found in Indonesian waters dating to the 9th century AD (Flecker 2000) and on the Egyptian Red Sea coast dating to the Islamic medieval period (Blue 2006). The link is finally confirmed by the presence of sewn vessels on the East African (Gilbert 1998; Hornell 1941; Lydekker 1919; Prins 1965), Arabian (Gilbert 1998; Le Baron-Bowen 1952; Vosmer 1997) and Indian (Hornell 1946b: 236) coasts of the Indian Ocean in recent times. Vessels built with the planks sewn together before being nailed to the frames have also been observed on the west coast of India (Hornell 1946a: 205).

Ethnographic Studies

From the perspective of this study, the most valuable work is the investigations, both formal and informal, which have taken place into the sailing techniques and technology of the Indian Ocean. These works provide a foundation into the technical operation of the Indian Ocean lateen/settee sailing rig. Most notable amongst these is the work of Alan Villiers (1940; 1952; 1961; 1962a; 1962b). As well as being a sailor with a keen eye for detail and an inherent understanding of the sea, Villiers is probably unique amongst the sources cited here for carrying out a study of the sailors he sailed with as well as conducting an examination of their vessels. He records a complete picture of shipboard life, both cultural and technical. Other significant work has been carried out by Moore (1925), Dimmock (1946) and Johnstone and Muir (1964). Although in reality more memoirs than ethnography, the writing of Henri de Monfried (1935) is of great importance to our understanding of the practicalities of navigation in the Red Sea and Gulf of Aden.

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[4] The Periplus refers to sewn vessels in East Africa (PME 15-16) and the Arabian Sea (PME 36). Marco Polo wrote of vessels at Hormuz in the thirteenth century "Their ships are wretched affairs and many of them get lost; for they have no iron fastenings and are only stitched together with twine made from the husk of the Indian nut" (Yule 1903: vol. 1, 111). Ibn-Jubayr for writes of the *jilabahs* built at Aydhab; "They are sewn with cord made from *qinbar*, which is the fibre of the coconut and which the makers thrash into a cord until it takes the form of thread, which then they twist into a cord with which they sew the ships (tr. Broadhurst 1952: 65).

In broader terms the work of Hornell (1942; 1946b) is obviously important although he was less interested in the rig of vessels and more their hull form. Hornell's work in India (1946a) and that of Prins in Lamu (1965) provides a welcome alternative from the bulk of material which concentrates specifically on Arab watercraft. In a similar vein the work of Le Baron-Bowen (1953a; 1953b), although now outdated in its theoretical standpoint focuses on the wider picture of technological development based upon ethnographical investigation. Le Baron-Bowen is one of the few authors, past or present with an appreciation of the situation in both the Mediterranean and the Indian Ocean as well as a willingness to alter his ideas as new evidence was uncovered (e.g. Le Baron-Bowen 1957). He is surpassed only by Hourani (1951) in his acknowledgment of the continuing connectivity between the Mediterranean and Indian Ocean regions. It is telling that although subsequent works have appeared which address Omani (Facey 1991) and Kuwaiti (al-Hijji 2001) seafaring, Hourani's work, which is now over 50 years old, is still widely referenced as the principle work on Arab seafaring and on the wider Indian Ocean in the medieval period.

Experimental Archaeology

Finally, the role of experimental or replica ships should not be overlooked in a survey of ethnographic source material. Ships have now been built which, in the case of *Kyrenia* II and *Kyrenia Liberty* closely replicate ancient remains from the floor of the Mediterranean (Katzev & Katzev 1989). In the instance of the Greek galley *Argo* (Severin 1985) sewn Kuwaiti Boom *Sohar* (Severin 1985) and the trireme replica *Olympias* (Morrison*, et al.* 2000) they are representative of a more conjectural, rather than archaeological reality. Such vessels do not accurately replicate an ancient way of life, something which is probably impossible given our own 21st century mental constraints. But they do impart valuable information regarding their potential performance and construction and the likely characteristics of other similar vessels (Cariolou 1997; Katzev 1990) (c.f. Ch. 2.3). Although the cultural context and ideology of the technology being replicated has been lost and replaced with our own, the study of experimental vessels still represents a source of evidence too illustrative and informative to be willingly ignored. Exercises in experimental archaeology can never prove that something was done in a particular manner, but they can at least allow certain possibilities to be eliminated (Muckelroy 1978: 236).

1.2.3 Summary

The full range of sources available for the study of maritime technology in antiquity is now clear, in terms of their advantages, limitations, scope and principle contributors. All of the sources discussed above have certain limitations and all have certain advantages, either through a specific characteristic or through relative abundance in a particular area in comparison to the other sources at hand. One of the strengths of this study is that it is not totally reliant on one single source of evidence. Paucity in one type of source material can usually be partly mitigated be recourse to an alternative. The consequence of this is that the weakness or limitation of any individual source should not have a detrimental effect upon the overall result of the study.

This study is using the sources of evidence outlined above to examine a specific example of technological change. The presence of existing work which has largely collated the available iconographic, textual and much of the shipwreck evidence, means there is little point creating new collections of these existing datasets. The situation regarding the archaeological remains of rigging is a more complex because of the limited nature of academic work carried out thus far. Only Carre (1983) has attempted to systematically assemble the archaeological remains of ancient rigging components, limited to Southern France. This initial work must be developed and expanded upon to include components excavated since 1983 and from the wider Mediterranean. Interrogation of such components, in conjunction with the complimentary evidence available from other sources should result in the establishment of a detailed technical understanding of the sailing rigs under discussion. This will fill an existing gap in our knowledge of ancient shipping as well as providing the basis for a rationalisation of technological change with wider factors, in accordance with the methodology outlined in the previous chapter.

1.3 Maritime Contextualisation

"The sea is a boundless expanse, whereon great ships look like tiny specks; nought but the heavens above and waters beneath; when calm, the sailor's heart is broken; when tempestuous, his senses reel. Trust it little, fear it much. Man at Sea is an insect on a splinter, now engulfed, now scared to death"

- Amr ibn el 'As of Egypt, 7th century AD

This reaction to the sea of the Arab conqueror of Egypt in the 7th century AD is a compelling one. The sea is at the centre of the Mediterranean world in more ways than simple geographical fact. Victory by Octavian at the battle of Actium brought the coasts of the Mediterranean under the direct control of a single state for the first and only time (Horden & Purcell 2000: 23). Although the western Empire fragmented after AD 395 the eastern Mediterranean remained bounded by a single political entity until the Arab invasions of the 7th century AD. The significance of this should not be lost upon a study of maritime activity in the region at this time. The Mediterranean Sea has always been a link, rather than a barrier to the peoples who dwelt around its shores (c.f. Horden & Purcell 2000: 11). The decrease in maritime warfare and piracy following Roman pre-eminence meant that for much of the Imperial period naval requirements were restricted to transport, communications and local patrolling (Greene 1986:17). The ease with which maritime communication provided the means to conduct trade and redistribute staple good between regions has been central to our current understanding of the Mediterranean past. The modern scholars who have wielded the most influence regarding the Mediterranean; Rostovtzeff, Pirenne, Braudel and Goitein have accepted this in describing and understanding Mediterranean history (Horden & Purcell 2000: 31). To contextualise every facet of the interaction between people and the Mediterranean for the whole of the Roman period is clearly beyond the scope of this study. The following chapter briefly sets out the basic elements influencing maritime activity in the Mediterranean during the period under discussion (ch. 1.3.1 & 1.3.2), and attempts to identify any alteration in these elements which might subsequently impact upon maritime technology. Because of the previously assumed origin of the lateen/settee rig in the Indian Ocean, that region is also afforded similar treatment (ch. 1.3.3). Finally some thought is given to the nature, scale and purpose of the shipping that operated in these two regions during the first half of the first millennium AD (ch. 1.3.4).

1.3.1 The Mediterranean maritime environment

A major constraint upon the watercraft of the ancient world was the environmental conditions in which vessels and crews operated. This is especially true of sailing vessels, which by definition are reliant upon the wind for their main form of propulsion. As well as providing vessels with a means to move, wind also dictates the ease with which vessels can sail in certain directions and under what conditions; calm seas, heavy waves, etc. Weather patterns undoubtedly affect sailing vessels and maritime activity on a short-term, even day to day basis. There are numerous accounts in the ancient literary sources of vessels remaining in port due to 'foul' or 'unfavourable' winds.[5] Likewise vessels are sometimes blown off course by a storm midway through a voyage and end up making landfall at an unintended point. There has been a long held assumption by scholars that the wind patterns of the modern Mediterranean are similar to the wind patterns of the ancient world, this is seemingly confirmed by focused academic work (Agouridis 1997: 2; Murray 1987). Pryor (1992: 12-24) provides a succinct description of the influence of Mediterranean weather patterns in the context of medieval shipping. Such considerations seem likely to have remained unchanged from the ancient period.

Predictable, seasonal weather patterns can be responsible for establishing traditions and patterns relating to sailing times and routes taken by mariners. For example, in the 12th century AD, Ibn Jubayr (tr. Broadhurst 1952: 326) records that westerly sailing from the Levant was primarily conducted during the spring and autumn during periods of easterly winds. Probably the most well known ancient account of the sailing seasons of the Mediterranean is that given by Vegitius in the 5th century AD (*re mil.* 4.39) who notes that the best season for sailing lies between late May to mid September and that the outside limits are between early March and early November (cited by Casson 1995: 270; Tammuz 2005: 146). This has given rise to the theory, termed *mare clausum* (closed sea), that no sailing occurred during the winter, unless exceptional circumstances arose (e.g. Casson 1995: 270-2; Rougé 1981: 15-16). This is reinforced by literary sources, such as an entry to the Theodosian Codex (AD 380) addressed to African shippers which defines 13th April to the 15th October as the sailing season, sailing being suspended otherwise (tr. Casson 1995: 271, n 3). While large institutions may well have minimised their risk by choosing not to ship goods during the winter, some winter sailing certainly took place in the ancient world. Tammuz (2005) has challenged the idea of *mare clausum* by citing a number of ancient texts which point to navigation occurring during most of the winter months, with the probable exception of January. The reality of the situation is likely to have been somewhere between the two. The dangers of winter sailing are obvious and clearly stated by Vegitius; scant daylight, long nights, dense cloud cover, poor visibility, and the violence of the winds would all have served to inhibit navigation during the winter months. Considering that navigation in the ancient Mediterranean was conducted without a magnetic compass, it is easy to see how persistent cloud cover could seriously impede successful open water crossings. However, if a need arose and a break in the weather permitted then there is no reason why sailing could not have occurred during the winter months.

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[5] For example Rutilius Namatianus (early 5th century AD) waited 15 days for fair winds (*De Reditu Suo*, 1.205-6, tr. Duff & Duff 1934: 783).

As well as the seasonal weather patterns which dictated when and where people sailed at given times of the year, mariners also had to deal with local conditions. Such conditions are attributable to a number of causes. As well as being funnelled down valleys and between land, wind can also be a product of the terrain that it has just passed over. The *Sirocco* is one such wind and is the result of the warm dry southerlies that blow off the hot area of North Africa. The direction and strength of wind can also follow a twenty-four hour cycle, commonly called *diurnal* winds. Such winds are the result of temperature differentiation between the land and the sea. This causes an offshore breeze during the evening and night and an onshore breeze, which gathers in strength, during the day. The impact of diurnal winds on coastal navigation is one of undoubted importance. Such winds would have allowed sailors to work coastlines and headlands with greater ease and also to enter and access harbour more easily. Rutilius Namatianus in his voyage from Rome to Gaul in the early 5th century AD (c.f. Pryor 1989) records the use of such a land breeze to get underway.

"The shades of night as yet are undispelled when we entrust ourselves to the sea. Born of the neighbouring hill-crest, a breeze befriends us"

- Rutilius Namatianus, De reditu suo 1:313-14 (tr. Duff & Duff 1934; c.f. Pryor 1989).

The increased strength and reliability of such diurnal winds during the summer months may offer another reason why navigation was preferable at this time of year. This might be especially true along routes which stayed close to the coast, or took place predominantly during daylight hours.

Although brief, this section illustrates some of the complexity of the Mediterranean sailing season. This season was dictated by a number of different weather conditions. No conclusive study of all the evidence available has yet taken place, however, a brief glance at those available suggest the following. That navigation along coasts and across open oceans took place throughout the spring, summer and early autumn when conditions would have been at their most favourable. Winter sailing did occur, although far less frequently than during the summer. Which routes remained open during the winter may simply have been the choice of the individual (merchant, sailor or bureaucrat) in charge of shipping a cargo from A to B, based on their assessment of the risks involved. Certain institutions may have had rules designed to mitigate against the loss of ships during the winter months. However the commercial trade of the Empire was largely outside such matters and so free to take its own risks.

There does not seem to have been any appreciable alteration to the overall environment of the ancient Mediterranean during the period with which this study is concerned. However, this statement does need quantifying slightly. Variation, over time, in the environment/ecology of different regions of the Mediterranean did occur. Such environmental changes as the enlargement of river deltas, soil erosion, river course variation or coastal inundation occur continuously. In general however, the over-riding environmental conditions which had a direct impact on maritime activities remained constant over a long time period. The prevailing winds and currents of the Mediterranean did not alter, water temperature and salinity remained at similar levels and the intensity of stormy or calm periods of weather continued at relatively stable levels. Observable environmental change may have occurred at a local or micro-regional scale. But such change is unlikely to have been significant enough to alter the Mediterranean wide maritime traditions and patterns of connectivity in force in the ancient world.

1.3.2 The Mediterranean during the Principate and Late-Antiquity

Study of the maritime activity of the Roman Empire and its trading partners must consider the mechanics of the Roman economy in order to understand some of the factors influencing and controlling maritime activity. The work of Garnsey & Saller (1987) provides a starting point for this investigation. They see the Roman State as having two fundamental goals (1987:20); the maintenance of law and order, and the collection of taxes, the two being to some extent interdependent. The Roman State did not interfere economically with the Empire; there was no control of goods, factories, or fleets for any mercantile purposes, the revenue of the State coming mainly from taxation (*ibid*: 21). The economy itself has been viewed as underdeveloped, with the great majority of the population living at or near subsistence level, most needs are met locally with goods made by small craftsmen often working at home (Hopkins 1980: 104). Roman conquest of the Mediterranean incorporated new areas into systems of long distance exchange, largely focused on providing for the City of Rome. This state-directed redistribution is often credited with providing most of the economic direction to the early Imperial period (below). Despite this, for the most part exchange within the Empire was rarely integrated above the regional level (Woolf 1992: 289).

While trade and commerce experienced modest growth during the Principate (Duncan-Jones 1990: 46), the attitude to trade amongst the wealthy aristocracy is revealing. There is a growth in the merchant class following Roman expansion beyond Italy during the Republic (Garnsey & Saller 1987: 45). This in itself must be evidence of a growth in commercial activity over and above state-directed trade. The reaction against this growth is reflected in the literary evidence which extols the traditional virtues of landowning and casts in a poor light the practice of commerce.[6] These prejudices against trade as a form of income went as far as to forbid senators to own ships (Duncan-Jones 1990: 46). Consequently their financial strategy was restricted either to buying land or to lending money (Tchernia 1997a: 272). The latter practice included the financing of commercial ventures. Maritime loans were a matter of routine, there were always ship owners needing credit to finance trade and lenders with the capital to invest (Temin 2001: 175). The large profits of luxury trade meant that high rates could be charged when making loans to merchants engaged in that form of trade, often making lending money to merchants more profitable than owning land (Tchernia 1997a: 272). Although not actively engaged in trade, the aristocracy ensured that the capital required to construct ships, warehouses and the like was always available, albeit at a price.

Administered Trade

Distinct from what we might recognise as trade and exchange was the 'administered trade' which was central to the running of the Empire. The huge population of Rome was unsustainable without the regular handouts of grain known as the *annona*, this has been estimated to amount to roughly 800 annual shipments of 340 tons apiece (Rickman 1980: 263). The grain itself came principally from Sardinia, Sicily, Egypt and the North African provinces. It has been noted above that the Roman State did not directly own merchant ships and so private ship owners were employed in return for tax benefits and other civic rights (Houston 1988: 558; Parker 1990: 340). Critically, the State was only interested in those who could carry in bulk for a set period. Claudius offered civil rights to those who would build ships of at least 70 tonnes for the use of at least six years (Houston 1988: 558). Within a century this had risen to one ship of 350 tonnes or several ships of 70 tonnes (*ibid*.). It has been estimated that a ship of c.400 tonnes, would cost 250,000-400,000 sesterces to build (Hopkins 1983: 84-109), only the rich could have built and operated such vessels, the investors must have included the Roman elite.

Operations such as the *Annona* would have been a major cause of the building of large merchant ships, although such ships would have been rare, making up as little as 5% of the overall merchant fleet (Houston 1988: 554) (below). The fact that the amount desired by the State to be transported increases fivefold in a century gives an idea of the scale of the operation. Not all of the surplus grain went to Rome, once Rome had taken its share the rest was distributed to other important cities in the Empire. An unidentified Emperor writes to the city of Ephesus;

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[6] Plutarch (*Cato the Elder* 21.5-6) writes that Cato "used to lend money in what is surely the most disreputable form of speculation, that is the underwriting of ships". The writing of Cicero in the mid-first century BC and Columella in the mid-first century AD have also been cited (Garnsey & Saller 1987: 45).

"first the imperial city should have a bounteous supply of wheat procured and assembled for its market, and then the other cities may also receive provisions in plenty"

- cited in Garnsey and Saller (1987: 99).

As well as transporting grain to Rome and other cities in the Empire, it should also be remembered that the grain had to be carried to its port of departure. In the case of the Egyptian supply the River Nile provided a convenient transport system. Like all navigable rivers the use of the Nile represented the most cost effective way of moving goods from the hinterland to the coast (Greene 1986: 30). A further illustration of this fact is the transport of olive oil from Baetica to Germania, which was previously thought to have been transported up the river Rhone and then overland (Blazquez 1992: 176). An alternative route has now been proposed which utilised an Atlantic sea route up the west coast of Europe, presumably to the Rhine (Blazquez 1992: 176). The *annona* was crucial to the survival of Rome's large population. A consequence of this was that the routes along which the grain was shipped had to be kept open by the Imperial Government regardless of other factors of circumstances. If the grain stopped arriving, Rome would starve. Duncan-Jones (1990: 28) interprets the movement of grain as the primary determinant of the shipping routes which ran from Egypt and North Africa to Rome. Any large city which was the terminus of some form of grain shipments was also likely to be at the terminus of a permanent shipping route and therefore a destination for goods which could not justify their own dedicated routes.

Grain was not the only product which required transport between regions. Olive oil and fish products were exported in large quantities from Spain and North Africa to a variety of other provinces, as well as Rome itself (Blazquez 1992: 173; Gibbins 2001; Temin 2001: 176). Some of these exchanges were state directed, such as the export of olive oil from Baetica to Germania for military provisions (Blazquez 1992: 174), while the remainder must have been the product of private enterprise. The transport of these staples along with others such as wine or timber must have further added to the standard shipping routes which operated between different regions in the Empire. Such routes are likely to have taken vessels directly across open water between destinations, as well as hopping from port to port along the coast. The discovery of shipwrecks dating between 100 BC and AD 400 in deep water at Skerki Bank on a direct line between Carthage and central Italy (Ballard*, et al.* 2000) attests to the former. With such permanent shipping routes in place, ship owners were able to further capitalise by 'piggy backing' other goods onto the bulk trade in staples.[7] The Mediterranean shipwreck evidence

[7] Legal texts make it clear that it was common practice for Roman ships to sail with mixed cargoes (Houston 1988: 558). Also shipwreck evidence points to a primary cargo being supplemented by a smaller secondary one, for

indicates that cargoes of mixed goods were a common occurrence (c.f. Horden & Purcell 2000: 368-372; Parker 1992; Tomber 1993: 145). Woolf (1992: 288) has noted that the distribution of imported tablewares show that regions are linked by shipping routes frequent enough to allow imported wares to compete equally with locally produced ones. It should also be noted that the shipping routes which ran along routes dictated by the *annona* were in essence subsidised by the State and so gave the merchant which exploited them a commercial advantage (McCormick 2001: 87-92; Wickham 1988: 191).

Duncan-Jones (1990: 32) questions whether or not transporting non-staples alone would have been economically viable. The numbers of vessels engaged in the Rome-India trade indicates that if the luxury market was profitable enough the investors and the ships would follow. Strabo for example reports that the fleet engaged in the trade with India numbered 120 ships annually from the port of Myos Hormos alone;

"Up to a hundred and twenty ships make their way under sail from Myos Hormos to India, whereas previously, under the Ptolomies, very few people dared to launch their ships and trade in Indian goods"

- Strabo, Geography. 2.5.12 (tr. H. L. Jones 1917).

The fact that this large fleet was trading almost exclusively in luxury items in both directions (c.f. Casson 1989a; Schoff 1912), suggests that carrying only non-staples was indeed viable, if a sufficiently large market and a sufficient quantity of goods were available.

This brief discussion of the potential maritime networks of the early Roman Empire paints a reasonably complex picture of the level of exchange involved. Although a lot of focus has been given to the state directed *Annona*, both for civilian and military purposes, there were other processes involved. The administered trade may well have provided the spur for much of the inter-regional exchange which occurred during the Empire, but it was carried out by private ship-owners in private vessels. Other privately initiated trade also took place between regions, the sheer variation of the cargoes carried on these ships supports the theory that the Roman economy had at least some elements of a market economy (Parker 1990: 342). The establishment of regular shipping routes between regions, cities and towns meant that it became possible to ship and trans-ship secondary cargoes at the same time. In some cases these may have been of luxury items but equally may have been of courseware or surpluses of staple goods The notion of the inter-regional redistribution of surplus goods as a means of survival has recently been used by Horden and Purcell (2000) to underpin their vision of the ancient

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example the Madrague de Giens (S029) and the Roman shipwreck from Plemmirio in Sicily which carried a cargo of North African olive oil and fish products supplemented by a consignment of iron bars (Gibbins 2001: 313).

Mediterranean. Some scholars (Temin 2001: 181; Woolf 1992: 289) have concluded that trade and exchange was rarely integrated *above* a regional level, however, there is enough evidence to conclude that inter-regional trade was widespread without ever providing a single empire-wide market for all goods.

Late-antiquity

Late-antiquity has been viewed as starting sometime between c. AD 200 (Brown 1971: 7) and AD 395 (Cameron 1993b: 8) and concluding with the Arab invasions of the early 7th century AD (Cameron 1993a: 1. The very beginning of the period is framed by the fifty years of unrest, termed *'the 3rd century crisis'* which saw a rapid turnover of emperors, almost constant warfare and general instability (Cameron 1993a: 1-3). Greene (1986: 43) sees the generally recognised problems of the 3rd century AD as being responsible for a reduction in long distance trade. He is unclear as to whether it is just the levels of trade which fall, or the administered trade of the *annona* with subsequent implications for the regular shipping routes. The extent to which the economy recovers again in the 4th century AD is equally unclear (Cameron 1993a: 113), although it is probably enough to say that the economy did not shrink any further during the 4th century AD. There also seems to have been a reduction in population in the western provinces in the 3rd century AD. In the eastern Mediterranean there is a rise in population from the 4th century AD until the first outbreak of plague in AD 541. (Kingsley 2004b: 79; Laiou 2002: 49-50; Laiou & Morrisson 2007: 25 & 38; McCormick 2001: 32-3; Morrisson & Sodini 2002: 172-6; c.f. Lewit 1991: 47-49 & 85-88). The rise in population witnessed in the eastern Mediterranean during late-antiquity does not seem to have been replicated in the west (Cameron 1993a: 114; McCormick 2001: 32-3).

Administered & commercial trade and exchange

The Mediterranean economy of late-antiquity was still based primarily upon agriculture and the role of towns remained similar to that of the early Imperial period. The later period witnesses a the growth of the church as an economic power and a change in the role of the aristocratic estates (Cameron 1993b: 84-90). The *annona* remained an important part of economic activity, although from AD 330 Egyptian grain was sent to Constantinople (Laiou & Morrisson 2007: 33-4; Kingsley 2004b: 115-116), Rome by now was small enough to be fed with grain from the western provinces alone (Garnsey 1983: 120). Whittaker (1983: 165) notes that the state cargo was still often mixed with a private cargo. Although, the attitude of the state towards this was obviously changing, as evidenced by an edict of AD 395 (*CTh*.13.8.1) which states *"[no] person shall place a private burden upon a public cargo, nor shall he dare to compel, by any necessity, the carriers of grain to accept his burden"* Quite what effect this change in attitude towards the exploitation of the *Annona* had on trade in general is unclear. Shipwreck evidence indicates that late-antique merchant ships were on average slightly smaller (Parker 1990: 341).

Meanwhile, the abandonment of features such as lead sheathing and the introduction of frame-first building practices by the late 5th century AD may have reduced shipbuilding costs (Hocker 1995: 203-4; Kingsley 2004b: 65; Kingsley & Decker 2001: 13; Parker 1990: 342). This may be an economic reaction to the reduction in the opportunity to exploit state subsidised trade, forcing merchants to economise in other areas (c.f. Lopez 1959: 71). The purely commercial trade routes of the eastern Mediterranean during late-antiquity do not seem to have followed the routes of the *annona* (Kingsley 2004b: 70; Ward-Perkins 2001: 174). For example, Egyptian Red Slipware did not travel north along the grain routes in the manner of its North African counterparts and Egypt actually imported Red Slipware from Phocae and Cyprus (Ward-Perkins 2001: 174). It may be the case that the threat implicit in the edict of AD 395 was carried out to a certain extent, with merchants being simply unable to take advantage of the subsidised routes because of Imperial policy.

As well as the state directed trade there seems to have been a significant level of fully commercial trade in the late-antique period (Kingsley & Decker 2001: 12-13; Laiou & Morrisson 2007: 35-6; Mundell-Mango 2001). The Palestinian wine trade serves as an example of this. Wine produced in Palestine during this period seems to achieve a near empire-wide level of distribution, based on the occurrence of LR4 amphorae which was its principle shipping container (Kingsley 2004b: 94). Quantified data points to a regular and continuous wine export trade from Palestine until the mid-7th century AD (Kingsley 2004b: 98). It seems unlikely that this was transported to the western Mediterranean as a single primary cargo, instead it probably formed secondary consignment as part of a more general cargo (Kingsley 2004b: 102). Finewares are also imported into Palestine during this period and are dominant in the local bowl assemblages from the 4th century AD to the mid-7th century AD (Kingsley 2004b: 119). Following the fragmentation of the Western Empire from AD 395, Palestinian wine continues to be imported, a fact which can only point to commercially open systems of trade (Kingsley 2004b: 117; c.f. Ward-Perkins 2001: 173-4). The existence of fully commercial trade is corroborated by the Dramont E shipwreck (Santamaria 1995 (Site 017)) which attests to the continuation of trade between North Africa and Gaul even after the Vandal conquest of Carthage in AD 439.

Closed redistribution

As well as administered and commercial trade there was also a further form of exchange and maritime activity based upon the behaviour of the landed aristocracy and the emergence of the church as an institution. Both were responsible for managing and maintaining large tracts of land, often as far apart as Britain and North Africa (Cameron 1993a: 117). The wealth of these estates was predominantly based upon agriculture, often resulting in the movement of goods and supplies from one estate to another and vice versa, a closed redistribution involving only the estates of one landlord (Cameron 1993b: 89). The church was also engaged in much the same sort of internal redistribution, the church granaries on the Tiber were supplied from its estates in Sicily for example (Whittaker 1983: 168). In some cases the church even owned its own fleets in order to facilitate such redistribution (Mundell-Mango 2001: 96; Whittaker 1983: 168). Exchange between the estates of different members of the aristocracy also took place. Sometimes in the form of extravagant gifts or acts of display (Cameron 1993b: 89), gift exchange could also take the form of staple goods or bulk items such as grain, oil or timber (Whittaker 1983: 171). One result of this exchange between nobles, estates and within the church was that private ports on rivers or the coast were a regular feature of the great estates (Whittaker 1983: 171) and the landlords of these estates often owned their own ships (Cameron 1993b: 121).

It seems likely that this must have given rise to a new network of permanent or semi-permanent shipping routes based on the exchange between estates, as well as the more traditional routes between cities and towns. It further follows that there must have been a possibility for ship owners who may have been hiring vessels to private landowners or the church to exploit them in the same way that the state shipping routes were exploited in the early Empire. This opportunity may have been partially mitigated by the fact that in some cases the aristocracy and the church already owned their own vessels in which to carry on this closed form of exchange.

The economic conditions of late-antiquity were therefore distinct from those of the early empire. Although institutions such as the *Annona* remained in operation their focus shifted from Rome to the new eastern capital at Constantinople. It is likely that there was also a similar shift in state subsidised shipping routes. However, in the late-antique period the Roman State is outwardly far more reluctant to allow merchants and ship owners to exploit these permanent routes for commercial gain. The distribution of Palestinian wine and the import of finewares to the Levant imply that an alternative network of commercial shipping routes also existed. This is witnessed on a wider scale by the ability of late-antique goods to travel in all directions; across State influenced routes as well as along them (Ward-Perkins 2001: 173). Finally the rise of inter-regional estates and the growing wealth of the church led to closed redistribution being carried out between these respective parties but free of State directed interference. Late-antiquity is distinctive from the early Imperial period with different trade networks, both commercial and otherwise, reflecting changes to the political and economic landscape. An increase in fully commercial trade is indicated by the archaeological evidence from the eastern Mediterranean. Changing patterns in shipbuilding practice following the ‘3rd century crisis’ seem to confirm this by suggesting that minimising capital outlay becomes an increasing concern among ship-owners. Throughout this, the relative costs of different types of transport and the physical geography of the Mediterranean basin remained unchanged. The sea and the inland waterways were the common link between all sides of the Mediterranean and they continued to be used as such.

1.3.3 Maritime networks of the Indian Ocean

As described above, much of the luxury trade of the Mediterranean travelled along permanent seasonal shipping routes. Initially developed in order to facilitate the distribution of the *Annona* they came to be exploited for commercial as well as Imperial gain. Many of the luxury goods which flowed along this network had their origin in South Asia and East Africa. In many cases they entered the Empire through the Red Sea ports of Myos Hormos and Berenike, were trans-shipped across the Eastern Desert to the Nile before being shipped downstream to Alexandria. Exports followed the same route in the other direction (Casson 1980: 22). While the trade and exchange networks of the Mediterranean were operated by people who were incorporated into and subject to the Roman Empire, the networks of the Indian Ocean were very different.[8]

Rome's trade with the East operated with little government interference. There is no evidence, literary, archaeological or otherwise to suggest that the Roman State ever tried to influence or control the commerce to any substantial degree (Young 2001: 213). The interest of the State rested on how much money could be extracted via taxes and customs duties. The route across the Eastern Desert from Myos Hormos to Coptos is mentioned by Strabo (16.4.5), who refers to the eight watering stations along the route and notes that the journey would take six or seven days (c.f. Peacock 2006: 7-8).

The Romans were not responsible for setting up the maritime networks in the Indian Ocean (Ray 2003: 277), they merely took advantage of existing systems and intervened within them (Thapar 1997: 11). By the 2nd century BC the coasts of India were already linked by active commercial networks (Rajan 2002) into which western trade introduced itself (De Romanis 1997b: 94). Mediterranean involvement in these networks was primarily concerned with direct long-distance routes. These tended to run directly across the Indian Ocean from the horn of Africa to the Southern coast of India, the region known as *Limyrike*, or along the coast of the Arabian peninsular and across the northern Indian Ocean to *Barygaza* on the Gulf of Cambay (Casson 1980: 31). The main trading ports of the *Limyrike* were *Muziris* and later *Becare* and *Nelkynda* (De Romanis 1997b: 105) and it was at these ports that merchants similar to the author of the 1st century AD *Periplus Maris Erythraei* (Casson 1989a; Schoff 1912) sailed to

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[8] For an excellent overview of Mediterranean involvement in Indian Ocean trade see Tomber 2008.

from the Red Sea. Here they could obtain a vast range of products from all over the subcontinent and beyond, in exchange for gold coinage and wine brought from the Empire.

The Monsoon and Indian Ocean trade

To say that the monsoon seasons of the Indian Ocean are the cause of trade and exchange in that region is to overstate their importance. Even without the monsoons, it seems likely that some form of long-distance trade and exchange would have developed between the cultures of the Indian Ocean. The importance of the monsoons is that they dictate the patterns of the trade; the routes, speeds and the annual nature of the trade. Generally speaking this blows from the south-west during the summer and from the north-east during the winter. Consequently sailing with a favourable wind can be achieved from just about any coast on the Indian Ocean to any other at a certain time of the year. It is no coincidence that the sailing seasons described by the *Periplus* (Casson 1980) are very similar to those used by Arab sailors nearly two millennia later (c.f. Villiers 1940). The two monsoons are not identical in character and their difference is best summed up by Villiers (1952: 6-7). He observed that the NE winter monsoon "is as gracious, as clear, and as balmy as a permanent trade [wind]", in contrast to this the SW summer monsoon is tempestuous, rainy and stormy. The SW monsoon is utilised by shipping, but generally only at the beginning and end of the season when the weather is a calmer and more predictable.

Textual sources from antiquity confirm that the monsoons were used in a similar way in the early part of the first millennium. Generally speaking, vessels sailed northward or eastward with the beginning or end of the southwest monsoon and southward or westward for the duration of the northeast monsoon (Casson 1984). Passage 57 of the *Periplus*[9] describes how the voyage used to be made in 'smaller' vessels which followed the coast. Later a Greek captain named Hippalus, calculated the location of the ports and made the voyage directly across the open water. The passage then describes how by using the southwest monsoon the whole trip from the Gulf of Aden, to any part of the Indian coast can be made with a favourable wind. A passage

[9] The passage in full, as translated by Casson (1984) reads "This whole coastal route just described, from Cane and Arabia Felix, men formerly used to sail over in smaller vessels, following the curves of the bays. The ship captain Hippalus, by plotting the location of the ports of trade and the configuration of the sea, was the first to discover the route over open water…In this locale the winds we call 'etesian' blow seasonally from the direction of the ocean, and so a south-westerly makes its appearance in the Indian Sea, but it is called after the name of him who first discovered the way across. Because of this, right up to the present, some leave directly from Cane and some from the Cape of Spices, and whoever are bound for Limyrike hold out with the wind on the quarter for most of the way, but whoever are bound for Barygaza and whoever for Scythis only for three days and no more, and, (?carried along) the rest of the run on their own proper course, away from the shore on the high seas, over the (?ocean) off the land, they bypass the aforementioned bays.

from the *Purananuru*[10] (66: 1-2) has also been interpreted as referring to the use of the monsoon winds (Hart & Heifetz 2002: 263, n.66); "*One of your ancestors mastered the movement of the wind when his ships sailed on the dark and enormous ocean.*" Open ocean, long distance sailing was probably very similar to that carried out in the Indian Ocean in recent times. Its outstanding feature was the environmental conditions of the monsoon which allowed such voyages to be carried out in predictable, favourable conditions.

The navigational technique described by the *Periplus* in passage 57 is very similar in practice to that used by medieval Arab navigators. The author of the *Periplus* describes how vessels must be steered along a certain route for a set amount of time before being steered on a new course. In this case the vessels bound for NW India sail the same initial course from Ras Hafun as the ships bound for *Limyrike*, but after three days on this course they change heading and make for the NW coast. This technique is similar to the navigational techniques described by Ibn Mājid (Tibbets 1971) in use during the medieval period of sailing a set course for a set distance before altering course for a further set period of time. Both systems rely on the captain of the ship being able to compensate for variations in the speed of the vessel along the preset course.

An existing maritime network

The scope of the existing trade networks already in place in the Indian Ocean and the long distance potential of Indian Ocean vessels can be illustrated by further passages from the *Periplus*. In describing the 'far-side ports' situated along the southern side of the Gulf of Aden the *Periplus 14.3-6* (tr. Schoff 1912) notes that *"ships are also customarily fitted out from the places across this sea, from Ariaca and Barygaza, bringing to these far-side market towns the products of their own places"* referring to the trade carried out by vessels from the west coast of India with the ports of the Horn of Africa. Further on passage 16 (Schoff 1912) describes how the port of *Muza* (in SE Yemen) controls the market town of *Rhapta* (near modern Dar es Salaam) and sends large ships, under the control of Arab captains between the two places. Muza is mentioned again in passage 21.7-9 as sending its own ships to trade with the far-side ports and also with *Barygaza* (c.f. Casson 1989b). The range of networks and contacts operating across the Indian Ocean clearly consists of more than just the routes sailed by Mediterranean sailors and merchants. The *Periplus* also alludes to the possibility that ships from India made the whole voyage as far as Egypt itself, reversing the route taken by Roman vessels. Passage 26.8-12 tells of *Eudaemon Arabia* (Aden) which *"in the early days of the city when the voyage was not yet made from India to Egypt, and when they did not dare to sail from Egypt to the*

[10] The *Purananuru* is an anthology of 400 poems written in Old Tamil between the first and third centuries AD by more than 150 poets of southern India (Hart & Heifetz 2002: xv). The translation used in this study is that carried out and published by Hart and Heifetz (2002).

ports across this ocean, but all came together at this place, it received the cargoes of both countries" The implication of this is that Indian ships now sail to Egypt and Egyptian ships to India, whereas previously neither party made the trip the whole way.

Further evidence for this can be found at the Roman Red Sea ports of Myos Hormos and Berenike. The remains of rigging material; brail rings and fragments of sails, have been excavated at both ports which are made from wood or cotton respectively which originated in India (Whitewright 2007b; Wild & Wild 2001: 211-220). This material might only represent the refitting of Roman vessels in India before their return to the Red Sea. However, the possibility remains that it may be traces of the Indian ships which the *Periplus* records as trading with the far-side ports and directly with Egypt. The concept of Indian ships sailing the full distance to Egypt is further reinforced by epigraphic (Salomon 1991) and archaeological (Tomber 2000) evidence from the Egyptian Eastern Desert. Ostraka bearing inscriptions in Prakrit and Old Tamil point to the presence of southern Indian merchants within Egypt, during the 2nd century AD (Salomon 1991: 731-6). Likewise, Indian finewares and coarse wares have been excavated from the sites of Myos Hormos and Berenike on the Red Sea coast which are absent from contemporary non-port sites in the region (Tomber 2000: 630). This points further to the presence of Indian merchants within Egypt (*ibid*). Their role may well have been to organise the purchase of cargoes for shipping to India on Indian rather than Roman vessels.

Many of the goods which were traded in the ports of the *Limyrike* came from further afield than the hinterland of *Muziris* or the nearby ports. A separate network, operating over around Cape Comorin, the southern tip of India, was responsible for bringing goods from as far afield as the Ganges and wider south-east Asia to the ports of the *Limyrike* (Rajan 2002: 86-9 & fig. 1). Without considering the ports of the SE coast, the full range of goods available in the *Limyrike* remain without origin. Referring to the ports of the SE coast the *Periplus* states

"Of the ports of trade and harbours in these parts at which vessels sailing from both Limyrike and the north call, the most important, lying in a row, are the ports of trade of Kamara, Poduke, and Sopatma. They are the home ports for local boats that sail along the coast as far as Limyrike and others, called sangara, that are very big dugout canoes held together by a yoke, as well as for the very big kolandiophonta that sail across to Chryse and the Ganges region."

- Periplus Maris Erythraei 60 (tr. Casson 1989a).

De Romanis (1997b: 116) sees these three ports of the SE coast as serving two roles. They represent the ports of call for the long distance trade of the Ganges, and they also provide a home port for vessels engaged in regional and local trade. Hence the different types of vessels mentioned in the *Periplus*. The focus of all of these networks is undoubtedly the ports of the

Limyrike. The SW coast was the point of arrival for eastbound Mediterranean ships and vessels from the NW coast of India. It was also the destination for vessels from the SE coast which were in turn trans-shipping goods from the Ganges and even further east (De Romanis 1997b: 118). *Limyrike* is the hub through which all the other networks connect.

As well as the more visible trade in staples and luxury items taking place over medium to long distances the ports of the *Limyrike* can also give us an idea of the type of local networks which would have surrounded a typical port. *Muziris* was also the focus for a local coastal network trading in fish and rice as well as the international trade (De Romanis 1997b: 95). This variety of different types of trading network is best summed up by a passage from the *Purananuru* referring to *Muziris*.

"In Muziris with its drums, where the ocean roars, where the paddy traded for fish and stacked high on the boats makes boats and houses look the same and the sacks of pepper raised up beside them make the houses look the same as the tumultuous shore and the golden wares brought by the ships are carried to land in the servicing boats, Kuttuvan its king to whom toddy is no more valuable than water, who wears a shining garland, gives out gifts of goods from the mountains along with goods from the sea to those who have come to him."

- Purananuru 343: 1-11 (tr. Hart & Heifetz 2002).

The 'golden wares brought by the ships' have been interpreted as referring to the Roman traders who often traded gold directly for goods (De Romanis 1997b: 95). The large numbers of 1st century AD Roman coins found in southern India are almost certainly the result of this international trade and exchange (Tchernia 1997a: 264-5). While this is one interpretation it is not the only one for the origin of these gold-bringing ships. Another section of the *Purananuru* 126: 14-17 (tr. Hart & Heifetz 2002) observes "*like boats in the western Ocean that belong to some lord other than Ceran who commands his raging armies and runs his ships that carry gold so that no other vessels dare to travel those waters"* This suggests that there were at least some Indian vessels which were also capable of carrying golden wares to *Muziris* other than the ships of Mediterranean origin. The passage also refers to the regional trade coming into *Muziris* 'the goods from the mountains along with those from the sea'. These represent the goods coming in from the wider hinterland of the port and the goods being trans-shipped around Cape Comorin. The local trade in staples is referred to; 'the paddy traded for fish and stacked high on the boats'. This section clearly refers to small local craft engaged in fishing and then selling the catch in return for other staples such as rice. Operations within the port itself are also mentioned, specifically the 'servicing boats' which are unloading the gold from the trading ships. This tells us that *Muziris* had limited quay facilities (if any) and that vessels had to anchor offshore and be unloaded by lighters. It does not seem unreasonable to expect this range of activity to be found in every large port in the Indian Ocean.

The final part of the Indian Ocean network which is often forgotten or overlooked by many of the authors cited here is the route along the East African coast. Ships departed from the same Red Sea ports as those engaged in the trade with the East (Casson 1989a: 22) and the *Periplus* describes a route down the coast to a point that has been interpreted as in the vicinity of Dar es Salaam (Casson 1989a: 283). Vessels using this route did not sail directly to their destination in the manner of the ships bound for India. In part because the route was their destination, they were inclined to conduct trade right along the route, 'tramping' from port to port as referred to by the *Periplus* 14: 9-11 (tr. Schoff 1912) *"Some make the voyage especially to these market-towns, and others exchange their cargoes while sailing along the coast."* It seems likely that the points of trade along the African coast would have assumed the same role in terms of local trade and exchange that ports such as Muziris fulfilled on the Indian coast. Although direct archaeological evidence for this trade is slim, some Roman artefacts are now being excavated in East Africa. Finds of Roman beads have come from the Rufiji delta (Chami 1999). While the site of Kivinja, a possible port site in antiquity, has yielded imported ceramics and glassware alongside local pottery and ironworking consistent with the exchange mentioned by the *Periplus* (Chami & Msemwa 1997: 674-5; c.f. Juma 1996).

The evidence presented above serves to outline the connectivity of the various cultures ranged around the shores of the Indian Ocean. These cultures are connected by the sea, often across large distances, by trade and exchange networks utilised by people from the Mediterranean as well as the Indian Ocean region. The available evidence suggests that Mediterranean people and their ships reached most of the areas in the western Indian Ocean and along the East African coast. In the context of the present study, this interaction represents the principle vehicle for maritime technology to travel between the Mediterranean and Indian Ocean and vice-versa. The longevity of interaction between the two regions further suggests that such technological transfer, if it occurred, would not have been inhibited by periods of isolation in either direction.

1.3.4 The nature, scale and purpose of shipping

This brief outline of the Mediterranean economy and the maritime networks of the Indian Ocean can give some indication about the nature and scale of the vessels involved. For people dwelling on the coast, an important source of food or income would probably have been derived from fishing activity as well as agriculture. An example of the type of vessel engaged in this activity is Fiumicino 5, excavated during the building of Fiumicino airport at Rome (Boetto 2006; Parker 1992: No. 402). The remains of this boat, c. 5m in length, seem to be the surviving fragments of a small fishing vessel from the mid 2nd century AD. Such vessels are representative of the small scale maritime activity that took place around all the coasts of the ancient world as people sought a living. These types of boats are likely to have reflected local or regional traditions in boatbuilding; unless the size or function of local ships required change there would have been no reason to do so (Greene 1986: 23). This view can be reinforced from an ethnographic perspective by the study of Le Baron-Bowen (1952: 186), who noted that fishing communities often continue to utilize their indigenous vessels even when technological change has rendered them outdated [from our westernized perspective].

Operating at a slightly larger size, but at a similarly local level, would have been the vessels that functioned as harbour craft, lighters, tug boats, barges etc. These types of vessel must have occurred throughout the Mediterranean and Indian Ocean where harbours lacked adequate quay facilities. They are mentioned by the *Purananuru* (343: 6-7); *"the golden wares brought by the ships are carried to land in the servicing boats."* This kind of arrangement has been postulated for the Roman port of Myos Hormos where excavation has revealed that ocean-going ships were probably moored in a roadstead (in that case a lagoon) before cargo was lightered ashore in smaller vessels (Peacock & Blue 2006: 175). Ports dealing with large vessels, or situated upriver are likely to have required tugboats and barges to facilitate the movement of larger ships in confined spaces and the transhipment of goods to their final destination. Reference to these activities can be found in the *Periplus* (44. 1-9 tr. Schoff 1912) in the context of the Indian Ocean. Casson (1965) gives a brief but detailed account of all the different craft in use on the Tiber in the Imperial service. These mirror the type of vessels found in the Indian Ocean and outlined above. Lighters, to unload the merchantmen at anchor in the open road-steads off Ostia (Casson 1965: 32). Barges, to carry unloaded goods upstream to Rome (Casson 1965: 32-3). Tug-boats to facilitate the movement of smaller vessels and barges to Rome and for manoeuvring the cargo ships alongside wharves and quays where applicable (Casson 1965: 33). Archaeological remains of the vessels involved in these activities survive in the form of Fiumicino 1, 2 & 3, flat bottomed river barges used in the transport of goods up the River Tiber to Rome (Boetto: NAVIS I Database; Parker 1992: No 402-413). Casson also notes the changes in the requirements of harbour craft following the building of the Claudian port in the first century AD (Casson 1965: 33-5). Lighters were no longer the crucial vessel which they had been, ample dock space meant that the biggest concern was getting vessels alongside quickly. Accordingly the numbers of tugboats increase at the expense of the harbour lighters. Following the building of extensive harbour facilities at the mouth of the Tiber, Puteoli was reduced to a provincial port as all seagoing vessels were able to tie up alongside at the ports of Rome (Casson 1965: 34). Presumably the smaller vessels engaged in running goods from Puteoli to Ostia also became redundant.

Finally there must have been an enormous number of merchant ships engaged in transporting the huge quantity of archaeologically attested trade goods around the Mediterranean and Indian Ocean. Such vessels varied from small cargo ships, such as the Kyrenia (S024) or Grado (S020) shipwrecks of under 15m to very large vessels such as the Madrague de Giens (S029) of over 40m in length. Greater size did not necessarily equal longer trade routes and vessels at the smaller end of the spectrum may easily have travelled around or across all areas of the Mediterranean. Parker's analysis of Roman shipwrecks has found that vessels of about 70 tons (16-20m) were the most common size of vessel (Parker 1990: 340), based on the archaeological evidence.[11] This contrasts with Casson's view, derived from literary sources that the average size of such vessels was c. 130 tonnes, and that vessels from 350 to 500 tonnes were far from rare (Casson 1995: 172). Houston (1988) has addressed comparative evidence from other pre-industrial merchant fleets to illustrate that relatively very large ships may have comprised only 5% of the overall number of ships (1988: 554), this figure is confirmed by Prins' (1965: 172-4) ethnographic work on the shipping of Lamu. The most common vessel in the Mediterranean or Indian Ocean during antiquity was probably small/medium sized merchant ships engaged in trade along and between coasts. This trade may have been direct trade between ports with specific cargoes, or the practice of cabotage from port to port. The trade and exchange conducted by these vessels has been conceived by Horden and Purcell (2000: 142) as a 'Brownian Motion' of shipping which links the potential all-around communication of the Mediterranean to the major shipping routes identified through the evidence (c.f. Arnaud 2005; Tchernia 1997b; Nieto 1997).

1.3.5 Conclusion

The wider context in which the watercraft of the Mediterranean operated is one of contrast over time. Firstly, the early Imperial period, seemingly greatly influenced by the organized redistribution of staple goods along a series of primary shipping routes between major ports. Secondly, the late-antique period witnesses an increase in the commercialisation of trade and exchange and potentially a greater dispersal of routes due to a number of factors including the development of a new Imperial capital and the development of the Church as a Mediterranean wide institution. Late-antiquity also witnesses the break-down of Imperial authority in the western Mediterranean and the fragmentation of the western Empire into a number of constituent parts. Exchange between these areas was almost certainly conducted on fully commercial, rather than directed terms. Throughout this period of time, the shipping of the

[11] For an earlier discussion on the likely tonnage of ancient shipping, derived from archaeological and literary sources, see the work of Pomey and Tchernia (1978).

Mediterranean seems to have operated within a fairly fixed set of environmental factors and within a recognised sailing season. The patterns of the Indian Ocean are harder to discern, however the lack of domination of the region by a single polity perhaps indicates that long-distance exchange operated on mostly commercial terms, with only limited internal redistribution.

The picture that can be built up about ancient shipping in the Mediterranean and Indian Ocean is complex, not least because of the huge range of potential vessels involved. Archaeologically visible Mediterranean shipping during the Roman period comprised a wide variety of vessel sizes and types, ranging from large merchant-ships through medium sized trading vessels to much smaller vessels used only for local work. There were also a range of vessels which fulfilled more specific roles within the maritime world; dredgers, river barges, lighters, etc. The majority of these commercial vessels were concerned with the transport of various types of cargo between the towns, cities, estates and regions of the Mediterranean. The range of vessel type and size in the ancient Mediterranean indicates the level of specialisation of purpose that shipping had achieved by the Roman period. Ships might be built for a specific area of trade, such as the Dolia transport vessels of the early first millennium AD, or been designed to operate within a specific environmental area; the deep, sea-going hull of the Madrague de Giens contrasts with the relatively flat-bottomed Comacchio vessel which was probably intended for river and estuarine work. The shipping of the Indian Ocean remains largely invisible in the current archaeological record. However, reference to literary evidence suggests that it was of a similar scale and fulfilled a similar purpose to contemporary Mediterranean watercraft.

The available evidence suggests that, despite some change in the nature of exchange itself, there was no shift in the purpose or role of the shipping which provided the principal means of bulk transport during the Roman Imperial and late-antique periods (c.f. Horden & Purcell 2000: 133-172). Trade still occurred between different regions of the Mediterranean which would have required open-sea voyages. Similarly, goods must still have needed to be transferred along coasts and up rivers by smaller vessels, or simply offloaded in harbours by lighters and barges. Likewise, the maritime networks of the Indian Ocean continued throughout the ancient and medieval period and there is no reason to envisage a dramatic change in the purpose of Indian Ocean watercraft during the period covered by this study. Furthermore, interaction between the Indian Ocean and the Mediterranean was maintained and would have allowed the transfer of maritime technology between the two regions if desired. The contrasting conditions of Mediterranean trade between the early Imperial and late-antique periods may have impacted upon the maritime technology used to conduct this trade. The possibility of this will be returned to below (part four).

Part Two: Mediterranean sailing rigs in antiquity

"at this time we are not even satisfied with sails that are larger than ships, but although single trees are scarcely enough for the size of the yardarms that carry the sails, nevertheless other sails are added above the yards and others besides are spread at the bows and others at the sterns"

- Pliny, Natural History, 19.1 (tr. H. Rackham. 1950).

The background to this study, set out in Part One, has highlighted two things about the sailing rigs of the ancient Mediterranean. Firstly from a theoretical standpoint; that a detailed understanding of every aspect of a sailing rig is required if changes to such maritime technology are to be fully observed and explained. Secondly from a practical perspective; that no holistic, detailed study of the sailing rigs of the Mediterranean during the Roman and late-antique periods, based on archaeological sources as well as other more commonly used ones, has been completed. The absence of such a piece of work makes understanding maritime technological change in the theoretical terms set out in 1.2 virtually impossible. As a consequence, before the question of technological change can be addressed it is first necessary to develop a detailed appreciation of the technology itself, including how it was used by ancient mariners. Part Two of this study sets out to illustrate both the physical detail and the technical practice required to operate the Mediterranean square-sail (2.1) and lateen/settee (2.2) sailing rigs. An assessment of the relative potential performance of these sailing rigs is conducted in chapter 2.3.

Chapter 1.1.1 and 1.1.3 highlighted the intention of this study to abandon geometric sail-plan as the principal means of defining a sailing rig and observing technological change/stasis over time. Instead, it was proposed to view a sailing rig as an aggregation of technology, comprised of inter-related rigging components. The arrangement of these rigging components was considered responsible for dictating the outward appearance of the sailing rig. The result of this approach is presented for the square-sail (Figure 2-1) and lateen/settee (Figure 2-15) rigs at the head of their respective chapters. The relevant rigging components and the technical practice required to operate them is then described.

2.1 The Mediterranean square-sail rig

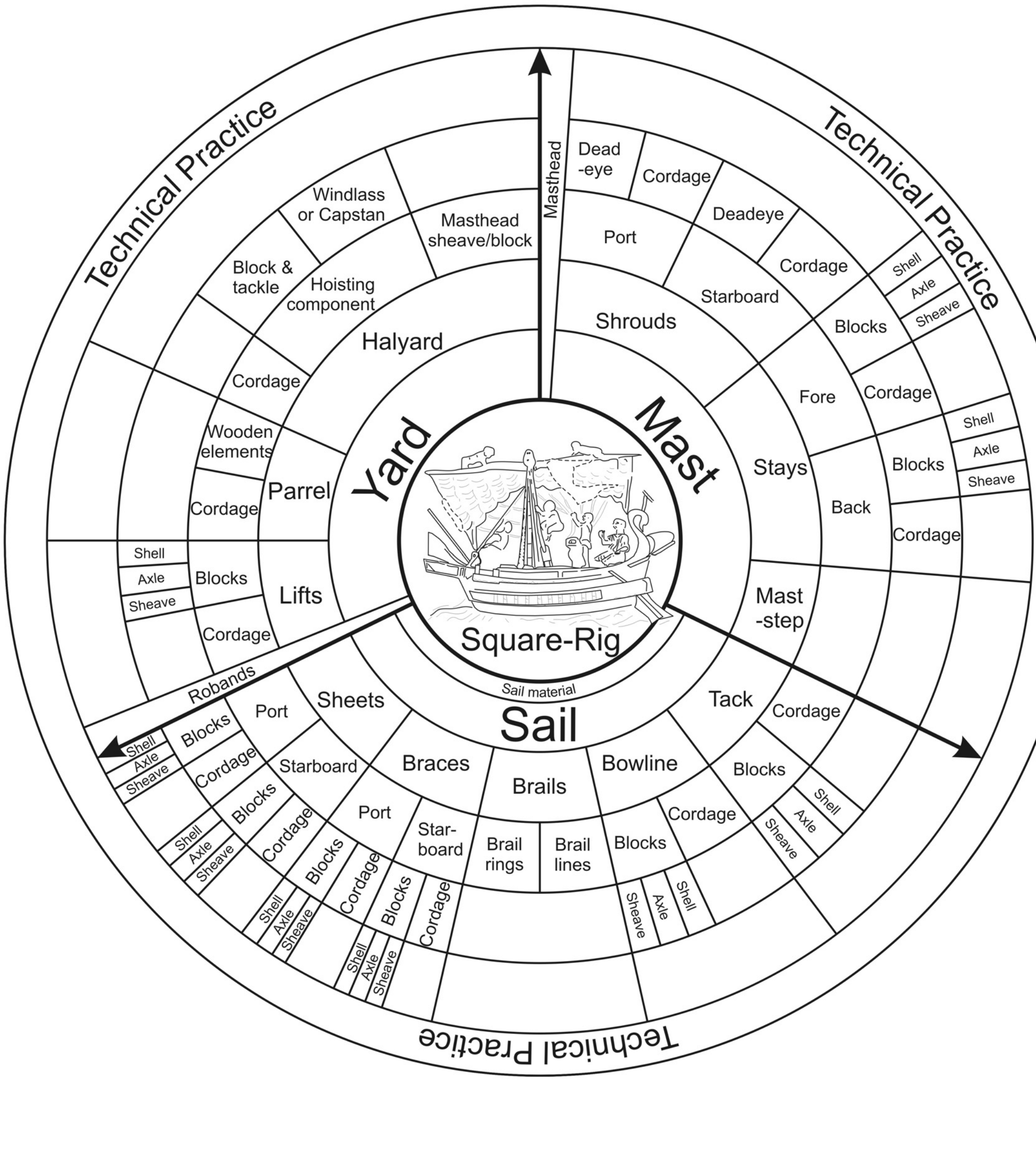

Figure 2-1. The aggregation of rigging components which comprise the Mediterranean square-sail rig. The rig is conceived as consisting of three main areas; Mast, Sail and Yard. These in turn comprise a series of component parts (e.g. brails), which are themselves created from a combination of rigging components (e.g. brail-rings and brail-lines). An individual system is incomplete unless every component, even the smallest, is present. All of these components and the systems which they are part of are enclosed by the technical practice used to operate the rig as an entire system. This technical practice provides the link between the rigging components and the user, in this case an ancient sailor. Alteration to the arrangement and use of rigging components will result in an alteration to the outward appearance of the sailing vessel at the centre of the aggregation.

2.1.1 Mast steps and balancing the sailing rig

Steffy (1994: 275) defines a mast-step as “A mortise cut into the top of a keelson or large floor timber, or a mortised wooden block or assembly of blocks mounted on the floor timbers or keelson, into which the tenoned heel of a mast was seated.” Archaeological remains of mast-steps from Mediterranean square-sail vessels indicate that mast-steps were formed by cutting a mortise into the keelson of the vessel. The keelson itself tended to be a massive timber, notched to rest on floors and frames along the centreline of the vessel. From about the 1st century AD a pair of central longitudinal timbers, termed *carlingots*, were placed on either side of the keelson to help brace it and remove the need for notching (Rival 1991: 252, n.12). The mast-step, in conjunction with any crossbeams with which the mast is secured to higher up in the vessel, transmits the forces generated by the sailing rig to the hull. It is an integral part of the sailing rig, not only physically, but also ideologically in the mind of the sailor.[12] Understanding this element of the rig can further inform us with regards to the working of the rest of a vessels rigging and can give strong clues as to a vessel’s potential performance. With regard to this the first issue to address is the position of the mast-step (and therefore the mast) in the hull of the vessel.

Single-masted vessels

The position of the mast on ancient single-masted square-sail vessels has traditionally been seen as being set amidships (Casson 1995: 239). This conclusion has generally been deduced based on the iconographic depictions of Mediterranean square-sail vessels rather than on the basis of archaeological remains. (e.g. V02, 03, 04, 05, 06, 11, 14, 18, 24, 25 & 26). The iconographic examples included here encompass a wide area of the Mediterranean until at least the early 7th century AD. Roman shipping is generally depicted with vertical masts indicating that the mast-step is directly underneath it, i.e. amidships. Such a location for the stepping of a single mast fits the traditionally accepted theory regarding the balance between the rig and hull of a sailing vessel. The aerodynamic and hydrodynamic forces which act upon a vessel when it is sailing act about two points, the Centre of Effort (CE) of the sail and the Centre of Lateral Resistance (CLR) of the hull.[13] These points have traditionally been derived by finding the geometric

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[12] The presence of coins, placed in the mast step before the stepping and rigging of the mast, to bring good luck to the vessel indicates the importance placed on this interface between hull and rig. Such offerings have been excavated from ships of different periods and cultural origins (e.g. Adams & Black 2004: 247; Carlson 2007; Marsden 1994: 99; Parker 1992: No 302, pp 140-1).

[13] A vessel pivots about the CLR of its hull, the direction and extent of this movement is determined by the CE and the amount of force acting upon it. For example if the CE is aft of the CLR the stern of the vessel will be pushed away from the wind and the bow into the wind, this is termed *weather-helm*. If the CE is ahead of the CLR then the bow will be pushed away from the wind, known as *lee-helm*. Neither of these traits is particularly desirable in a

centre of sail and hull respectively (Marchaj 1996: 268-9) and both have been widely assumed to be stationary points (*ibid*). This view has been upheld by maritime archaeologists who have accepted that the CLR is in the geometric centre of a vessel's hull and that to balance this, the mast should be stepped above it - amidships (Roberts 1995: fig. 2, 3 & 4). It follows that vessels with a mast stepped in a different location must have been rigged with a different type of sail (Weski 1999: 373), with a different CE location in order to have a balanced rig. Consequently it makes sense that ancient single-masted vessels should step their square sail over the centre of the vessel (as shown by the iconography noted above), this should in theory place the CE vertically above the CLR and produce a well balanced sailing vessel (Figure 2-2). The reality of the situation is however, far more complicated.

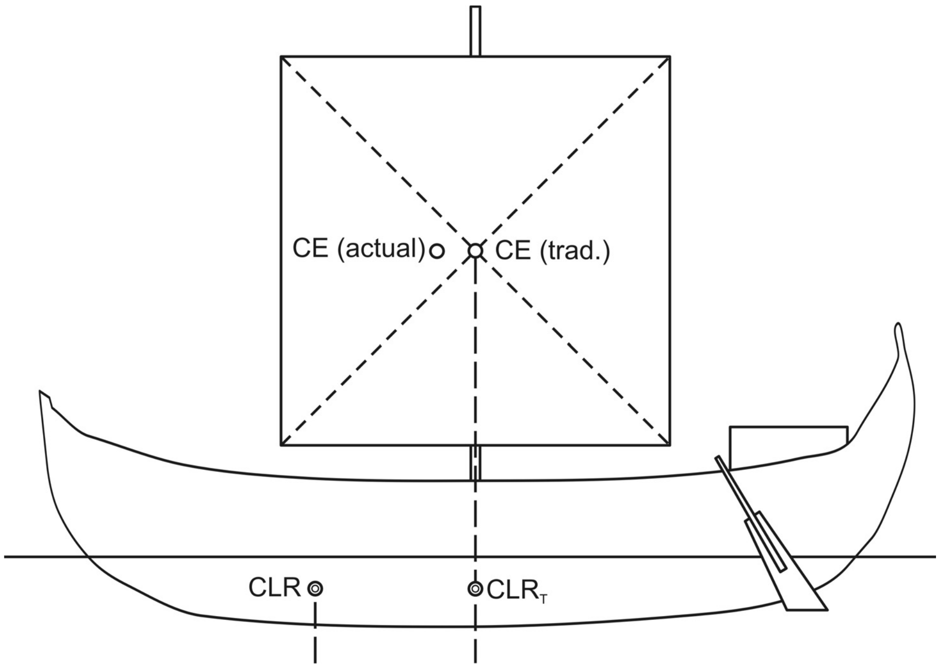

Figure 2-2. Traditionally derived *Centre of Lateral Resistance* (CLR_T), located amidships, along with the *Centre of Effort* (CE) for a generic Mediterranean single-masted, square-sail vessel. The real position for CLR is actually around 30% of the waterline length of the vessel from the bow, while the actual position of CE is around 40% of sail chord.

Firstly, neither the CE nor the CLR are stationary points (Marchaj 1996: 269). Both points shift location depending on the attitude of the vessel, its speed and heading relative to the wind (*ibid*). The actual CE is generally in front of the geometrically derived CE, around 40% of sail chord (*ibid*) and the actual CLR is forward of the geometrical CLR when the vessel is close-hauled and moves aft as the vessel bears away (*ibid*). Work by Garret (1987: 163) and Palmer (1987; 2008a) has further confirmed the view put forward by Marchaj and has shown that the

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vessel so ideally CE should be in-line with CLR. Yacht designers have traditionally set the CLR of a vessel about 10% ahead of CE to compensate for some of the difficulties in accurately locating both points.

CLR in most types of sailing vessel is actually well forwards of amidships, often at around 30% of waterline length. For ease of explanation, the traditionally derived *centre of lateral resistance*, located amidships, is termed CLR_T from here on. This has also been noted in less empirical terms by Tilley (1994) in relation to vessels from the ancient Mediterranean. However, if the CE is located amidships (based upon the iconography of the mast positions of Roman sailing vessels) then the position of the CLR in the forward half of the hull, would lead to an obvious imbalance (visible as weather-helm) between hull and rig, especially when sailing close-hauled. Such instability has further obvious implications for a vessel's overall capability and seaworthiness.

Archaeological remains of mast-steps

The direct archaeological evidence, derived from excavated shipwrecks clarifies the issue. Several shipwrecks have been excavated throughout the classical world with a mast-step intact and still in-situ (Table 2-1).

Shipwreck site	Mast-steps	% bow	Reference
Calanque de L'Ane (S008)	One	< 50%	(Ximénès & Moerman 1998)
Cavaliére (S011)	One	c. 33%	(Charlin, et al. 1978: fig. 33)
Diano Marina (S014)	One	c. 33%	(Pallarés 1996)
Dor 2001/1 (S016)	One	c. 50%	(Mor & Kahanov 2006)
Dramont E (S017)	One	c. 33%	(Santamaria 1995: Fig. 132b)
Grado (S020)	One	c. 50%	(Beltrame & Gaddi 2007)
Kyrenia (S024)	One	c. 33%	(Steffy 1985: 73,74)
Laurons 2 (S026)	One	c. 33%	(Gassend, et al. 1984: Fig. 19 & 21)
Madrague de Giens (S029)	One	c. 33%	(Rival 1991: Fig. 68 & 70)
Port Vendres 1 (S039)	One	< 50%	(Chevalier & Santamaria 1973: 13)
Rabiou (S041)	One	< 50%	(Joncheray & Joncheray 2005; 2006)
Ravenna (S042)	One	< 50%	(Medas 2003)
Saint Gervais 3 (S044)	Two		(Liou & Gassend 1990)

Table 2-1. Mediterranean shipwrecks excavated with surviving mast-steps or where the probable location of the mast-step is accurately inferred. '%bow' refers to the distance of the mast-step from the bow of the vessel in single-masted examples.

The traditionally held view, based on the iconography, is of masts being stepped amidships (e.g. Casson 1995: 239). However, the majority of the archaeological remains have masts stepped in the forward half of the hull, normally c.33% (⅓) of the length of the vessel from the bow. The remaining vessels have their masts stepped amidships and one example (Saint Gervais 3) has two mast-steps. According to the traditional view of mast-step position, vessels with their masts stepped in the most forward position should be unbalanced, however, the reality is that such vessels exhibit a good balance between the CE and CLR (Figure 2-3) because of the actual corresponding forward position of the CLR. Vessels with their mast stepped amidships, would appear to have poor balance because of the discrepancy between CE and CLR (Figure 2-2).

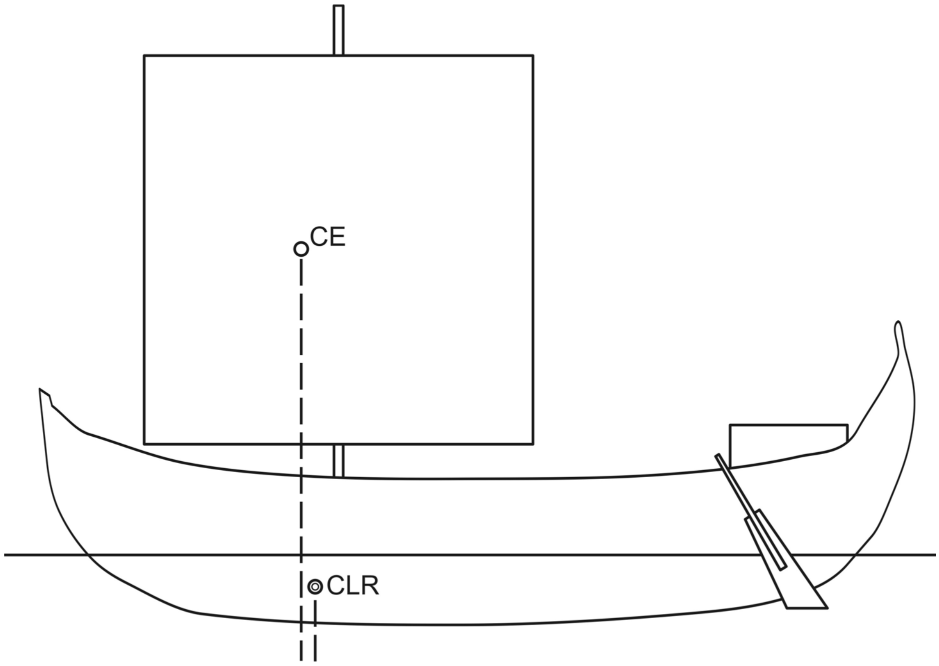

Figure 2-3. Balance of CE and CLR for a single-masted square-sail vessel with the mast stepped 33% from the bow.

Given the need to balance the CE and CLR of a vessel it seems likely that shipwrecks with a mast-step set well forward of amidships were rigged with a single mast. The discrepancy between the archaeological remains and iconographic evidence highlights the potential problems of the latter source of evidence, as outlined in 1.3 and the value of direct archaeological evidence.

Artemons, mizzen masts and two-masted ships

Roman shipwrecks have also been excavated which have been built with a mast-step set amidships (Table 2-1). Obviously, if these vessels had been single-masted they would have been subject to an imbalance between CE and CLR as shown above (Figure 2-2). Such vessels must have had a way of balancing these forces to ensure they retained reasonable sailing qualities. Such a technological solution to the problem of rig balance is probably represented in the iconographic record through the depiction of vessels rigged with a small foresail, or *artemon* (e.g. V02, 06, 09-11, 15-16 & 22). Archaeological remains of *artemon-steps* are rare. Beltrame notes (1996: 135-6) that foremast steps differ from those of mainmasts ‘because of their very advanced position in the bows and because of the absence of elements supporting the mast’.

Possible examples have been excavated from shipwrecks at *Torre Sgarrata* (Geannette 1983: 27), *Punta Ala*, *Torre Santa Sabina* and *Procchio* (Beltrame 1996).

The *artemon* itself was a small mast, carrying a square sail, rigged at a pronounced angle over the bow of the vessel, it is mentioned by Pliny (*NH 19.1*) as a 'sail spread at the bows'. The drive produced by such a sail would have been at best limited, this was noted during the sailing trials of the trireme replica *Olympias* when the mainsail blocked the wind from the *artemon* (Morrison*, et al.* 2000: 258) its main purpose was to provide a counterbalance to a single mainsail, set amidships. By moving the combined CE of the two sails further forward than it would otherwise have been with a single mainsail, the rig once again becomes balanced (Figure 2-4). This use of the *artemon* to balance the mainsail is noted by Casson (1995: 240 n. 70) in a passage from Augustine where the helmsman has lost his course; "What good is his superb skill at managing the *artemon*, manipulating it, keeping the bow to the waves and [preventing] the ship from broaching to". This passage superbly illustrates the role which the *artemon* plays in the balance of a vessels rig, without it the ship would have undue weather-helm resulting from the CLR being ahead of the CE and would have a tendency to drive up into the wind and to broach. The passage from Pliny (*NH 19.1*) at the head of this chapter also alludes to the use of a sail at the stern of the vessel, usually termed a *mizzen*, this is likely to have also fulfilled the role of a steering sail, as it has done on sailing vessels ever since. In the same way that the *artemon* moves the CE of a rig forwards the *mizzen* causes it to move aft. It is particularly useful when tacking ship in order to force the head of the vessel up to and through the wind by concentrating the CE at the stern with the *mizzen*.

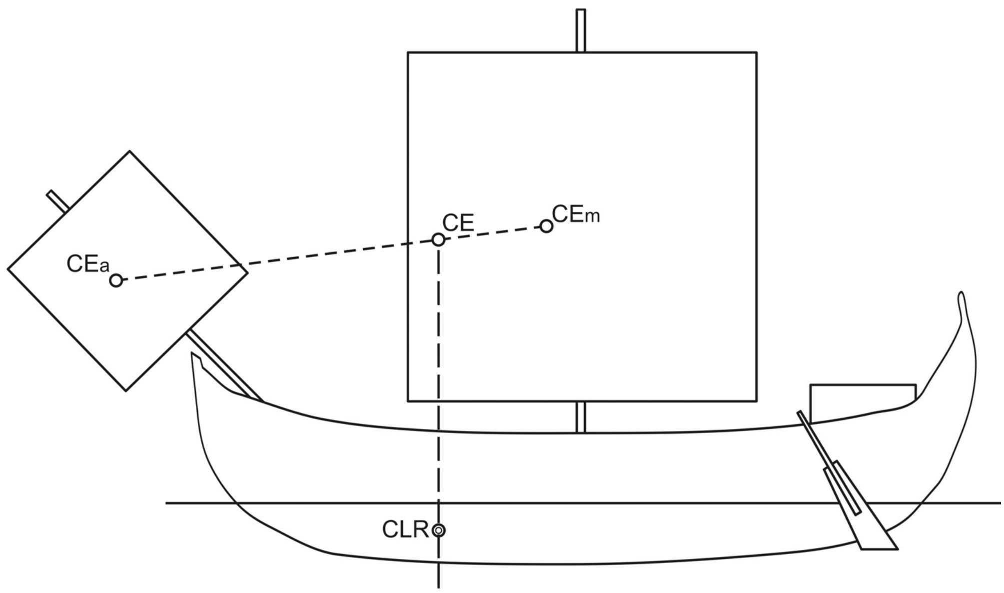

Figure 2-4. The combined *Centre of Effort* (CE) of the mainsail (CEm) and artemon (CEa) against CLR.

The situation regarding mast position undergoes a further increase in complexity by the 2nd century AD. At this time iconographic depictions begin to show vessels with two equally sized masts and sails (e.g. V08, 12, 20 & 23), these are distinct from those vessels which set an *artemon* as the second sail. Appreciation of the problem of balancing CE and CLR can be seen from the equal size of the two sails, in conjunction with the main sail being set further aft, in order to balance the increase in the size of the foresail (Figure 2-5). The foremast is also shown set back from the stem of the boat, quite distinct from vessels rigged with an *artemon* which rests upon the vessels bow. It may well have been impossible to engineer the single-masted rig to a size suitable for efficiently propelling the largest Mediterranean vessels. Adopting a rig comprising two smaller masts and sails presents a safer and more flexible rig than having one large sail; the physical forces acting on the rig and the size of materials required are both reduced. The best archaeological example of this arrangement lies in the remains of the St Gervais 3 shipwreck (S044).

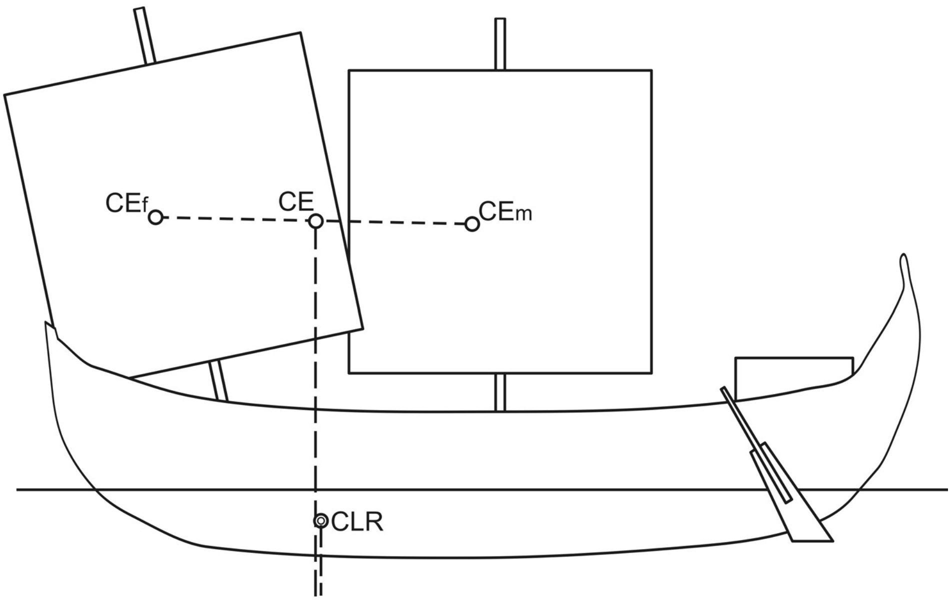

Figure 2-5. Combined Centre of Effort (CE) for a two-masted vessel with sails of equal size, mainsail (CEm) and foresail (CEf).

Discussion

It seems unlikely that sails of such otherwise limited use as the *artemon* or *mizzen* would have been rigged for any other reason than to improve the balance of the vessel while under sail given the limited propulsion which they provided. If they were intended for propulsion, such sails would have been of a similar size to the mainsail, in the manner of the two-masted rig. The use of additional sails to balance the rig and hull of the vessel, in conjunction with the forward position of the mast-step on single-masted ships highlights the developed appreciation which ancient mariners held of the forces acting upon their vessels. Indeed, the appearance of the *artemon* in the iconographic record from the middle of the first millennium BC may represent a solution to the problems encountered by mariners during their initial attempts to sail to windward. Currently, the earliest evidence for the use of a single mast, stepped ⅓ of the way from the bow is the Kyrenia, some 300 years after the first evidence of the *artemon*. The mainsail and artemon represents an equally viable, alternative solution to the problem of rig balance as the forward placement of a single-masted rig. The difference in approach in order to achieve the same result (a balanced rig), coupled with the concurrent use of both approaches, points to the diversity which was present in the square-sail rig of the ancient world. This diversity of rig further highlights the willingness of ancient sailors to experiment and adapt different areas of the rig in different ways to suit their specific requirements. What cannot be clarified from the available evidence is the differing cultural or environmental contexts within which such different rigs were used. For example it is unclear if single-masted rigs were primarily used by vessels of a certain size, or engaged in a certain practice. It can however be suggested at this stage that shipwrecks which have surviving mast steps located amidships probably carried *artemons* and that vessels with mast steps set around ⅓ of the way along the waterline of the vessel probably did not.

A final point of interest regarding the balancing of CE and CLR can also be provided here. In his work on sail theory, Marchaj (1996: 269) notes, with regard to this problem;

"Due to the shortcomings of the above philosophy concerning CE and CLR, it is often necessary to tune a yacht's balance. In practice it is not usually feasible to change the shape of hull or keel, and so tuning becomes a matter of adjusting the position of the sail-plan, or the sail-plan itself, in relation to the hull. Shifting the mast in the appropriate direction, or reapportioning the total sail area between main and foresails can work wonders for directional balance."

In the light of this, the observation by Steffy (1985: 86) that the mast step of the Kyrenia shipwreck (S024) may have been stepped in a different location at a previous time and the very development of the *artemon* itself makes a great deal more sense. The practice of tuning a sailing ship in order to get the best performance may be visible in the archaeological record preserved in the Kyrenia shipwreck. Similar movement of the mast-step has been observed in the late 2^{nd} century AD Grado shipwreck (S020) (Beltrame & Gaddi 2007: 139-141). Balance could also have been achieved in other ways such as through cargo stowage; biasing the weight of the cargo towards the stern will move the CLR aft and a bias to the bow will move the CLR forward. A feature of the ancient Mediterranean rig was the system of brails (below) which allowed the shape of the sail to be altered at will, a factor which was also used when dealing with the fine balance of a sailing vessel. For example, brailing up the after half of the sail will shift the CE of the sail further forward, this practice is noted by Aristotle and obviously refers to attempts to balance a sailing vessel. Although the sailors are described as running before the wind, this account can only realistically be applied to a vessel sailing close-hauled.

"Why is it that [sailors], when the wind is unfavourable and they wish to run before it, they reef the sail in the direction of the helmsman, and slacken the part of the sheet towards the bows? Is it because the rudder cannot act against the wind when it is stormy, but can when the wind is slight and so they shorten sail? In this way the wind carries the ship forward, but the rudder turns it into the wind, acting against the sea as a lever. At the same time the sailors fight against the wind; for they lean over in the opposite direction."

- Aristotle, Mechanical Problems. 851b.7 (tr. W.S. Hett, 1955).

It was also practiced during the sailing trials of *Olympias* where the vessel's tendency to weather-helm could be corrected by brailing up a portion of the leeward (aft) side of the sail (Morrison*, et al.* 2000: 257-8). There are several ways in which ancient vessels could have been fine tuned, many of them invisible to us. The position of the mast however, was fundamental of the sailing qualities of the vessel and its position is often visible in the archaeological record. The differences in rig position and rig plan represent an attempt by the ancient mariner to rationalise some of the issues regarding sail and hull balance before setting out on a voyage.

2.1.2 Masts and mast-fittings

Having established the location of the mast along the centreline of the vessel and the implications of the variation in this position, attention can be turned to the characteristics of the mast itself (Figure 2-6(3)). Casson states that the masts of the ancient world were likely to have been of composite construction (Casson 1995: 231). He bases this observation upon the iconographic evidence which often shows vessels with banding around the masts (e.g. V15-16 & 18) this he interprets as the wooldings, located at fixed intervals to hold the sections of the mast together. As with the location of the mast it is the direct archaeological record which can further inform us with regard to the details of this particular constructional feature. Although mast remains are rare in the archaeological record, a few examples have been excavated or surveyed; 'wreck D' in the Black Sea (S003) (Ward & Ballard 2004), the Dramont E shipwreck (S017)(Santamaria 1995: 164-171) and from the port of Olbia (S037) (Riccardi 2002).

The mast remains excavated from Olbia from a 1st century AD deposit amounted to a section 7.6m long and 420mm in diameter from the base of the mast, including the foot, which ended in a semi-circular tenon 180mm long (Riccardi 2002: 268). The size of the mast suggests that it came from a vessel of between 30 to 35m in length (Riccardi 2002: 269). Riccardi (*ibid*) suggests that the mast was broken at about half of its length, the lower half of the surviving length is octagonal in section while the upper remains have large flat planes on either side.

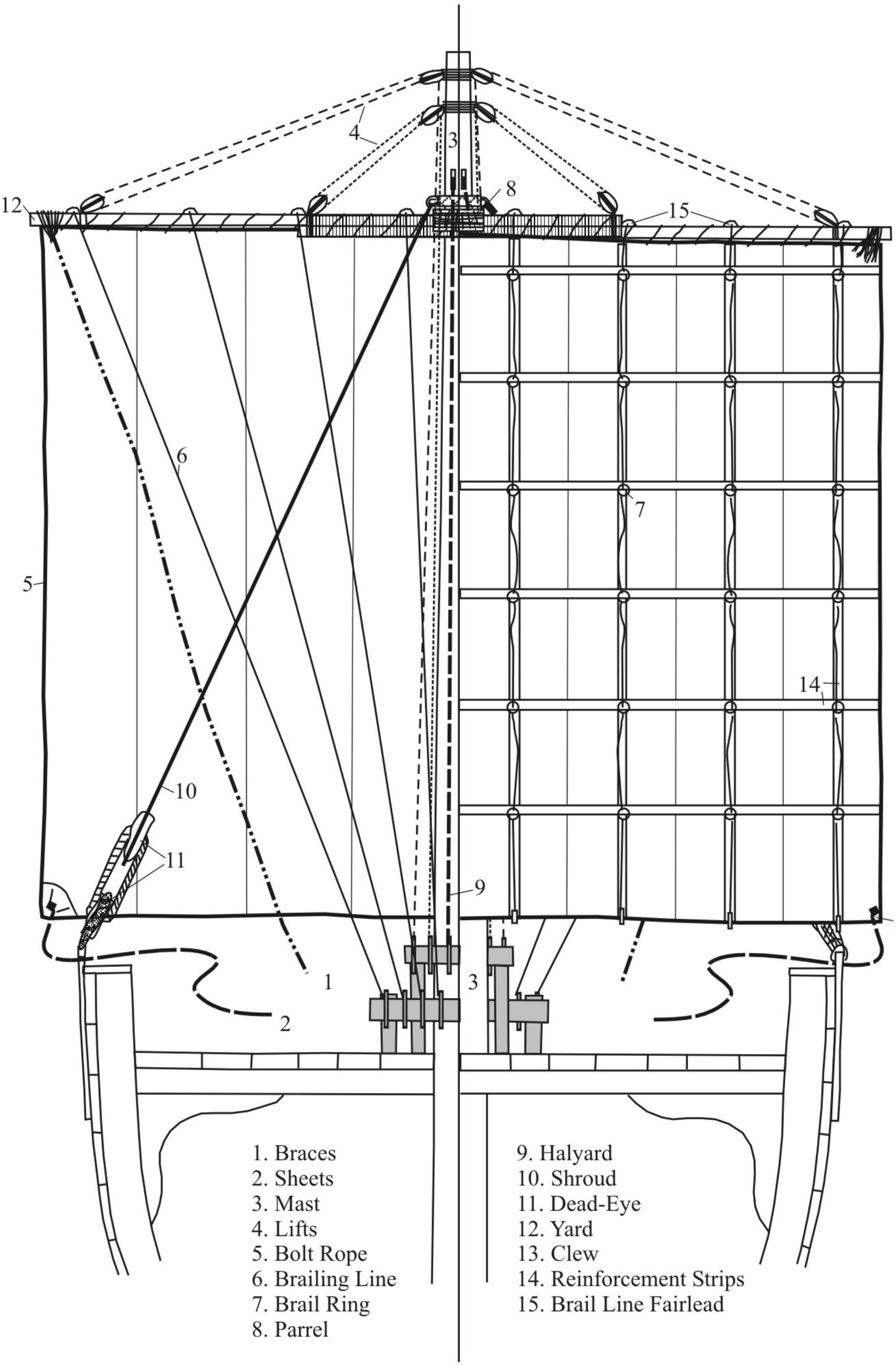

Figure 2-6. Simplified locational diagram of rigging-components on the Mediterranean square-sail rig. The right-handside illustrates a view of the sail from the front, while the left-handside illustrates a view from the stern of the vessel (J.Whitewright).

These planes have mortices cut into them, presumably to enable timbers to be fitted to strengthen the mast or for the upper section to be fished to the lower one. It is still unclear if the complete mast would have been made from a single piece or from two sections, the presence of significant length of mortices along its central area suggests the latter. Only the foot of the mast, made from fir, survived on the Dramont E shipwreck and was set into the mast-step using a semi-curved tenon. The mast itself was not perfectly round and measured 275mm fore-and-aft and 235mm from side to side (Santamaria 1995: 164), significantly smaller than the Olbia mast. The overall size of the Dramont E vessel is estimated at 16m in length (Santamaria 1995: 176), roughly confirming the estimate of the vessel size suitable for the Olbia mast. In 2000 a 5th century AD shipwreck was surveyed on the floor of the Black Sea which had its mast still standing (Ward & Ballard 2004: 6-11). The mast on that vessel was made from a single length of timber and stood 11m above the sea-bed (deck level) of the vessel, the vessel was interpreted as being 12-14m in length (*ibid*). Based on this scant evidence it seems too soon to state simply that masts in the ancient world were all of composite construction. A single timber (10.5m long) was also used on the *Kyrenia II* replica which was 14m in length (Katzev & Katzev 1989: 164 & 173). While it may be the case that large sailing vessels had a composite mast, it seems equally likely that smaller ships continued to use single piece masts. The use of fir for the mast of the Dramont E shipwreck and the continued use of this wood for masts suggests that it was a likely material for their manufacture in antiquity.

Lifts

The mast would also have carried many of the fittings which allowed the rig to function, uppermost of these would probably have been the blocks for the lifts (Figure 2-6(4)) which supported the yard. Yards supported by either one (V05, 19 & 26), two (V20), three (V10) or four (V09 & 21) are shown in the iconographic record.

"the sailor swinging himself aloft by the ropes and then running the length of the yard along the top in perfect safety holding on to the lifts"

- Lucian, Navigium. 4 (tr. Kilburn 1959).

Where only a single lift is present these may have consisted of a single block set at the mast head for a line to run through on its way from yard to deck and providing some mechanical purchase. In the case of vessels with two or more lifts per side then it seems likely that a set of blocks, probably incorporating a double block at the masthead and single block at the yardarm, would have been used. Although double blocks are rare in the archaeological record, examples have been found on the Grado shipwreck (S020) (Beltrame & Gaddi 2005: 81). The use of blocks such as these would allow the rigging of two or more lifts on each side of the vessel allowing increased support for the yard, by using more lifts, and giving mechanical advantage to the sailor trimming the yard. The use of the double block would also serve to reduce both the amount of gear required to be rigged at the mast head and the number of lines needing to be lead to the deck.

How crucial the lifts are to the operation of the rig is difficult to say, there are many iconographic examples of ships without lifts (e.g. V02, 04, 07 & 24). This may easily be the result of artist convention as much as a characteristic of the particular vessel depicted. The reconstruction of Skuldelev 1, the *Ottar*, from Roskilde in Denmark has a square-sail of c.95m^2, the mast and yard are each made from single substantial timbers but no lifts are used. This replica vessel may have relevance here as Pliny (*N.H.* 19.5) notes that on some vessels whole tree trunks served as single yard arms. In contrast to this is the second replica of the Kyrenia ship, *Kyrenia Liberty*, which is a slightly smaller vessel than the *Ottar* but which does employ the use of a single lift on either yardarm (Figure 2-7). Where the *Ottar* has a yard made from a single length of timber the *Kyrenia Liberty* is rigged with a yard fished together from three lengths of timber. This makes for a very flexible yard and the lifts in use (one set per side) are certainly needed in order to support the yard during sailing. One noticeable consequence of a flexible yard which became apparent while sailing the *Kyrenia Liberty* is that the natural downward flex of the yard leads to the luff of the sail becoming slack when sailing close-hauled. To counteract this, the forward lift must be tightened in order to add more tension to the luff, something that the *Ottar*, with its rigid single piece yard did not have to deal with. McGrail (1998: 234) has noted that as ships grew in size and yards became bigger and heavier, lifts would be required. While Emanuele (1977: 183) comments that the absence of lifts in a vessel may lead to yards drooping or curving downwards at the ends, the fact that *Kyrenia Liberty* carries lifts but still suffers from a down-curving yard is perhaps the most significant point here. The evidence from the two replica vessels suggests that the reality of the situation may be slightly different from that described thus far in the literature. Simply that vessels with single piece yards were able to make do without lifts and the vessels rigged with composite yards had to fit them out of necessity.

Masthead blocks

As well as fittings for lifts the masthead would also have accommodated the blocks for the halyard, this could have been done in two ways. Firstly to incorporate a sheave (pulley) into the mast itself, this is a common characteristic on vessels from all ages and geographical locations. One of the best examples can be seen on the traditional trading ships of the Indian Ocean, either of Arab or East African origin which incorporate sheaves into the masthead, either a single one for a smaller vessel or a double sheave for a large vessel (Dimmock 1946: 37) (c.f. Figure 2-18 in ch. 2.2). The second option would be to have a halyard block at the masthead. This is the arrangement which was used on the rigging of the *Kyrenia Liberty* where two blocks were set up at the mast head to provide the crew below with some assistance in hoisting yard and sail (Figure 2-7). As with the ships of the Indian Ocean it is probable that larger vessels would have used a double halyard in order to provide the required strength without having to manufacture unusually large diameter halyards.

Figure 2-7. Masthead blocks on the *Kyrenia Liberty* replica. The central block is one of two halyard blocks, while the blocks on either side are carrying the lifts supporting the yardarm (Photo: J.Whitewright).

A further possibility may be that some vessels had an extra fitting attached to the masthead which incorporated sheaves for the halyard. Some of the vessels depicted in the iconography show an addition at the masthead (e.g. V04 &11) which could represent such a fitting. This is also the interpretation which has been applied to the 'wreck D' found in the Black Sea (S003) with its mast standing in situ (above) but which had a recess in the top of the mast (Ward & Ballard 2004: 10) which was presumed to be the socket for such a fitting.

Halyards

The actual technique involved in hoisting the sail is open to some conjecture. On smaller vessels the crew alone could hoist the sail using a conventional block and tackle, this is the case on the *Kyrenia Liberty* replica. On larger vessels the sail may been hauled up using a windlass or capstan, the sheer weight of the yard and sail making this a necessity, these are mentioned by Lucian, again in reference to the *Isis*.

"anchors in front of them, and capstans, and windlasses, and the cabins on the poop"

- Lucian, Navigium, 5. (tr. Kilburn 1959).

There is one further technique for hoisting sail, which, as well as being largely undiscussed thus far in the maritime literature also provides a glimpse at the possible origins of the lateen/settee sail. It was noted above that large Roman sailing vessels may have utilised capstans or windlasses when hoisting sail. It is however of relevance to this study to note that the large sailing vessels of the Indian Ocean do not use any such machinery, although they carry a yard which is longer, by nature of the sail-plan used (c.f. 2.2), than that of a similarly sized Roman vessel. The double halyard of a large Arab vessel, having passed aft through the double sheaves set into the masthead, is made off around a large multi-sheaved block, a corresponding block is set into the keel or crossbeam of the vessel (Johnstone & Muir 1964) (c.f. Figure 2-18 in ch. 2.2). Each of these blocks can have as many as four sheaves in them, making for a substantial purchase when hoisting the yard. The same type of block was also excavated from the wreck of the Serçe Limani (S045) vessel dating to the 11th century AD (Mathews 1983: 78; 2004: 171-2 & Fig. 11-4), a vessel probably rigged with a lateen/settee sail (Mathews 1983: 133; 2004). Early depictions of lateen/settee sails from the Mediterranean also show, in some detail, this kind of halyard arrangement (V32 & 34). One of its characteristics is that when the sail is hoisted the upper (mobile) block is at its lowest point (usually near to the deck) and when the sail is lowered the upper block is at its highest (c.f. ch. 2.2.4). This fits with both of the early depictions noted above.

Such a halyard system (2.2.4), traditionally associated with the lateen/settee sail is also visible in the iconography of the single-masted square sail-rig of the Mediterranean. V04, dated to the 1st century AD, from a tombstone from Pompeii shows exactly the same arrangement. The yard is hoisted and the crew are taking in sail, one of the crew is climbing up the halyards (a practice also common on Indian Ocean lateeners (Villiers 1940: 95) and immediately beneath him is the upper block of the halyard arrangement. The ropes running down to the lower block are also visible in the depiction. A similar arrangement is visible on vessel 015, also dating to the 1st century AD. An archaeological example of such an arrangement may be present on the Port-Vendres A (S039) shipwreck dating to c. AD 400 (Parker 1992: 329 No.874). In his report, Parker (1992: 330) records that "Other rigging pieces found include a large, 6-sheaved block (probably from the yard hoist), a 9-sheaved block (perhaps mounted on the deck as a rope-guide)". Beltrame and Gaddi (2005: 81) have alluded to the large multi-sheaved rigging block excavated on the Grado (S020) wreck being used in the vessels halyard system in the same fashion as that described above. However given that the sheaves of the block from the Grado wreck are set at right angles to one another and are therefore quite distinct from both the Serçe Limani block and those observed ethnographically, this block almost certainly represents an as yet unidentified piece of rigging. Other very large disc-sheave blocks in keeping with this system have been excavated on the Grand Ribaud D (S022) (Hesnard*, et al.* 1988: 113-126) and Laurons 2 (S026) (Ximénès & Moerman 1990: 5-6) shipwrecks. At least three different methods of hoisting the sail can be inferred; with blocks set aloft, with some form of mechanical aid such as a capstan or windlass or with the halyard arrangement commonly seen on Indian Ocean lateeners. The appearance of this last piece of technology in the iconography of the Roman square-sail ship obviously has implications regarding the development of the lateen/settee rig and any attempt to identify its origins. These are discussed in Part Three.

2.1.3 Standing Rigging

While sailing, two main physical forces are imposed upon a mast; those which are inherent to its physical properties (size and weight) and those which are imposed by the very action of sailing. As noted above, the point through which the aerodynamic forces driving the ship forward act through, is known as the Centre of Effort (CE). The forces acting through the CE affect a sailing vessel both laterally and longitudinally, however, the lateral forces imposed while sailing close-hauled are significantly greater than the longitudinal ones which result from downwind courses. The scale of the forces which act upon a vessel's mast vary still further, depending on the size of the vessel and the conditions in which it operates. In order to counteract these forces a system of rigging known as *standing rigging* is used to support the mast. Important in the definition of items of standing rigging is the fact that they are permanently fixed, adjustments might occur in port or during maintenance but it would be most unusual to alter the standing rigging during actual sailing.

Longitudinal support for the mast is provided by stays. Referred to as forestay and backstay, they run from masthead to bow and stern respectively and they prevent the mast from toppling forwards (backstay) or backwards (forestay). The backstay is obviously of greatest use when a vessel is running with the wind as it braces the mast against the pressure of the wind blowing from astern. It may be that some ancient vessels were able to utilise their halyard system in the place of a backstay by securing it some way aft rather than at the base of the mast. Such a solution can be seen in the Bronze Age ships used by Queen Hatshepsut for her expedition to Punt (Vinson 1994: fig. 27). An ethnographic parallel for this can be seen in the Arab vessels of the Indian Ocean which are rigged in exactly this way (c.f. 2.2.4). The use of a similar halyard system on Mediterranean shipping (above) makes this possibility more than simple conjecture. The forestay also functions along the longitudinal axis of the vessel and acts to counteract the pressure placed on the mast by the aerodynamic forces when sailing on close-hauled courses or when the wind is directly ahead during manoeuvres. It is most unlikely that an ancient vessel of any size could function efficiently without the use of a forestay.

Both backstay (e.g. V02, 22, 25-26) and forestay (e.g. V02, 04, 09, 11, 14-16, 22) are very common in the iconographic record and are one of the most frequently depicted items of rigging. From a practical point of view they are likely to be made from a very thick cable, attached to the masthead before being made off and tensioned at bow or stern. Archaeologically, the materials used serves to make stays almost invisible. Rope of any sort is prone to decay and there are no substantial examples of cordage surviving from the period that can be definitively identified as stays rather than any other area of rigging. The wooden elements are likely to be similar to those used to tension shrouds (below). Stays do appear at regular intervals in the textual record, often in more detail with regards to their numbers, the *Argo* for example had a double forestay;

"But now they stept the tall mast in its box and fixed it with forestays drawn taut on either bow"

- Apollonius of Rhodes, The Voyage of the Argo, 1:570-1(tr. Rieu 1959).

This kind of evidence is useful when analysing the exact makeup of the rig. Rather than simply saying that a vessel had a forestay, to know that double forestays were in use suggests that the available materials were inadequate to serve as a single forestay in this context. Ancient cordage itself is likely to have come from a variety of sources depending on geographical location. Pliny (*NH* 19.30) tells of esparto grass being widely used for ships cordage. This is confirmed by large quantities of esparto rope, ranging from 4mm to 55mm, excavated from the Punic shipwreck at Marsala (S031) (Frost 1981: 93-94). Esparto was also used in the construction of the Comacchio shipwreck (S013) (Berti 1990: 154-156, Figs 10 & 11) and was excavated from the Roman shipwreck at Caesarea (Raban 1989: 189). Meanwhile Herodotus (7.25.1, 34.1, 36.3) mentions the use of papyrus by the Egyptians and flax by the Phoenicians. Cordage excavated from the Red Sea port of Myos Hormos (S034) was from a variety of different plants including palm, grass and bast (Richardson 2001: 67).

Shrouds & deadeyes

As well as the longitudinal support provided by the stays the mast also required lateral support when sailing on close-hauled and reaching courses, this was provided by a system of ropes known as shrouds (Figure 2-6(10)). A single thick rope from the masthead ran downward, nearly to deck level where it was made off around a block known as a deadeye (Figure 2-6 (11)); Figure 2-8). This in turn had holes for smaller ropes which ran to a second deadeye, this second block had another large rope made off around it which was secured to the side of the vessel. The smaller ropes allow the whole arrangement to be tensioned and made off using as much mechanical advantage as possible. Typically there may have been several of these to each side, usually attached to the vessel athwartships of the mast or slightly aft of it, thereby giving the largest resistance to any side forces acting upon the mast. Wooden components belonging to shrouds or stays may be distinguishable by their location in a shipwreck. Blocks from shrouds are likely to have been found amidships while those from stays may be deposited at bow and stern. The deposition of a group of deadeyes on the Laurons 2 wreck (S026), adjacent to the mast-step indicates their use as shroud blocks (deadeyes) (e.g. Ximénès & Moerman 1990: 7).

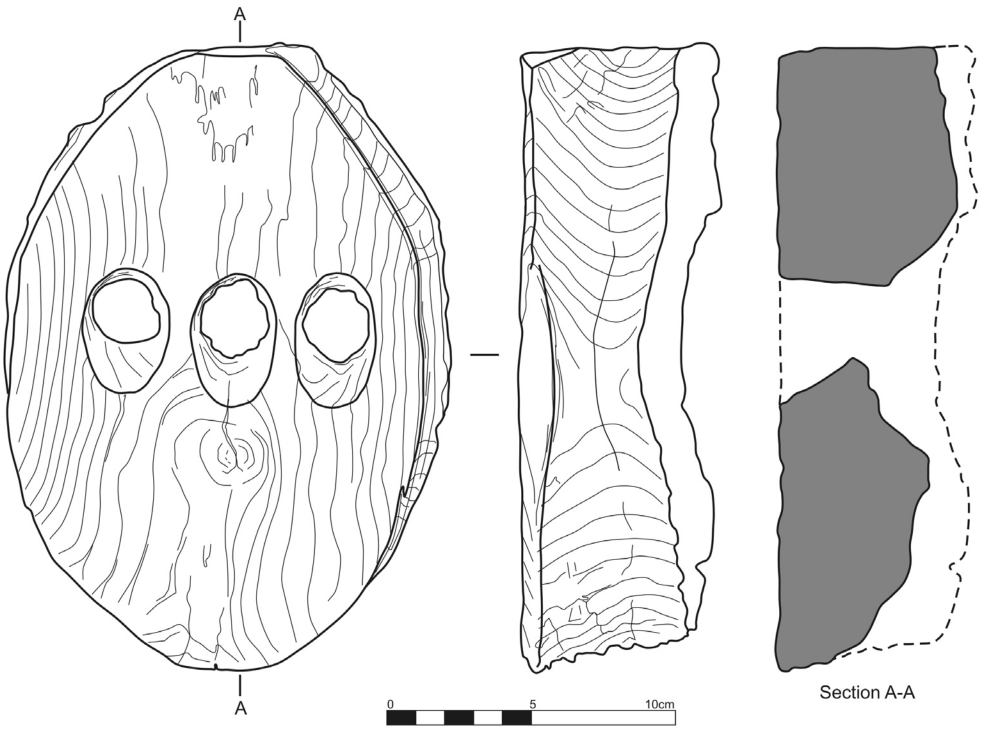

Figure 2-8. Roman deadeye from the Red Sea port of Myos Hormos (J.Whitewright).

Shrouds appear in the iconographic record (e.g. V04, 06-09 & 18), although given their location in the vicinity of the mast it can sometimes be difficult to distinguish them from other lines which the artist has chosen to show near to the mast, such as halyards or lifts. The clearest examples are where the artist has also shown the deadeye blocks themselves (e.g. V09 &18). There is liable to have been a degree of variation in the number of shrouds from vessel to vessel depending on both its size and personal preference of its skipper. Needless to say, larger vessels are likely to have more shrouds than smaller vessels. Like the stays mentioned above, the actual cordage used for shrouds is difficult to locate in the archaeological record, fortunately the deadeyes used in the rigging of the shrouds (and stays) are distinct from other blocks used in a vessels rigging. An example from the Red Sea port of Myos Hormos is illustrated in Figure 2-8 and other examples have been excavated from the Grado (S020), Laurons 2 (S026) and Nin

(S035) shipwrecks. Wood species used to manufacture deadeyes included beech and walnut in the Mediterranean (Ximénès & Moerman 1990) and blackwood in the Red Sea/Indian Ocean. The use of systematic standing rigging, especially static blocks such as deadeyes, is one of the characteristic features of the Mediterranean square-sail rig (Whitewright In Press-b).

2.1.4 Running Rigging

While the standing rigging of a vessel is stationary and mainly used in the structural support of the mast, running rigging is that part of a vessel's rig which is free to move, 'to run' and is usually directly related to the working and handling of the sail. As with the standing rigging discussed above, the cordage of the running rigging is very difficult to trace in the archaeological record, it is only the wooden elements, mostly blocks and sheaves, which survive. As with the standing rigging, because of the perceived scarcity of the archaeological record the majority of analytical work carried out by scholars on running rigging has been based upon the iconographic record with some recourse to the textual evidence. This has lead to a good understanding of the elements which make up the running rigging, but which lacks detailed knowledge regarding the material characteristics of this part of a vessel.

Sheets & braces

By the first millennium AD the running rigging related to the square-sail had been relatively uniform in character since the Late Bronze Age. The sail was controlled/trimmed using sheets (Figure 2-6(2)) and braces (Figure 2-6(1)) and shortened/furled using a system of brails. Although a square-sail is rigged ostensibly with two sheets, one running to each clew (lower corner) of the sail, the precise terminology for both the sheets and the corner of the sail may vary depending upon the course being sailed (ch. 2.1.6 & Figure 2-12). Although sheets are by no means universal in the iconographic record, operation of the lower portion of the sail is impossible without them and so their presence can be safely assumed. There are also various literary descriptions of the use of sheets to trim the ancient sail. For example the use of both sheets to control the sail indicates that the *Argo* is on a course running before the wind;

"When this was done, as the wind was blowing hard, they re-embarked, let down the sail and drew it taut with both sheets. And Argo sped eagerly over the sea"

- Apollonius of Rhodes, The Voyage of the Argo, 2:930-2 (tr. Rieu 1959).

Braces are used to control the sail by adjusting the lateral position of the yard and hence the sail, in relation to the course of the ship. Braces are generally attached to the yardarm itself rather than to the sail, as it makes for a far easier attachment point. They are normally depicted as attached at the outer end of the yard during the Roman period.[14] The primary function of the brace is to control the position of the sail when a vessel manoeuvres, to this end they perform a crucial role in ensuring that the yard and sail is positioned correctly. This is of most importance when a vessel is tacking or wearing and the yard has to be swung around to the other side of the vessel. Once a course has been set, especially a close-hauled course, they can be used to remove some of the twist from the sail which is detrimental to its performance. Braces are usually depicted running to the rear of the vessel as this gives the crew trimming them the greatest mechanical advantage in moving the yard. As with sheets, braces are often absent from the iconographic record, but like sheets they form such a fundamental part of the square-sail rig that their presence can be safely assumed. Braces would be used during manoeuvres such as those described below, which probably allude to a vessel tacking (ch. 2.1.6 & Figure 2-12).

"as one man they swung round the high ends of the yard-arms and swung them round again"

- Virgil, The Aenaid, 5:830-4 (tr. West 1991).

On smaller vessels the crew of the ship could have operated the sheets and brails without any mechanical assistance, this is the case on both the *Ottar* and *Kyrenia Liberty* replicas. On larger vessels than these both sheets and braces may have been rigged with pulley blocks in order to gain a mechanical purchase.

Eyelets, toggles and bitts

Rigging components such as sheets and braces are virtually invisible in the archaeological record. The cordage from which they are made rarely survives in an identifiable form and it is difficult to positively associate surviving sheave blocks specifically with sheets, braces or both. Another group of wooden component does however survive in the archaeological record which probably had a role in the trimming and control of the sails. These are the eyelets, toggles and bitts which have been excavated from some sites (e.g. S012, 020, 026, 029, 032, 034 & 035) (see Polzer 2008 for a summary). Toggles were probably spliced into the ends of rope allowing the rope to be attached through an eyelet securely (Beltrame & Gaddi 2005: 81), but in a manner which could be quickly removed. Direct attachment of ropes with knots may have been uncommon because of the tendency of rope to swell when wet, making the knot impossible to undo. Such an event is recorded in the voyage of Bishop Synesius from Alexandria to Cyrene in the early 5th century AD (tr. Fitzgerald 1926: 85-86). This system may have been further refined by the use of wooden eyelets inside eyesplices (Ximénès & Moerman 1990: 9) to prevent the loop of the eye from changing size.

[14] This contrasts with depictions of Mediterranean shipping from earlier periods where braces are often shown attached midway along the yard (e.g. Vinson 1994: fig. 27) .

Rigging bitts and belaying pins provide the means for making off ropes such as sheets and braces. They may be fixed in a single place on the vessel or they may be moved around the vessel depending on where they are required. The latter are usually referred to as mobile bitts. Bitts and belaying pins have been excavated from the Grado (S020) (Beltrame & Gaddi 2005: 81-93) and Laurons 2 (S026) (Ximénès & Moerman 1990: 11-12) shipwreck. The three bitts from Grado were found under the starboard bow of the vessel, indicating their probable location in the vessel. One of these was 1035mm in length and was notched to fit over an element of the vessels hull (Beltrame & Gaddi 2005: 82 & Fig. 7). The remains of two nails suggest it was permanently secured to the side of the vessel. Its location in the bow of the vessel suggests that it may have been used to secure the tack of the sail, vertical posts in a similar area of the vessel can be seen in the iconographic record (V09, 10, 11, 15, 16 & 22).

Sheave blocks

Mediterranean square-sail vessels utilised a distinctive form of sheave block which employed a cylindrically shaped sheave (Figure 2-9). Such sheaves were set between two relatively flat (when viewed face on) pieces of wood joined together by wooden dowels. Oleson (1983: 161) has termed this form of block a 'Caesarea type' block, however it seems preferable to simply refer to them as 'Mediterranean blocks' or where only the sheave remains as cylinder sheaves. Examples of Mediterranean blocks and cylindrical sheaves have been found at sites across the Mediterranean and on the Red Sea (S001, 006, 007, 012, 013, 020, 022, 024, 026, 029, 030, 032, 034, 035, 037, 038, 041 & 047). Wood species used to make the blocks or sheaves found at these sites have included boxwood, common oak, evergreen oak, beech and mulberry. As well as Mediterranean style blocks, sailing vessels also utilised blocks fitted with conventional disc-sheaves rather than cylinder sheaves and the remains of these blocks and sheaves have been found at a range of sites (S009-011, 020, 022, 026, 029, 032, 034, 039, 040). Such blocks are also visible in the depiction of naval spoils on the triumphal arch at Orange (Amy 1962: pl. 25). Disc sheaves and blocks have been made from bronze, walnut and ash in the Mediterranean and teak and blackwood in the Red Sea/Indian Ocean.

Disc sheaves and cylinder sheaves also occur within the context of a single shipwreck or terrestrial site (S020, 022, 029, 032, 034, 037, 038) indicating that the two forms are not exclusive. Both Mediterranean style blocks and disc-sheaved blocks could have fulfilled a variety of roles within the overall Mediterranean square-sail rig, for example; halyards, lifts or to provide purchase to the sheets and braces. In the absence of the excavation of in-situ blocks, associated with other rigging components, it cannot be stated which precise area of the rig would have used which type of block.

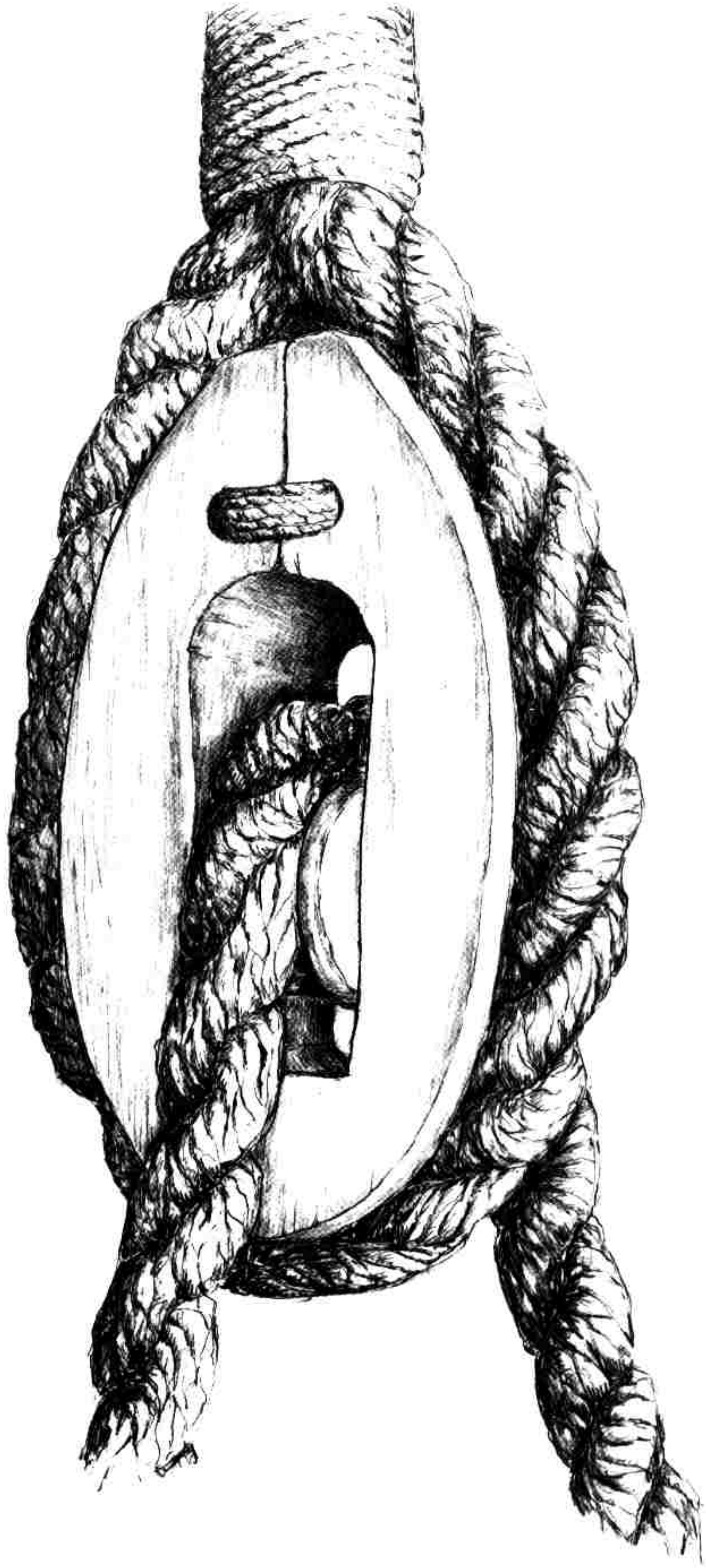

Figure 2-9. Artistic impression of the Mediterranean block excavated from the Comacchio (S013) shipwreck (Berti, NAVIS I Database).

Bowlines

The Roman bowline is an ephemeral area of the ancient ship rig, indistinguishable archaeologically from other running rigging and only occasionally depicted in the iconography. Casson (1995: 230) identifies the bowline as one of the gaps in our knowledge of the ancient sailing rig. Although the bowline is not an integral part of the ancient square-rig, it is potentially a very significant one. The bowline consists of a block, tackle and rope, attached to the luff of the sail, led forward and secured to a convenient point, such as the forestay or stem of the vessel. When sailing close-hauled the bowline can be tensioned to help keep the luff of the sail tighter and flatter and so aid progress to windward. Moore (1925: 44) notes that the bowline increased with importance as the size of vessels got larger and larger and it became more and more difficult to keep the luff of large square sails under tension.

Iconographic evidence suggests the use of the bowline in the Roman period. La Roërie (1956b) cites a mosaic from Tunisia (V12), dated to the mid 3rd century AD, which depicts lines running from the front edge of the mainsail to the vessels foremast, the other vertical edge of the mainsail has a series of loops which could represent the attachments for the bowline when on the other tack. Further evidence comes from Tarquinia and a depiction of an Etruscan merchantship, this vessel dates to the early 5th century BC (Casson 1995: 70). The luffs of both the foresail and mainsail are depicted with the loops similar to those on the mainsail of the vessel from Tunisia. On both sails the loops are completed by short lines which lead forward, very much in the manner of a bowline rig. Both of these examples are obviously open to iconographic interpretation. Basch (1987b: 476, Fig. 1074a, b, c & d; 1989: 328, Figs 3 & 4) cites depictions of oared galleys (V19) of providing further evidence of the use of bowlines. In both cases the galleys have a spar set in the bow of the vessel to which lines are led from the luff of the sail. These lines, in conjunction with the spar seem to be clearly fulfilling the role of a bowline. Several other iconographic depictions are shown with spars set in the bow of the vessel which presumably provided a lead for the bowlines (V03 & 04). The use of spars, set in the bow of the ship therefore seems the most plausible method of setting a bowline and improving the windward performance of the rig.

2.1.5 Sails

Sails are perhaps the most enigmatic aspect of ancient rigging. Although depictions of sails are abundant in the iconographic record of the period, this does little for our knowledge other than to describe their quantity on a particular vessel and perhaps their basic shape. The depictions of ancient sails indicate that Roman period sailing vessels had a sail with an aspect ratio (AR) of c.1, higher than those seen on earlier Mediterranean craft. This iconographically derived AR is reinforced by the graphical reconstruction of the rig of the Laurons 2 ship (S026) (Figure 2-10) in which a sail of AR=1 fits the spatial constraints of the vessel. Little is known about the physical properties of the ancient sail (Black & Samuel 1991: 217); fabric, structure, weight, porosity, stretch and other characteristics that are inherent in any detailed and holistic analysis. What is known about the material characteristics of sails comes mainly from textual sources with a little evidence coming from the archaeological record. This archaeological evidence for the properties of the ancient sail comes exclusively from terrestrial finds in Egypt and the Egyptian Red Sea (S002, 018 & 034).

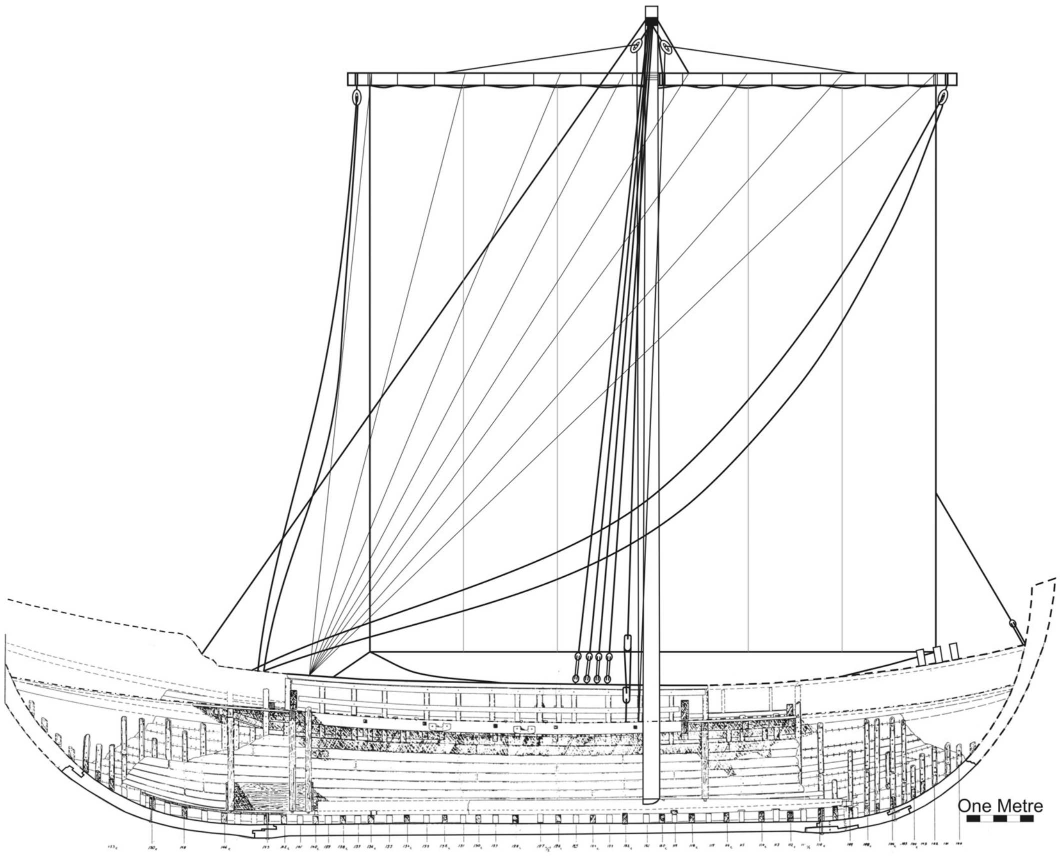

Figure 2-10. Graphical reconstruction of the Laurons 2 shipwreck based on the published hull plans, mast-step location and find spots of deadeyes (Gassend *et al.* 1984: Fig. 19 & 21; Ximénès & Moerman 1990: 7). Mast height is derived from comparative analysis with the Kyrenia II replica. The width of the sail is confined by the need to secure the tack of the sail in the bow of the vessel when sailing close-hauled. This precludes the use of a sail with a greater chord than illustrated here. Deadeyes are the same size as those found on the vessel (Ximénès & Moerman 1990: Fig. 2), halyard block and brace pulleys are those excavated from the similar sized Grand Ribaud D shipwreck (Hesnard *et al*. 1988: 105-126).

Until recently scholars have had to rely on textual sources for information relating to ancient sail material. As with the cordage the classical texts point to sails being made from a variety of sources, depending upon geographical location. Black and Samuel (1991: 220) cite both Theophrastus (*Enquiry into plants, 4.8.4*) and Pliny (*NH 22.72*) who report of sails and cordage being made from the inner bark of papyrus, linen is also widely recorded as being used for sailcloth (Pliny, *NH, 19.21*; Apollonius of Rhodes, *1.565*; Virgil, *Aeneid 3.686*) and was probably the main material used in the Mediterranean (c.f. Gleba 2004). It was the material used in the sail fragment from Edfu (S018) (Black & Samuel 1991: 220). The archaeological record can add further to this list of sail materials. The sail fragments from Berenike (S002) and Myos Hormos (S034) (Figure 2-11) were both made from cotton (Whitewright 2007b: 289; Wild & Wild 2001: 211-220). Sails were constructed from strips of textile sewn together. Such strips could have been manufactured to the maximum width allowed by contemporary looms, upto 1.5m in width if made on a Roman horizontal loom (Wild 1987: 469; pers.comm.). It has been postulated that needles associated with a maritime use, such as sail-making were double-eyed, whereas needles used in terrestrial contexts were single-eyed (Bigagli 2000: 100). Five such needles, curved and made from iron or bronze have been excavated from the Roman harbour at Pisa (S038) (Bigagli 2000: 100, 106-7 & Figs 5, 8 & 11).

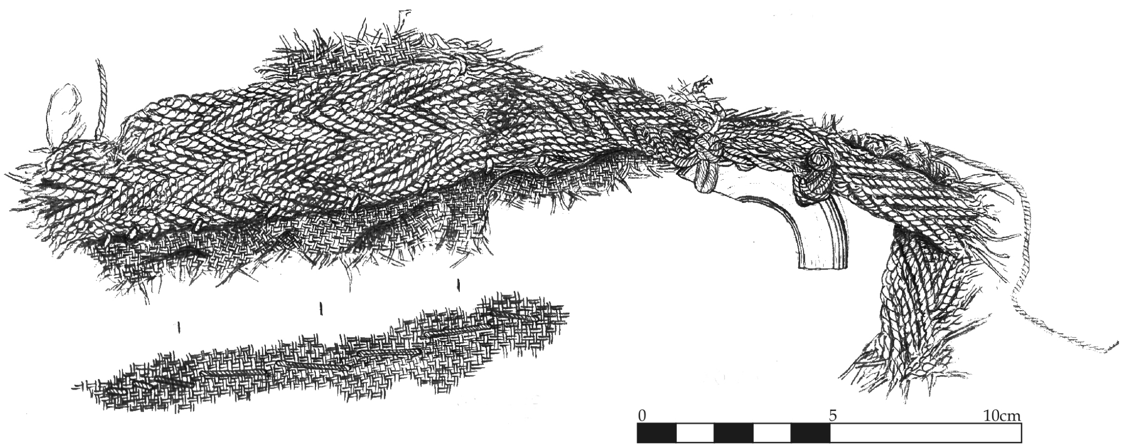

Figure 2-11. Roman sail fragment and remains of wooden brail-ring from Myos Hormos, the herringbone patterned textile is the reinforcement strip sewn across the face of the sail (J.Whitewright).

Cotton is known to have been produced in Egypt by the 1st century AD (Wild 1997: 289-290) and locally produced fabric was generally woven from S- or anticlockwise spun yarns (Wild & Wild 2001: 212). The cotton excavated as sail fragments from Myos Hormos and Berenike tells a different story, both sail cloth and reinforcement strips being produced from Z- or clockwise spun yarns (Handley 2003: 57; Wild & Wild 2001: 213), cotton spun in this direction is generally accepted as coming from India (Wild & Wild 2000: 271-273). The use of cotton originating in India in the ports of the Red Sea contrasts markedly with the Edfu sail fabric which came from the Nile and was made of S-spun Egyptian linen (Wild & Wild 2001: 213) reinforced with locally produced flax (Wild 2002: 13). Cotton is generally seen as a superior fabric to linen for sailmaking, because it can be woven more closely it does not stretch as much as linen and has a lower porosity (Black & Samuel 1991: 222). Wild (2002: 9) notes that the thread count of the sailcloth found at Berenike falls within the same general range as those from the *Vasa* shipwreck and other more recent Swedish examples. This suggests some minimum requirements in the weight of fabric used in pre-modern sailmaking, even over widely separated cultural contexts.

As well as increasing our understanding of the materials used in sailmaking, the finds from the Roman ports of the Red Sea also carry important information regarding the variation in sailmaking and the small detail these variations can pass onto the sail of any given vessel. Roman sails are often depicted in the iconographic record with a series of vertical and horizontal lines running across their face (V04, 06, 08, 09-11, 14-21 & 25). These have been interpreted as being light ropes or strips of textile or leather used to reinforce the sail (Casson 1995: 68-9, 234). The sail fragments from Berenike and Edfu confirm this. The fragments from Berenike were made with cotton reinforcement strips running both vertically and horizontally (Wild & Wild 2001: 214). Likewise the Edfu sail (Black 1996: figs 5 & 6) which has a brail ring attached to the horizontal strip at the point of intersection with the vertical one. The horizontal strip can be identified because of the alignment of the two holes in the brail ring, experimentation with the two Kyrenia replicas have shown that the attachment point must be uppermost. Sail fragments from Myos Hormos do not indicate the use of intersecting reinforcement strips on the same sail. Some fragments have only vertical strips while others have only horizontal strips at the point where the brail rings were attached (Whitewright 2007b: 290).

This evidence suggests that there were at least three approaches to sailmaking in use amongst the shipping of the Red Sea and Indian Ocean rigged in a Mediterranean style. One approach has been identified by scholars from the iconography and confirmed by archaeological finds from Berenike and the Edfu sail. This utilised vertical and horizontal webbing strips which intersected across the face of the sail and to which the brail rings were attached. A second technique, identified at Myos Hormos, used only horizontal webbing strips to reinforce the sail, while a third technique seems to have used only vertical webbing strips (c.f. Whitewright 2007b: 290). It is likely that the reinforcement strips corresponded with the seams joining length of sailcloth together. As such sails may have been made with either vertically set or horizontally set seams. These slightly different sailmaking practices provide further illustration of the presence of differing approaches to the manufacture of outwardly similar rigging components in the ancient world.

Topsails

The Roman period also sees the development of the topsail, which although not a uniform addition is common in iconographical depictions (e.g. V06, 09, 11, 14, 18, 22 & 25) and is also referred to in the textual sources (Lucan, *The Civil Wars*, 5; Lucian, *Navigium*, 5; Seneca, *Medea 327-28*). Topsails would have provided a vessel with extra canvas with which to catch the winds as this passage from Lucan indicates;

"The ropes shook out the canvas at full stretch; the sailors bent the yards and slanted the canvas, keeping the sheet to the left, and spread the high topsails to catch the breeze that would otherwise be lost."

- Lucan, The Civil Wars, 5:428-434 (tr. Duff 1928).

The development of the topsail therefore increased the conditions in which sailing vessels could operate effectively, giving them a greater sail area in light conditions. The passage above also tells us that the wind could be from directions other than dead astern when rigging the topsail. Keeping the sheet on the left and slanting the sail to the wind implies a starboard course, either reaching or close-hauled with the sail 'slanted' more towards the centre line of the vessel.

Casson (1995: 242) notes that on some occasions, in order to clear the forestay the topsail was comprised of two right-angled triangles, one on either side of the mast. A similar arrangement has been commented upon by Moore (1925: 82) with regard to vessels from the Baltic. There, triangular topsails were permanent fittings and ran with hanks on the lifts of the vessel's square-sail yard, Moore goes onto note (*ibid*) that sails of this type were formerly called *raffees*, although he had never heard that word used by a sailor. In the case observed by Moore the topsail was permanently rigged, suggesting that the same could have been true in the Roman period. In order to carry a topsail a vessel would need several additions to its standard rig. Another halyard would be needed to raise the sail, this in turn would require another block or sheave at the masthead. Roman topsails are different from those of medieval and later periods. The Roman topsail is triangular while those of later ages are square, like the mainsail. As a consequence of this shape the Roman topsail does not have a yard of its own and is attached to the mast at its uppermost point. The lower corners were probably then taken to the yardarm end and secured there, the sail was loose-footed. Such a sail could have been rigged and set in a similar way to modern triangular gaff topsails, without the need for a crewman to go aloft.

The introduction of the topsail is undoubtedly significant. From a technical point of view it leads to an improvement in performance on running and reaching courses in suitable conditions, meaning that vessels can sail faster. From a psychological point of view it should be recognised that it represents a more advanced approach to sailing, a willingness to experiment, but also that is requires a slight change in the mindset of the ancient mariner because of the additional complexity to the rigging and use of the sailing rig.

Brails

The Mediterranean square-sail, like sails from all periods needed to be reduced in size when the wind was too strong to sail safely, this practice is known as shortening sail. The sailors of the ancient Mediterranean employed a unique method to do this known as brailing. Ropes, called brails or brailing lines (Figure 2-6(6)), were attached to the foot of the sail and ran up the front of the sail through a series of fairleads known as brail-rings (Figure 2-6(7)) over the yard and returned to the deck. By taking in the brail lines the foot of the sail was hauled upwards, either partially or all the way to the yardarm to totally furl the sail. If shortening sail, once the overall area of the sail was reduced, the yard would then need to be lowered in order to lower the CE of the sail and reduce the heeling force on the vessel. This is noted by Katzev (1990: 252) as part of the procedure when shortening sail in strong wind on one of the voyages of the *Kyrenia II* replica. And was also observed by Seneca;

"Whenever the wind makes up and becomes too strong for comfort, the yard is lowered; for the wind exerts less force from low down."

- Seneca, Epist. 77.2 (tr. Casson 1995: 275, n. 20).

The system of brails also provided an effective means of furling sail without having to lower the yard or send men aloft. Consequently there are several depictions of vessels with the sails furled to the yard and the yard left raised to the masthead (e.g. V07, 09 & 21). Brails and their lines are regularly depicted in the iconography (V01-04, 06-07, 09, 17, 21) and are also attested to in the textual records

"they took up on the brails and, lowering the mast made for shore under oars"

- Lucan, The Civil Wars, 3:44-45 (tr. Duff 1928).

Like the other rigging components discussed in this chapter, the material nature of the brailing system has gone largely undiscussed in the literature thus far, with analysis being confined to iconographic and textual sources. As with other areas of the Roman sailing rig it is the fittings, the brail rings, which are most likely to survive in the archaeological record while the brail lines disappear in the manner of the other cordage. Brail rings, as their name suggests, are round rings which are attached to the face of the sail to prevent the brail lines from becoming tangled. Brail rings have been excavated from sites in the Mediterranean and the Red Sea (S002, 005, 011, 015, 018, 021-023, 029, 033-034) and have been made from wood (Black 1996: 105; Charlin*, et al.* 1978: 57-60; Hesnard*, et al.* 1988: 105-126; Whitewright 2007b; Wild & Wild 2001: 214), lead (Benoit 1961: 178-9, pl. 30; Bound 1985: 60; Fitzgerald 1994: 169; Kingsley & Raveh 1996: 55, pl. 49) and horn (Hamilton-Dyer 2001: 360, Fig. 11.4; Whitewright 2007b; Wild & Wild 2001: 214). As noted above, brail rings were attached to a reinforcement strip which ran across the face of the sail (Figure 2-11). The means of attachment was simply by tying around the body of the ring, through holes bored through the body of the ring, or through a lug on one side of the ring.

Brail rings are not a uniform size across the sites where they have been found. This may reflect the different sizes of ships rigged with brails in the ancient Mediterranean. A larger brail ring will provide a fairlead for a larger rope, which in turn is more likely to be used on a larger vessel with larger sails than a smaller vessel with smaller sails. The relationship between vessel size and brail ring size is obviously clouded by two-masted ships and vessels using *artemon* or *mizzen* masts as both of these relatively smaller sails could be expected to be rigged with smaller brail rings. At the Red Sea port of Myos Hormos (S034) 169 brail rings were excavated which range between 37mm and 95mm in diameter (Whitewright 2007b: 285). This could be expected at a port site where a range of differently sized vessels may come and go over a period of time. In contrast to this, 171 brail rings were excavated from the Kyrenia shipwreck (S024) (Swiny. pers.comm.). 131 were pierced with attachment holes through the body of the ring and measured between 59 and 67mm in diameter. The remaining 40 were attached via a lug and measured between 65 and 72mm in diameter. A similar pattern emerges from the Grand Congloué site (S021) (Benoit 1961: 178-9) where it is now recognised that two shipwrecks were found. The largest number of brail rings (c.80) have a consistent diameter or c. 80mm and are made without a lug or attachment holes. The remaining rings are larger, 90-120mm and are made with attachment lugs. The two groups of brail rings probably represent the two different shipwrecks present on the site. The relative consistency of the diameter of brail rings from the sites at Kyrenia and Grand Congloué, serves to confirm the idea that brail ring diameter is related to overall vessel size.

The system of brails utilised on the Mediterranean square-sail is a unique way of shortening sail. Other square-sail rigs from later period and different parts of the world have used different systems such as bonnets or reefs. The Mediterranean square-sail is the only sailing rig to have made use of such a widespread system of brails across the whole face of the sail. The physical remains of this system are not the ropes used as brailing lines but the seemingly innocuous brail rings used to provide a fairlead up the face of the sail. As such, the presence of brail rings in the rigging components of a site is indicative of the use of the Mediterranean square-sail at the site or on the shipwreck. Brail rings, if they are present at a site, provide the best archaeological evidence for the type of rig carried by a particular vessel.

2.1.6 Sail Handling

The final section of this specific study into the Mediterranean square-sail addresses the use of the square-sail on a day to day basis. This links the rigging components identified above, such as brail rings, deadeyes or sheave blocks to the crew themselves via the technical practice used to operate the sail. This allows a further characterisation of the Mediterranean square-sail to be made, based on how it is used, as well as an assessment of its rigging components and sail shape.

Brails

The unique nature of the system of brails for shortening sail, used in the Mediterranean square-sail was noted above. Brails also allowed sailors a large degree of flexibility with regard to the overall shape of the sail. This was touched upon in 2.1.1 with regard to attempts to balance the sailing rig. In the cited quote, Aristotle (*Mech*. 851b) wonders why sailors brailed up the after half of the sail when sailing into the wind? It seems likely that this must have been done in response to an imbalance in the relationship between the CLR of the hull and the CE of the sail acting upon the vessel when sailing close-hauled. Exactly balancing the CE and CLR is unlikely to have happened on every voyage made by every vessel, there are simply too many variables such as mast-step position or cargo weight and stowage to be accounted for. However, the use of brails presented Mediterranean sailors with a simple and rapid way of refining the balance of their vessel *during* sailing. As noted by Aristotle this would have been especially used when sailing close-hauled when the forces acting on hull and rig are at their greatest. As well as allowing a sail to be rapidly furled or shortened. The system of brails created a sailing rig which could be fine-tuned according to the course and conditions experienced by sailors. It is the flexible nature of the Mediterranean square-sail rig when under sail, which sets it apart from most other pre-modern sailing rigs[15] and the system of brails which allows such flexibility in the first place.

Running and reaching

A square-sail vessel running directly downwind has the sail set in its natural position, with the yard square to the centreline of the vessel. At this point the sail is primarily controlled by the braces attached to the end of the yard and the sheets will hang free and both run towards the stern of the vessel (Figure 2-12(1)). As the vessel turns towards the wind, onto a broad run or reach, the leeward end of the yard is brought astern and the windward end moved forward (Figure 2-12(2)). The front edge of the sail is now the luff and the aft end the leech. Correspondingly the lower corner becomes the tack and the aft corner the clew. As the vessel is turned increasingly towards the wind the tack is taken further forward and is attached to the side of the vessel. The leeward brace is kept taut throughout and acts to reduce the amount of twist in

[15] The 19th century saw the splitting of topsails and topgallant sails to increase the flexibility and ease of handling of the square-rig (Bennett 2005: 12; Landstrom 1978: 172; Moore 1925: 68), however, crew still had to go aloft in order to furl or make sail.

the sail and keep the yard (and sail) in the correct position. If the vessel continues to turn towards the wind the sail is brought increasingly towards the fore-and-aft centreline of the vessel (Figure 2-12(3)). The tack is taken further forward and the clew is hauled aft with the sheet. Eventually, the yard will be unable to pivot any further and the vessel can be described as being close-hauled (Figure 2-12(4)). On a vessel rigged with a Mediterranean square-sail, the forestay and shrouds will prevent the sail attaining a completely fore-and-aft alignment as both will interfere with the set of the sail. This would not prevent a vessel from sailing close-hauled.

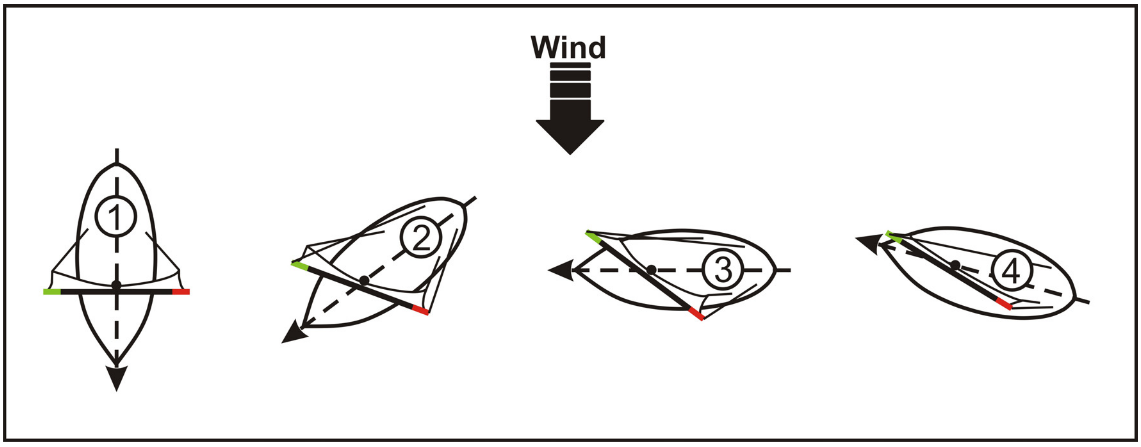

Figure 2-12. The changing position of yard and sail, tack and clew, sheets and braces when altering course, on a starboard tack. 1) Dead run: yard and sail are set across the vessel and both sheets and braces are used to control the sail. 2) Broad run/reach: Port yardarm is braced aft and the port clew is sheeted aft, starboard brace and sheet are loosened. 3) Beam reach: Port yardarm is braced further aft and port clew is sheeted in further, starboard clew is secured forwards of the mast is becomes the starboard tack. 4) Close-hauled: The sail is set as close to the centreline of the vessel as possible, port clew is sheeted in as far as possible and port yardarm is braced around as much as possible. Starboard tack is secured further forward and the starboard lifts (if fitted) may be tensioned to help maintain the tension in the luff of the sail. Bowlines (if fitted) would also be set up on this course.

Going about - tacking and wearing

Changing course (going about) from port tack to starboard tack, or vice versa, can be done in two ways (Figure 2-13). The first, known as tacking, requires the bow of the vessel to be turned towards the direction of the wind. When the bow has turned past the direction of the wind the vessel is said to be on the new tack and it can proceed. The second method is known as wearing and involves turning the vessel by turning the bow away from the wind. The turn away from the wind is continued until the stern of the vessel has passed the direction the wind is coming from and the vessel is on the new tack. In either case the yard and sail have to swing around the front of the mast in order to bring them onto the other side of the vessel, ready for the new course. The square-sail is symmetrical in shape, which means that the tack and clew can simply be exchanged and the luff and the leech swapped over, in other words the whole sail is alternated end for end. The yard of a square-sail is generally rigged underneath the forestay which means that the yard and sail can swing around while the forestay remains rigged. This is advantageous when tacking but does mean that the yard cannot be set fully along the centreline of the vessel when sailing close-hauled because its forward end is inhibited by the forestay.

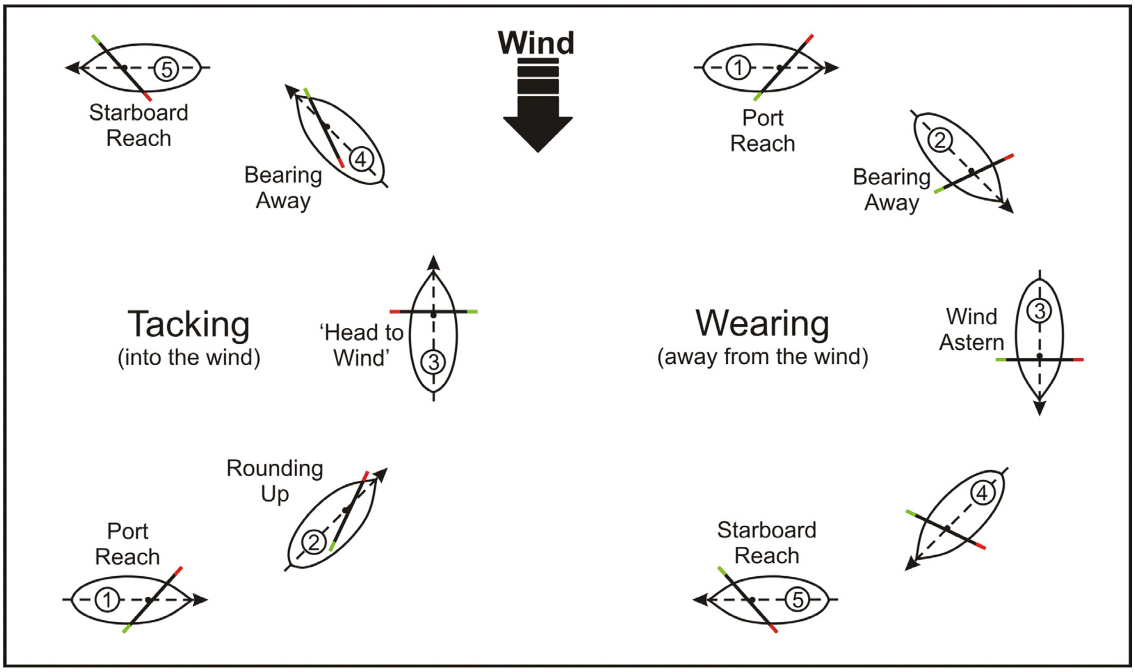

Figure 2-13. Square-sail: tacking (left) and wearing (right). Vessel and yard orientation for tacking and wearing a single-masted square-sail vessel from a port reach to a starboard reach. The relative gain/loss of ground shown in either diagram does not reflect reality, but allows diagrammatical clarity.

Wearing ship is easier than tacking because steerage is maintained throughout the manoeuvre, the yard and sail simply have to be pivoted as the vessel is turned to the new course. The relatively gradual nature of the process means that there is ample time to swap the tack and clew of the sail around as the vessel comes up onto its new course. The disadvantage of wearing ship is that some ground to will inevitably be lost to leeward because of the process of bearing away prior to wearing ship. Such a manoeuvre would be unsuited to a vessel sailing to windward in a confined space, such as a river. In those circumstances any ground made to windward may be lost while wearing ship. In open water, or on long voyages where there is likely to be plenty of time between wearing ship there is more opportunity to make back the lost ground.

In contrast to this, tacking in order to change course is a far more difficult, because the manoeuvre has to be carried out *into* the wind rather than *with* the wind. The crucial stage of the manoeuvre is when the vessel is head to wind and must be made to 'pay off' or bear away on the new tack (Figure 2-14). Cariolou (1997: 95) records how this procedure was aided by keeping the fore part of the sail under tension to encourage the bow of the vessel to blown off the wind in the desired direction. Similar techniques of backing a headsail or part of a sail are used on many traditional sailing vessels to help the vessel to pay off onto the new tack. At this stage a vessel may drift slightly astern before while the bow is paying off. A vessel being sailed in the manner observed by Archimedes (above), with the after part of the sail brailed up would do this naturally. At this stage the yard arm must be hauled around to the other side of the vessel using the braces, the forepart (previously the aftpart) of the sail must be un-brailed. Strong wind and associated wave action can prevent a vessel from tacking successfully by not allowing the bow to turn through the eye of the wind. The skippers of replica vessels such as *Kyrenia II* or *Kyrenia Liberty* generally opt to wear ship in wind above force 4 (Cariolou 1997: 93). In strong wind there is also more chance of damage to the vessel when directly head to wind when the sail can be caught aback the mast. The main advantage of tacking rather than wearing is that less ground is lost during the manoeuvre. Completion of a tack without having lost ground would be considered an achievement by the crew of any square-sail vessel. This is obviously desirable when operating in enclosed waters. Contrary to the impression given by some authors (e.g. Hutchinson 1997: Fig. 3.9), the addition of an *artemon* or *mizzen* to the sail-plan of a vessel would not result in extra ground being made during a tack. Such an addition would simply increase the likelihood of the vessel getting the bow through the eye of the wind by using the sails to steer the vessel.

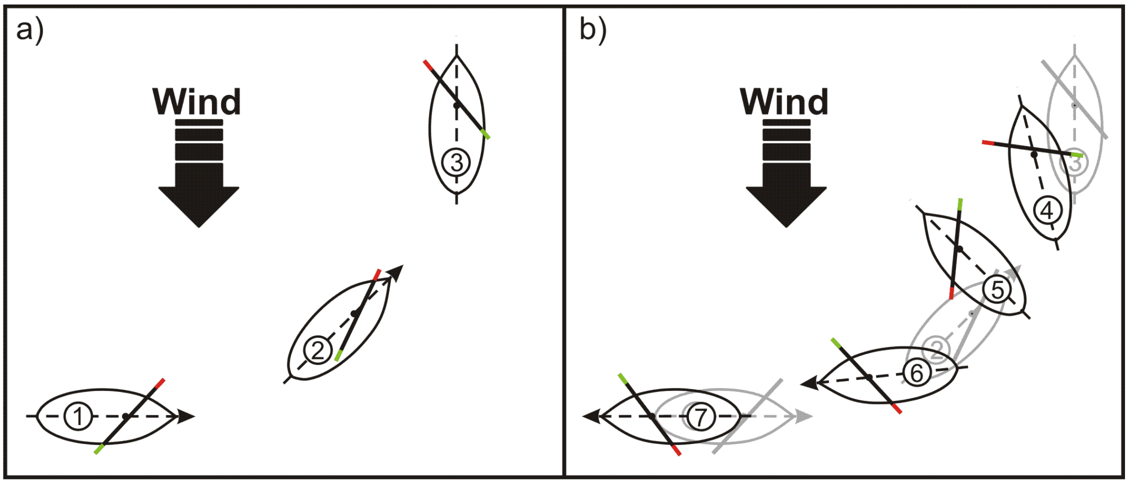

Figure 2-14. Detail of tacking a square-sail vessel. a)1-3: The vessel rounds up into the wind until head to wind, the steering oars are kept in place to help get the bow of the vessel through the wind. b)4: The forward part of the sail is backed against the wind while the sheet and the aft half are let fly, the vessel begins to pay off (move away from the wind on the new tack). The steering oars are now reversed as the vessel starts to drift astern. b)5: Vessel continues to drift astern but has paid off sufficiently to allow the yard to be hauled around with the braces. b)6: The bow of the vessel has paid off and the yard is completely swung over, the vessel begins to gather way on the new tack. b)7: The tack is completed, the vessel is underway and continuing its voyage. In this example no ground has been lost between the vessel rounding up into the wind and gaining speed on the new tack. If the bow of the vessel cannot be got through the wind, a vessel may drift astern and downwind with the steering oars reversed until the bow comes through the wind and ground may be lost.

It is impossible to say whether Mediterranean square-sail ships were usually tacked or worn about in order to change tack. The likelihood is that it was dependent on the context in which the vessel was operating at any given time. A skipper sailing in strong winds or open waters may have opted to wear ship, simply because it was easier. When faced with more suitable conditions or in confined waters where it was important not to loose ground it may have been preferable to tack. Either way, the Mediterranean square-sail rig was not restrictive in how it could be operated. Its sailors had a clear choice of tacking or wearing, the rig being suited to both manoeuvres.

2.1.7 Conclusion

Previous studies of ancient ships and their rigging have been exhaustive in terms of the textual and iconographic evidence (e.g. Basch 1987b; Casson 1995). However, by themselves these sources cannot produce a complete picture of the Mediterranean square-sail rig. Only by recourse to the archaeological record can the detail of the sailing rig be understood. For example, without archaeological remains it is unlikely that the presence of a unique form of sheave block in the Mediterranean sailing rig would be acknowledged. The study presented above also highlighted the existence of the Mediterranean system of brails as a set of rigging components which remain unique to the Mediterranean square-sail rig in the extent of their application and use. It is the use of brails for furling, shortening, adjusting and fine-tuning the rig which makes the Mediterranean square-sail rig distinct from other forms of square-sail. Not until the 20th century would mariners develop a rigging system which allowed such a flexible approach to sailing with the minimum of effort or risk on the part of the crew.

The archaeological record can also serve to correct some of the misconceptions that have arisen because of an over-reliance on the iconographic and textual sources. The most prominent of these is the re-assessment of mast position in square-sail ships conducted in 2.1.1. This demonstrates both that vessels with masts stepped forwards of amidships could have been rigged with square-sails and that ancient sailors had a developed understanding of the complex forces acting upon a vessel while under sail. Acknowledging this allows the development of the *artemon*, *mizzen* and two-masted rig to be more accurately located within the context of sailing in the ancient world. Ancient mariners appear to have been willing to experiment with maritime technology to the extent of introducing different forms of square-sail rig and altering the form (but not the function) of the rigging components they utilised. The development and use of these rigs (helpfully described by textual sources) indicates that Mediterranean square-sail ships must have been sailed on close-hauled courses from at least the 4th century BC. The potential for such vessels to sail to windward is discussed fully in chapter 2.3.

This chapter has attempted to describe and characterise the Mediterranean square-sail rig via all the available evidence; archaeological, textual, iconographic or otherwise. This has enhanced the general picture of the ancient Mediterranean sailing rig with a more refined and detailed image, including an understanding of the technical practice required to operate the square-sail rig. This fulfils the requirement set out in chapter 1.1 of this study that technological change can only be addressed from the position of a complete understanding of the technology in question. Complete achievement of this is impossible when dealing with an ancient technology which has now fallen out of use. The archaeologically based approach adopted in this chapter provides the most suitable and accurate alternative.

2.2 The Lateen sail

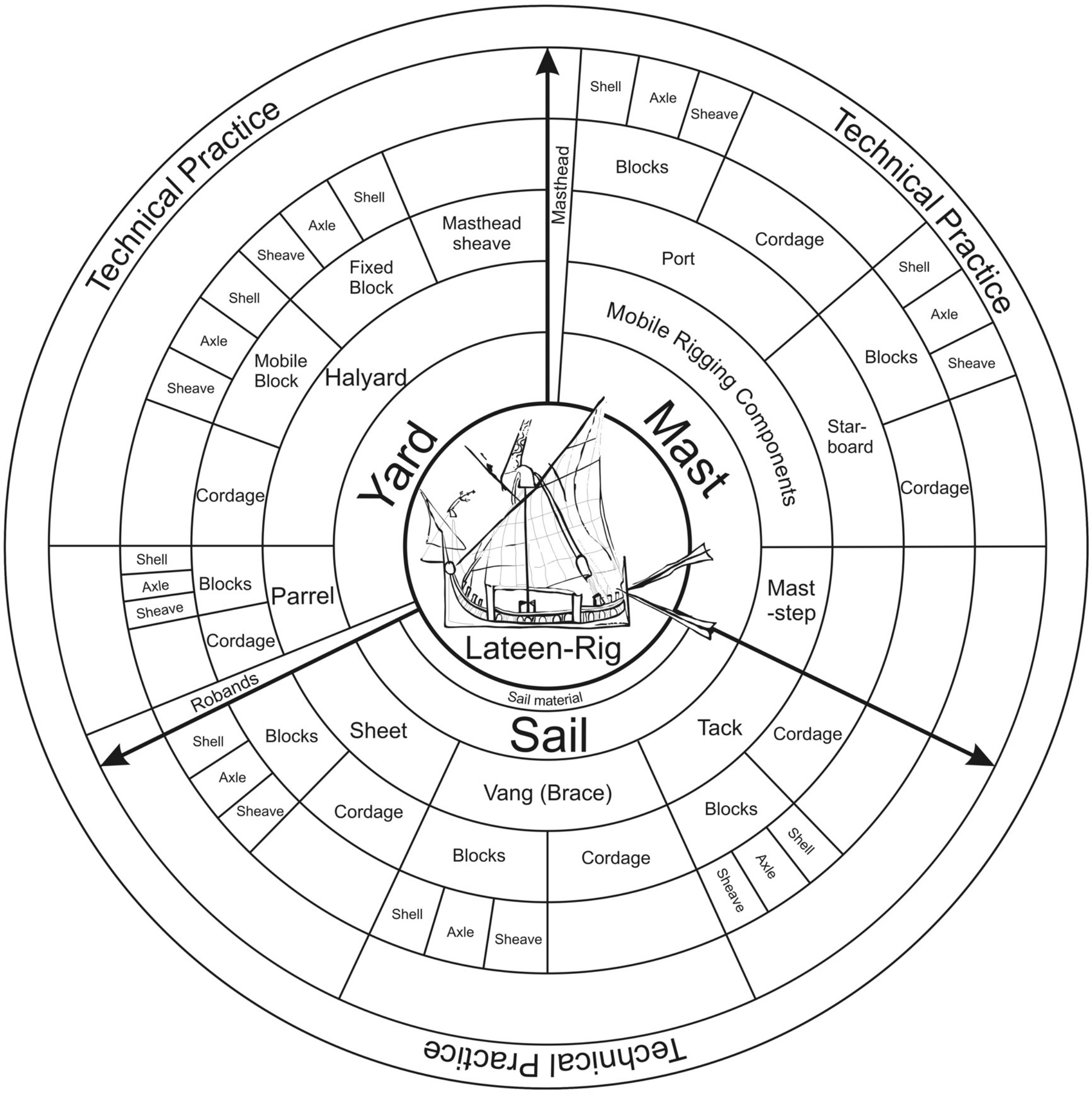

Figure 2-15. The aggregation of rigging components which comprise the Mediterranean square-sail rig. The rig is conceived as consisting of three main areas; Mast, Sail and Yard. These in turn comprise a series of component parts (e.g. halyard), which are themselves created from a combination of rigging components (e.g. mobile-block, fixed-block, masthead sheave and cordage). An individual system is incomplete unless every component, even the smallest, is present. All of these components and the systems which they are part of are enclosed by the technical practice used to operate the rig as an entire system. This technical practice provides the link between the rigging components and the user, in this case an ancient sailor. Alteration to the arrangement and use of rigging components will result in an alteration to the outward appearance of the sailing vessel at the centre of the aggregation.

The lateen/settee sail of the ancient world represents a different interpretative challenge for maritime archaeologists compared to the Mediterranean square-sail. The latter has been the subject of many studies and can be confined to a reasonably well defined temporal and spatial distribution. In contrast to this, the date of introduction, origin and overall distribution of the lateen/settee rig in the Mediterranean during late-antiquity remain uncertain (ch 3.3). Furthermore, while the Roman square-sail rig has become extinct, the lateen/settee rig has remained in use, often in commercial contexts, in the Mediterranean and Indian Ocean. The scarcity of archaeological, iconographic and textual evidence regarding the detailed use of the lateen/settee rig in the ancient world means that the related evidence from the medieval and modern periods must also be considered. The primary value of the evidence from later periods lies in informing us of the technological detail of the lateen/settee rig rather than more over-arching data regarding the chronology and distribution of the rig. Comparative evidence from later periods has the potential to fill in some of the technical gaps occurring in the evidence of the ancient world.

A lack of direct archaeological evidence means that a certain amount of speculation is required when reconstructing the lateen/settee rig of the ancient Mediterranean. Some components of a vessel's rig must have been different in form to the corresponding component on a contemporary square-sail vessel, sail shape is an obvious example. However, there is no reason to believe that such elements would have been constructed from different materials, simply that their physical dimensions were different. Lateen/settee rigged vessels should be viewed alongside the variety of square-rigged vessels detailed in chapter 2.1. All ancient sailing vessels plied the same waters and were subject to the same overall social and environmental operating conditions. The builders of lateen/settee rigged vessels would have drawn upon the same material resources during their construction and been subject to the same influencing factors as the builders of contemporary square-rigged vessels. The lateen/settee rig is simply another way of arranging a set of rigging components with a resulting difference in the outward appearance of the sailing rig.

2.2.1 The lateen sail in the ancient world

The origin of the lateen/settee sail has traditionally been attributed by scholars to the Indian Ocean (Brindley 1926: 14; Casson 1956: 3; 1995: 243-245; Hourani 1951: 100-105; Kingsley 2004a: 78; La Roërie 1956a: 238; Le Baron-Bowen 1953b: 192; Ward & Ballard 2004: 12) and its introduction into Mediterranean waters ascribed to the Arab expansion of the early 7th century AD (e.g. Hourani 1951: 103). The latter was due mainly to the earliest (at that time) iconographic depictions of lateen/settee rigged ships from the Mediterranean (V35-37) post-dating the Islamic expansion into the Mediterranean basin (Frost 1995: 154; Kingsley 2004a:

78). It follows that the Indian Ocean origin of the lateen/settee is founded on the predominance of the lateen/settee amongst the sails of the Indian Ocean in recent times. It was assumed that the Arab people who invaded the Mediterranean basin in the 7th century AD carried with them the sailing rig with which they were familiar. Only Dolley (1949: 55) and Adam (1976: 561) were able to address the available evidence in its wider context and advance the hypothesis that the lateen/settee rig was in use in the Mediterranean from the late 6th century AD. The 9th century AD depictions and their accompanying theories have since been superseded by unequivocal depictions of lateen/settee rigged vessels which predate the Arab expansion of the 7th century AD and place its use at least as early as the mid-5th century AD (V32 & 33) (see Basch 1991a; Friedman & Zoroglu 2006; Pomey 2006; In Press for examples). The exact location of the lateen/settee rig within the overall chronology of maritime technological change in the ancient Mediterranean is outlined fully in Part Three (ch. 3.3 & 3.7). There can be no doubt that the lateen/settee sail was in use in the Mediterranean from at least the late-antique period and probably before that. It is these early lateen/settee rigged vessels which this chapter is concerned with reconstructing and understanding.

Settee or lateen – an issue of nomenclature

It is of use at this point to discuss and clarify an issue of nomenclature regarding the lateen/settee sail. In terms of sail-plan, two forms occur in the iconography of the ancient Mediterranean. One is a quadrilateral sail with a short luff (e.g. V31, 32 & 37) and the other is a fully triangular sail (e.g. V34-36 & 38). In recent times the latter has usually been distributed in the Mediterranean and the former in the Indian Ocean, although both were clearly known in the Mediterranean during late-antiquity. It is obviously useful to be able to differentiate between the two types of sail-plan using a simple, yet precise terminology. To this end the triangular sail will be referred to as a *lateen* sail, while the quadrilateral sail will be referred to as a *settee* sail (c.f. Moore 1925: 88). The same differences in sail-form have been noted by Pomey (2006: 329) who uses the alternative term 'Eastern lateen sail' to refer to the settee sail on the basis of the terminology set out by Beaudouin (1990). The term *settee* remains more concise, less prone to confusion and will be used from here on.

The physical differences between a lateen and settee sail are illustrated below (Figure 2-16). The two examples shown below are both generic and serve to illustrate the difference in shape between the two types of sail. In reality there are many different variations in shape to different parts of each sail, which in turn alter its overall appearance. For example, the luff of the settee sail can be longer or shorter than that shown, modern examples in the Indian Ocean exhibit very different luff lengths as a result of the design chosen by a ship's captain (al-Hijji 2001: 86-7). Likewise the dimensions of the lateen sail are also potentially highly variable. There is no reason to think that every lateen rigged ship in the ancient Mediterranean would have had exactly the same sail shape and yard angle as one another. Recent Mediterranean lateen rigged vessels certainly do not (for examples, see Gillmer 1994: chapter 4; Moore 1925: chapter 4).

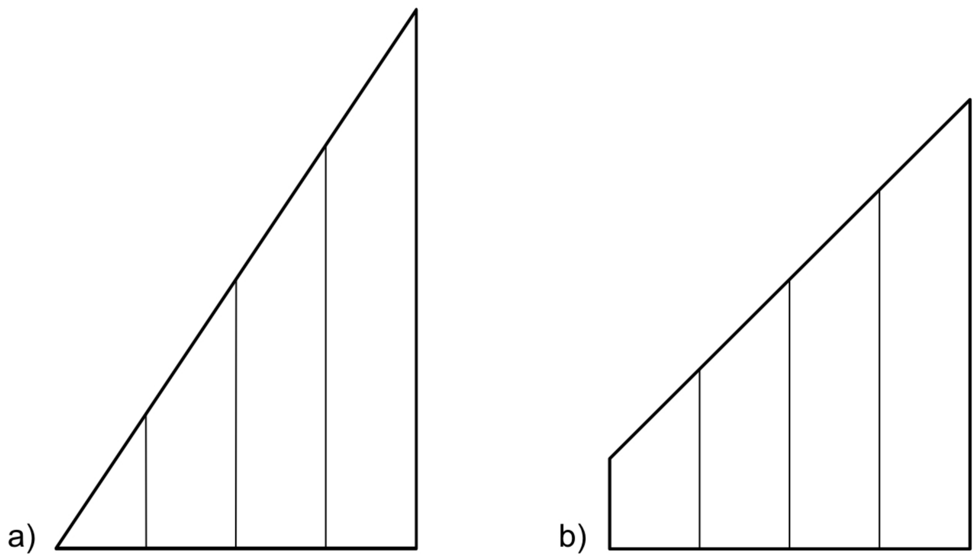

Figure 2-16. Sail-form: a) The triangular lateen sail, b) The quadrilateral settee sail.

2.2.2 Masts & yards

Indian Ocean settee rigged craft, observed in the early to mid 20th century are generally rigged with a mast constructed from a single piece of timber, even on the largest of vessels (Lishman 1961: 57; Villiers 1961: 253). Contemporary Mediterranean lateen rigged craft are also recorded with a mast made from a single length of wood (Gillmer 1994: chapter 4). Because of the shape of a lateen/settee sail the mast itself is relatively short (Dimmock 1946: 37; Hornell 1942: 12) when compared to a vessel rigged with a square-sail of the same size. This allows the use of shorter lengths of timber for making a mast than on the equivalent square-rigged vessel. It has been concluded by some authors that ancient Mediterranean vessels were sometimes rigged with masts made from two or more pieces of timber joined together (Casson 1995: 231). The balance of the available archaeological evidence suggests that masts on square-sail vessels in the ancient Mediterranean were probably made from single pieces of timber (ch 2.1.2). The ethnographic evidence available for Indian Ocean lateen/settee rigged ships indicates that such vessels in the ancient Mediterranean also used masts constructed from a single length of timber.

Ward and Ballard (2004: 10) note that the mast of ‘wreck D’ (S003) (which they claim carried a lateen sail) is canted forward, but it is unclear whether or not this is deliberate or occurred during the deposition of the vessel on the seafloor. Iconographic evidence of ancient lateen/settee rigged ships and wider ancient Mediterranean shipping in general is ambiguous on this point. Some vessels are shown with vertical masts, some with a forward rake and some with a rake aft; they may all be the result of artistic error, interpretation or a reflection of reality.

Recent Indian Ocean lateen/settee rigged vessels have a universal and definite forward rake to their masts (Dimmock 1946: 37; Moore 1920a: 74; Moore 1940: 211; Prins 1965: 106) to facilitate the handling of the sail (ch. 2.2.6). Post medieval latten/settee rigged shipping from the Mediterranean exhibits a variety of mast angles ranging from forward raking to aft raking. Some two masted vessels even have an upright main mast and a forward raking foremast (Gillmer 1994: Fig. 4-47) and it is this arrangement which is found in the medieval iconography and shipwreck evidence of lateen/settee rigged vessels (see Bonino 1978), particularly with regard to the foremast of such vessels. Consequently, there can be no real certainty in associating a particular mast angle with the lateen/settee sail of the late-antique Mediterranean.

Mastheads

Many of the ropes (halyards, stays etc) used in rigging a sailing vessel terminate at the masthead. The masthead is the centre of a web of lines all fulfilling different functions in the overall rig of the vessel. To operate successfully, many of these ropes need to pass through some form of purchase, such as a sheave block, in order to reduce the muscle power required to move them, or simply to ensure a smooth change of direction. One way of achieving this is by attaching a series of pulley blocks to the masthead for individual or multiple lines to run through. An alternative arrangement is to insert sheaves into the top of the mast itself, allowing ropes to run through the mast. This represents an efficient way of returning halyards from the yard to the deck and can be seen on settee rigged vessels in the Indian Ocean (Johnstone & Muir 1964: Fig. 10; Lishman 1961: 57; Moore 1925: 130-1; Williams 1959: Fig. 8), lateen/settee rigged ships in the Mediterranean (Moore 1925: 98) as well as many other traditional craft from around the shores of Europe (personal observation). This approach represents a common and widespread solution to a specific technical problem.

If more sheaves or attachment points are required, or if the natural diameter of the masthead is not big enough it can be enlarged by fitting another piece of wood. This additional fitting can then be used to provide attachment points for rigging or have multiple sheaves inserted. Such an arrangement is visible on V04, where the top of the mast has clearly been expanded and pierced with holes. The mast of ‘wreck D’ is completely free from fittings of any sort along its whole length, only the very top has a cavity which suggests that some sort of masthead fitting would have been located there (Ward & Ballard 2004: 10). In the absence of other fittings on the mast, the presence of such a masthead block would have been required to provide a location for halyard sheaves at the very least. All of the early depictions of lateen/settee rigged vessels (V32-37) seem to be shown with an additional element at the masthead. In V33 & V34 the halyard lines can clearly be seen running through the expanded masthead before being attached to the yard (c.f. Pomey 2006: 328). In each of the cited examples the masthead fitting is depicted with exactly the same form, resembling a hook-shape pointing towards the bow of the ship. Other depictions of Mediterranean lateen/settee sails from the medieval period are also shown with a hook-shaped masthead fitting (Adam & Villain-Gandossi 1991: 21; Brindley 1926: Fig. 4; Mathews 2004: 179; Nicolle 1989: Fig 43a) but it seems to be unknown on earlier, non-lateen/settee rigged vessels (Pomey 2006: 328). It has been suggested that its function was to hold the halyard as far forward of the mast as possible (Pryor 1994: 70). The hook-shaped mast-head fitting has been noted (Adam & Villain-Gandossi 1991: 21) as being characteristic of lateen/settee rigged vessels during the medieval period (e.g. V35-39). Its presence on V32, V33 and V34 means that it should also be viewed as characteristic of lateen/settee rigged craft in the late-antique period.

Mast-steps

Chapter 2.1.1 illustrated that Mediterranean square-sail rigged vessels do not necessarily have their mast-steps located amidships, in accordance with the iconographic evidence. Depending on the sail-plan of the vessel the main mast-step may be located between 30% and 50% of the waterline length on square-sail vessels. Interpreting the mast-step position for early lateen/settee rigged ships is difficult for several reasons. Firstly and most obviously, is the fact that no definite shipwreck of an early lateen/settee rigged ship has been excavated so far. The 7th century AD Yassi Ada (S048) and 8th century AD Tantura F (S046) wreck have been assumed to be lateen rigged because of their dating, but this is not proven beyond all doubt. Medieval Mediterranean ships reasonably assumed to have carried a lateen/settee rig[16] which have survived in the archaeological record (the Serçe Limani ship (AD 1025) and Contarina 1 ship (AD 1300)) seem to have been rigged with two masts (Bonino 1978: Fig. 4; Mathews 2004: 184-5). The foremast is placed well forward in the bow and the mainmast slightly aft of amidships. In both cases the foremast is assumed to be raked forward and the mainmast to be vertical in the manner depicted in contemporary iconography. Ethnographic evidence also presents problems because of the variation in the rake of the mast; two contemporary vessels may carry their mainsail in the same position when viewed from the side, however, differences to mast rake may mean large variation in the location of the mast-step for a given sail position. Consequently it is impossible to discern whether or not a vessel was rigged with a square or lateen/settee rig based on its mast-step location. Either rig could be served by mast-steps located anywhere from the bow of the vessel to slightly aft of amidships.

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[16] The lateen rig seems to have been the only rig depicted in Mediterranean iconography between the 7th and the 12th centuries AD (Mathews 2004: 183-4) and seems to be the dominant form of rig from at least the 9th century (*ibid*). Two masted lateen-rigged ships were probably in use from the early 9th century (Dolley 1949: 52-3; Mathews 2004: 184).

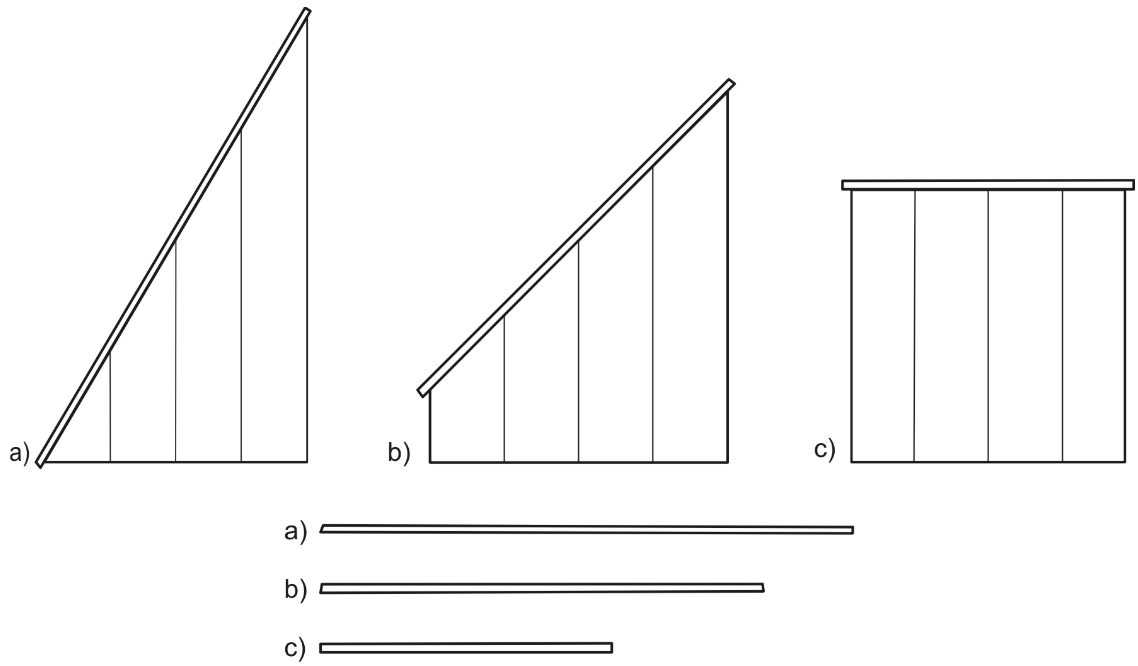

Figure 2-17. The relative length of yards for a) lateen sail, b) settee sail, c) square-sail of aspect ratio one. All sails are the same area.

Yards

The generally triangular shape of a lateen/settee sail causes a vessel's mast to be shorter than a similar single-masted square-sail vessel, because the point at which the sail is attached is not as high above the deck. The yard on which the sail is hung to be much longer than that of a square-sail of the same size in order to maintain the appropriate sail area (Figure 2-17). It is this difference in relative length for a given sail area which leads al-Hijji (2001: 80) to note that the yards of Kuwaiti Booms, rigged with settee sails, are long by western standards. The yards of lateen/settee rigged vessels can often be nearly as long, or sometimes even longer, than the vessel itself (Lishman 1961: 57; Moore 1925: 98). Al-Hijji (2001: 86) goes on to note that many of the Kuwaiti captains prefer a sail with a luff (a settee) over a full lateen because it enables the yard to be shortened without losing sail area, this in turn makes handling the yard a little easier.

As a consequence of the great length of the yard, modern lateen/settee vessels in both the Indian Ocean and the Mediterranean have yards constructed from several pieces of wood, fished together (Dimmock 1946: 37; Lishman 1961: 57; Moore 1925: 98; Moore 1940: 212; Villiers 1961: 254). The exact number depends on the desired length of the yard and the availability of suitable wood. It seems likely that even if a single timber of the required length was available for the yard it would not be used. Such a length would be overly heavy and probably too rigid and so prone to snapping under strain. The use of several lengths of smaller diameter wood serves to reduce the weight of the yard, in turn lowering the vessel's centre of gravity, it also allows the yard to be more flexible and is more easily repaired if damaged. The requirement for the yard on a lateen/settee rigged vessel to be able to flex can be overlooked, but it is nevertheless important. The upper end of the yard generally has no means of support other than its own inherent strength. In observing the *feloukas* of Port Said, Moore (1925: 91) noted how the flex of the peak of the yard allows the sail to spill any gusts of wind before its force heels the boat over dangerously, once the gust is passed, the sail returns to its normal shape.

Archaeological evidence has nothing to add to our understanding of the yards of early lateen/settee rigged vessels as none have been excavated and recovered from a Mediterranean site. Five items likely to be yards were identified on the deck of 'wreck D' (S003) from the Black Sea (Ward & Ballard 2004: 6-7). Their relationship to one another and to the vessel remains unclear, they may be the remains of a single yard, or comprise the constituent parts of several yards. Recently observed practice on Mediterranean lateen/settee rigged ships indicates that more than one yard may have been carried, even on a single-masted vessel (Moore 1925: 98).

Parrels

The final rigging component associated with the mast and yard is the parrel. The sole purpose of this piece of a vessels rig is to hold the yard of the vessel against the mast. It is difficult to construct an accurate picture of this area of a vessel's rig because archaeological examples are unknown for early lateen/settee rigs and iconographic depictions of such vessels omit to show this area of the rig. Parrels on recent European vessels form a joint between yard and mast and to prevent the yard from blowing away from the mast. As such they are often attached to the yard and then passed around the mast, they are free to move up and down the mast with the yard. Obviously this effect can be achieved in a number of ways including a simple rope strop, a circular piece of metal or round pieces of wood laced together. The only prerequisite is that the parrel must be able to run smoothly up and down the mast. All of these approaches could feasibly have been used on early Mediterranean lateen/settee rigged vessels as well as on their square-sail contemporaries.

A further parrel arrangement occurs on the Indian Ocean settee rig and is operated in a different way (see Figure 2-18 for details). Instead of being attached to the yard and passed around the mast, the parrel is passed around the halyard and the mast, directly above the yard (c.f. Moore 1925: 128). When the yard is hoisted and the parrel is tightened and pulled downwards the yard is naturally held against the mast. The downhaul of the parrel runs to the deck where it often serves as an extra stay, being made off to windward or further aft as desired (Weismann 1998: 255). Being rigged in this way allows full control of the distance between the yard and the mast to be maintained. This is especially important when going about as the yard needs to be able to swing free of the mast in order to be transferred around the mast (ch. 2.2.6). This is achieved by slackening the parrel downhaul (c.f. Pryor 1994: 67).

2.2.3 Sails

Sails themselves represent one of the most enigmatic areas of the ancient sailing rig. Although many depictions survive showing the sails of ancient vessels and several textual accounts provide descriptions of sail material, very few examples survive in the archaeological record. Only three definite examples of sail cloth have been documented from the ancient world, all were found in Egypt and all relate to square-sail vessels (ch. 2.1.5). In terms of the material used for sail-cloth, there seems no reason for ancient sailmakers to have used different materials for lateen/settee sails than for square sails. The environmental conditions in which the sails were used were largely the same and factors such as wind strength or exposure to sunlight and/or saltwater which degrade sailcloth would have remained unchanged. The limited pattern suggested by the textual and archaeological remains for the square-sail indicate that Mediterranean sails may well have been made from linen, while those in use in the Indian Ocean were made from cotton. Ibn Mājid refers to the use of ropes made from flax (tr. Tibbetts 1971: 123), which illustrates that it might have been used for other elements of the rig. Hourani (1951: 100) states that the sails of early Arab vessels in the Indian Ocean had sails woven from palm leaves or made from cotton. This is reinforced by Ibn Jubayr's observation that the ships of the Red Sea at 'Aydhab have sails woven from palm leaves (tr. Broadhurst 1952: 65). Alternatives to cotton or linen are attested to in the ethnographic literature relating to the Indian Ocean. The *Mtepe* of Lamu, observed in the early part of the 20th century, had a square-sail made from palm matting (Hornell 1941: 58; Lydekker 1919: 88; Nance 1920: 35; Prins 1965: 122) as did some Arab vessels (e.g. Moore 1940: 212).

Sailmaking

The lack of surviving fragments of ancient lateen/settee sails means that establishing the sailmaking technique used is heavily reliant on iconographic evidence. This in turn is limited to only six depictions of lateen/settee rigged vessels. On one of these (V33) the yard is lowered and no sail is shown and on another the sail-cloth is depicted with no detail (V37), this leaves only four informative depictions. In the earliest of these (V32) the mosaicist has shown the vessel's sail with vertical lines of slightly darker tesserae running from the head of the sail to its foot. The presence of reefing points (below) on the sail indicates that these lines are not brail lines and therefore probably represent the vertical orientation of the lengths of fabric used to make the sail. The next chronological example (V34) has a clear depiction of the vessel's sail, which is shown criss-crossed with vertical and horizontal lines. The detailed and seemingly accurate nature of the artist's depiction of the other elements of the vessel's rig suggests that they were familiar with the type of vessel in question. However, the sail of the vessel remains ambiguous and it is impossible to say whether or not the sail was made from vertical or horizontally set pieces of fabric, squares of fabric may even have been used (Basch 1991a: 6). The third example (V35) is fairly clear in its depiction of the vessel's sail. The lateen sail is shown with darker vertical lines running from the head of the sail to the foot. Between the vertical lines, the artist has shown fainter horizontal lines which give the impression of vertically laid 'brickwork'. The continuity of the vertical lines and the discontinuity of the horizontal lines suggest that the sail is made using vertically set fabric. This provides a contrast with earlier square-sails (V27) and sprit sails (V30) also shown with a 'brickwork' pattern on their sails. In these cases the continuous lines run horizontally across the face of the sail suggesting horizontally laid fabric.

The use of vertically set fabric on V32 and V35 is consistent with modern settee sailmaking techniques observed in the Indian Ocean region during the 20th century. Prins (1965: 113-116) and al-Hijji (2001: 87-90) both record sails being made by pegging out a length of rope in the desired shape of the sail on an area of suitably sized flat ground. The final design of the sail is dictated by the captain of the vessel rather than the shipbuilder (al-Hijji 2001: 86). Strips of fabric are then sewn together (by the crew of the vessel) inside this outline, running parallel to the leach and luff of the sail, finally a bolt rope is sewn into the edge of the sail to strengthen it. This process takes around one to two days to complete (*ibid*). The distribution of maritime artefacts associated with sail repair at Myos Hormos (S034), away from densely populated areas of the site (Handley 2007), indicates that a similar process may have been undertaken in antiquity. Villiers (1940: 126) records that sails were often deliberately poorly sewn together with round seams, this resulted in the sail splitting along the seams when the wind became overly strong. In turn it prevented undue strain being placed on the mast and rig, for as Villiers (*ibid*) notes; 'It was better to lose an indifferent sail than a good mast.' This method of sailmaking, gives an illustration of potential techniques which may have been used for Mediterranean lateen/settee sails during late-antiquity. It is important to note that in these modern contexts, the sails are made (and subsequently repaired) by the ordinary sailors of the vessel as part of its fitting-out. Sailmaking is not a specialised industry but part of the day to day use of the vessel. Sailmaking could easily have held had a similar place in the organisation of antique Mediterranean shipbuilding.

Shortening sail

For a sailing rig to be successful it must be made smaller ('shortened') as wind strength increases. This reduces the pressure of the sail on the mast and rig as well reducing the heeling force which may cause a vessel to capsize. The system of brails used for shortening sail with the Mediterranean square-sail (ch. 2.1.5 & 2.1.6) is depicted in the iconographic record and the remains of brail rings are widespread in the archaeological record. Early Mediterranean lateen/settee rigged vessels must have had an effective way of shortening sail, otherwise it seems unlikely that the rig would have become widely adopted due to its inherent danger in strong or changeable wind conditions.

The earliest unequivocal depiction of a lateen/settee rig (V32) does not depict a sail rigged with brails (Pomey 2006: 329). Instead a row of reefing points (a reef-band) is visible below, but not parallel to, the head of the sail (*ibid*). The furled up foot of the sail implies that a second reef-band was located near to the foot of the sail (*ibid*). It is interesting to note that the way the artist has shown the furled portion of the sail in V32 is very similar to the convention used by the artist of V35 for showing a furled up sail, despite their separation by some 400 years. The depiction of a reef-band in V32 is the earliest known evidence of this system for shortening sail. The practice of reefing sail simply involves rolling up an area of sail below the reef-band, up to the level of the reef-band. Reefing lines, sewn into both faces of the sail are then tied together around the rolled up portion of the sail, securing it. Like the contemporary system of brails, reefing a sail uses the idea of raising and securing a portion of the sail in order to reduce the overall size of the sail. Although more demanding in terms of time and manpower, reefing removes the need to manufacture and rig a comprehensive system of brail-lines and brail-rings. In any case, brails are likely to have been incompatible with the system of sail-handling used on antique lateen/settee rigged vessels (below - 2.2.6).

Reef-bands at the head and foot of the sail were still in use on Mediterranean lateen/settee rigged vessels during the 20th century (Gillmer 1994: chapter 4; Moore 1925: chapter 4). Such reef-bands are not parallel with either the head or the foot of the sail, but lie at an angle between the two, Pomey (2006: 329) sees their diagonal alignment as characteristic of lateen sails. Certainly, square-sail vessels rigged with reef-bands always have them aligned parallel to the head and foot of the sail, this maintains the rectangular shape of the sail when reefed. The presence of a reef-band at the head and foot of the sail on both ancient and modern Mediterranean lateen/settee rigged ships has a functional explanation. Positioning a reef-band above the foot of the sail allows sail to be shortened without the need to send men aloft or to lower the sail (also an advantage of brails). However, because the head of the lateen sail is its longest edge positioning a reef-band below the head of the sail allows for the greatest reduction in sail area to be made (Moore 1925: 90). Reefing along the head of the sail would obviously require men to be sent aloft or the yard to be lowered.

Indian Ocean craft rigged with settee sails operate a quite different technique for shortening sail. The sails themselves cannot be altered in size by brailing, reefing or any similar system

(Dimmock 1946: 37; Facey 1991: 113; Glidden 1942: 70; Hornell 1942: 11; Hourani 1951: 109; Moore 1920b; Villiers 1962a: 121). Instead vessels carry a suite of differently sized sails to cope with different wind conditions (Dimmock 1946: 37; Hornell 1942: 11; Villiers 1940: 121, 125-6; Weismann 1998: 246). In light winds the largest of these sails is used, if the wind increases in strength the yard and sail are lowered, the sail is removed, a smaller one attached and the yard and sail re-hoisted. On large ships, such as the Kuwaiti boom *Bayen* on which Villiers sailed, changing sails could take up to two hours to complete (Villiers 1940: 126). Compared to brailing or even reefing the Indian Ocean technique for shortening sail cannot be carried out quickly or in response to rapidly changing weather conditions. However, as Villiers points out, modern Arab sailors try to maximise the favourable, predictable nature of the monsoon winds and nearly always sail with a fair wind (Villiers 1940: 51). The presence of reefing points on V32 suggests that Mediterranean sailors opted to shorten sail on early lateen/settee rigged vessels by reefing. The more unpredictable nature of Mediterranean weather, when compared to the generally favourable monsoon conditions of the Indian Ocean may have influenced this choice of technique.

2.2.4 Halyards

The most significant rigging component on a lateen/settee rigged ship is the halyard system (Figure 2-18). It has drawn the most comment from ethnographic observers and is consistently depicted by artists on early iconographic examples of lateen/settee rigged vessels. The halyard itself fulfils a dual role on the settee rigged craft of the Indian Ocean where it serves as the backstay as well as providing a means to raise the yard (Hornell 1942: 12; Villiers 1962a: 122; Vosmer 1997: 221). Smaller vessels tend to use a single halyard while larger vessels employ a double halyard (Dimmock 1946: 37). This distinction is simply down to the extra weight of the long yard on the larger vessels requiring increased support from the halyard ropes. Early lateen/settee vessels in the Mediterranean also seem to have employed the halyard in a dual role, acting as a backstay as well. The three earliest depictions (V32-34) all show vessels rigged with a forestay and halyard system running to the stern of the vessel, no dedicated backstay is shown. All three depictions show double halyard systems in use, running to the characteristic mast-head fitting (above). In two cases (V33 & 34) it is clear that the halyard lines pass through the masthead (presumably running on sheaves) before continuing to the yard, where they are attached (c.f. Mathews 2004: 179).

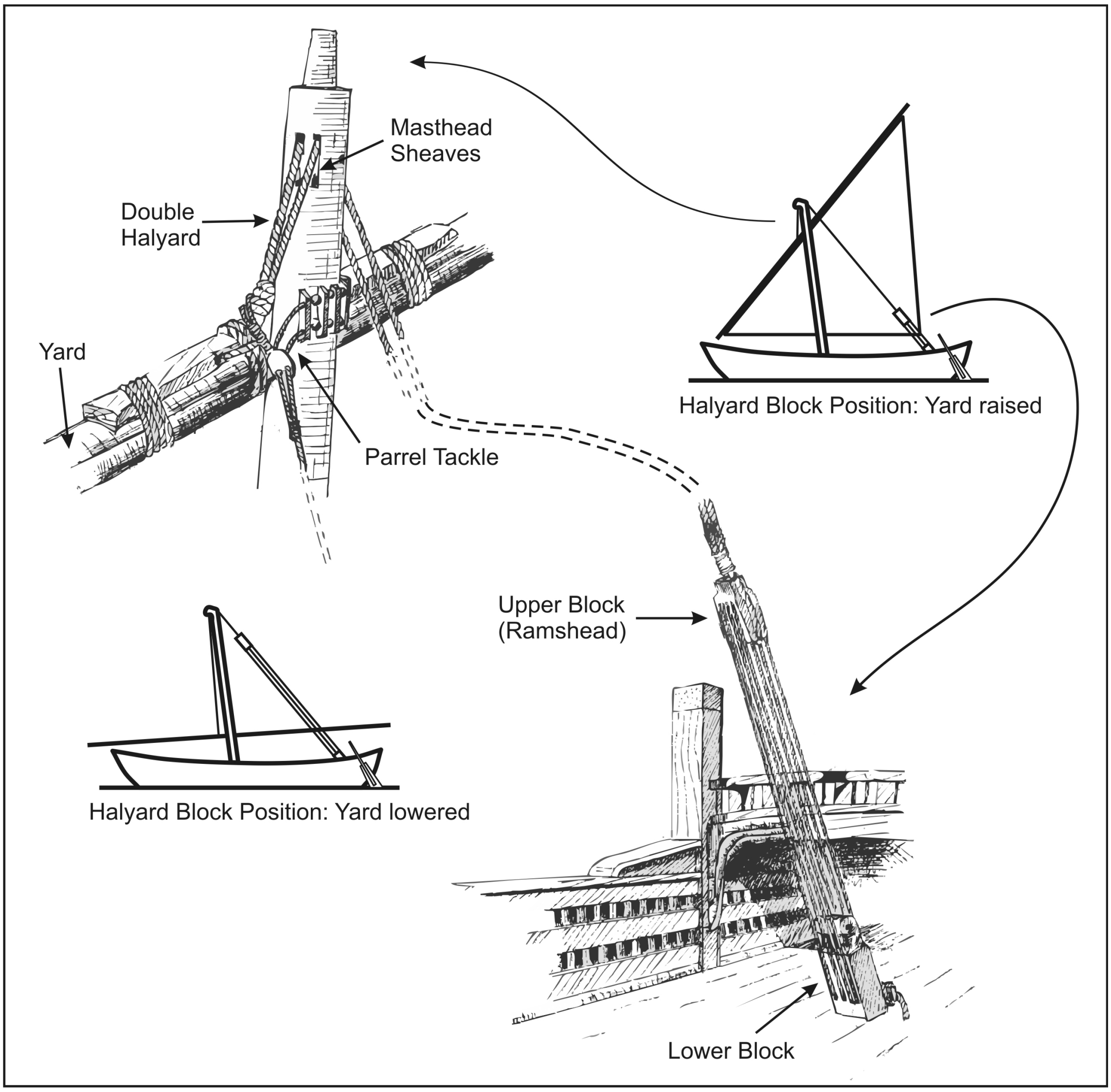

Figure 2-18. Rigging details of lateen/settee rigged vessels. The various elements of the characteristic halyard system are shown in the top-left and bottom-right. The relative positions of the yard and upper halyard block when the yard is either raised or lowered are shown in the top-right and bottom-left respectively (top-left and bottom-right drawings after Johnstone & Muir 1964: Fig. 10 & 21).

The halyard system observed in the Indian Ocean and depicted on early Mediterranean lateen/settee rigged vessels was also utilised by modern Mediterranean lateen/settee rigged vessels (see Moore 1925: 98-9). The following generic description is based on accounts from the Indian Ocean and the Mediterranean, it provides the basis for understanding the halyards depicted in the earliest iconographic examples of lateen/settee rigged vessels. The halyard (either single or double) passes through sheaves in the mast-head and the forward end is made off around the yard. The aft end of the halyard is then secured to the upper of a pair of blocks which form the halyard tackle and provide the purchase required to raise the yard. The upper block (sometimes referred to as the *ramshead* (Moore 1925: 98)) usually has a transverse hole bored in its upper portion to allow the halyard to pass through it. The lower block of the pair is secured to the deck and remains static. Some variations on this general arrangement can be expected. The halyard rope may pass around the *ramshead* before being secured, rather than through it. Moore (1925: 99) observed another Mediterranean vessel with a double halyard which used two individual blocks, one for each halyard, rather than one block attached to both halyards.

The mobile nature of the *ramshead* means that it follows the movement of the yard (Figure 2-18). When the yard is lowered the *ramshead* moves toward the masthead as the rope comprising the tackle connecting the upper and lower blocks is let out. When the yard is at its lowest point the *ramshead* is at its highest. The situation is reversed when the yard is raised; as the tackle connecting the two blocks is hauled in, the upper block moves downwards towards the deck hauling the yard towards the masthead. The process of raising the yard on the ocean going boom *Bayen* could take as long as an hour (Villiers 1940: 24). The consistent position of the *ramshead* relative to the yard position can perhaps serve to give some idea of the accuracy with which artists portrayed vessels rigged with lateen or settee sails in late-antiquity. The mosaic from Kelenderis (V32) shows the halyard block in its correct position relative to the yard, as does the graffito from Kellia (V34). The artist responsible for V35 is less accurate; two crew members are shown raising the yard, which has reached the masthead, however, the *ramshead* is also near the masthead. This must be interpreted as an artistic error. The same situation occurs with the settee rigged vessel V37 where yard and *ramshead* are both shown near the masthead. The final depiction (V33) is more ambiguous, the *ramshead* block is missing but the inclusion of multiple lines near to the aft side of the masthead give the impression that the block as at its highest point. As the yard appears to be lowered on this vessel such a scenario would make sense.

Examples of halyard blocks found *in-situ* in the archaeological record are rare. The definitive example comes from the wreck of the Serçe Limani ship (S045), dating to c. AD 1025 (Bass*, et al.* 2004: 4). The remains of a triple-sheaved block which exactly fit the illustrations and descriptions of halyard blocks given by modern authors was excavated from the bow of the vessel (see appendix 1). The block has been interpreted as representing the remains of one of the halyard blocks from the foremast of the vessel (Mathews 2004: 178). A large sheave, too big to fit the foremast block, was located toward the stern of the ship and suggests the presence of a second, larger pair of blocks serving the mainmast. The rig of the Serçe Limani shipwreck and in particular the halyard system provides a clear link between early depictions of lateen/settee rigged shipping in the Mediterranean and those observed during more recent times in the Indian Ocean and Mediterranean.

2.2.5 Running & standing rigging

A further characteristic feature of the Indian Ocean settee rigged ships observed during the last century is the absence of rigging components which a European sailor would classify as standing rigging (Dimmock 1946: 37; Moore 1925: 130). This statement requires a little more clarification however. It is certainly true to say that there is not the standing rigging, particularly shrouds, which can be seen on the systematically categorized rigging of Western Europe and which is identifiable on the Roman square-sail rig (ch. 2.1.3). However, this does not mean that the mast is left un-stayed and un-supported. The rigging which serves to support the mast also fulfils other, additional functions and simply does not fit the specific descriptions favoured by modern western sailors and maritime scholars. The situation is perhaps summed up best by Villiers (1940: 121), who writes; “As for rigging, none of this is standing, in the sense of being fixed and having only one purpose, and one place.” The reality of the situation is that while there may be no permanently rigged shrouds and stays, the flexible nature of the running rigging of the Indian Ocean settee rig means that it can double up to support the mast as well.

Early imagery of lateen/settee rigged ships from the Mediterranean consistently includes the characteristic halyard system in the rigging depicted by the artist (V032-34). Other areas of the rigging are far more ambiguous; certainly there are no easily identifiable components such as shrouds or deadeyes as there are with images of Roman square-sail vessels. Yet masts must have had some form of lateral support. The absence of such elements in the iconographic record may indicate that, like their modern Indian Ocean counterparts, the Mediterranean lateen/settee sailors of late-antiquity utilised a far more informal system of standing rigging than their square-sail contemporaries. With this in mind it is pertinent to study the standing and running rigging of documented lateen/settee rigged vessels in an attempt to shed some light on their forerunners. This is done in the following section moving from the stern of a vessel to its bow and covering what a western sailor would describe as standing rigging and running rigging.

Backstays

The most obvious multi-purpose component is the halyard system (2.2.4) which also serves as the vessel’s backstay (Figure 2-19). The base of the halyard system of early Mediterranean lateen/settee rigged vessels is generally located by artists towards the stern of vessels and no backstay is shown on any of the examples. This indicates that the halyard system of these vessels also fulfilled the role of the backstay in supporting the mast as well as raising the yard. The likelihood of the halyard system of these early vessels carrying out a dual role is corroborated by later evidence. Mediterranean lateen/settee rigged ships of both Christian and Islamic origin depicted during the medieval period also lack a dedicated backstay (for examples see Landstrom 1978:50-60; Nicolle 1989: 168-183; Pryor 1994) as do those recorded in the 18th

century (Chapman 1768: plate 62, No. 16), the early 19th century (see Gillmer 1994: Fig 4-49 & 4-51) and observed in the early 20th century (Moore 1925: chapter 4).

Running stays

As noted above, the Indian Ocean settee sail has no standing rigging which would fall under the western definition of shrouds. However, as well as the halyard and parrel which are used to support the mast as secondary roles to their primary function of setting the yard, there are also several movable blocks and tackles which fulfil a variety of functions. Johnstone and Muir (1964) refer to them simply as shifting stays or 'runners' and this is probably the simplest name to call them. In form they are all identical, the masthead end is eye-spliced and the eye is placed over the masthead. The lower blocks are in turn made about with a strop and a toggle is spliced or tied through the end. This toggle is passed through a loop of rope made off to the side of the vessel. The fall of the line from the block can then be made off around it, once it has been tensioned (Villiers 1962a: 122). A fragment from this area of the rig has been excavated from an Islamic context at the medieval port of Quseir al-Qadim on the Red Sea. The find comprised a wooden toggle and a small amount of cordage from the running stay of a small vessel. In this instance the rope was attached to the toggle using a spar hitch, an identical arrangement can be seen on a historic vessel located in the Ottoman fort at the modern town of Quseir.

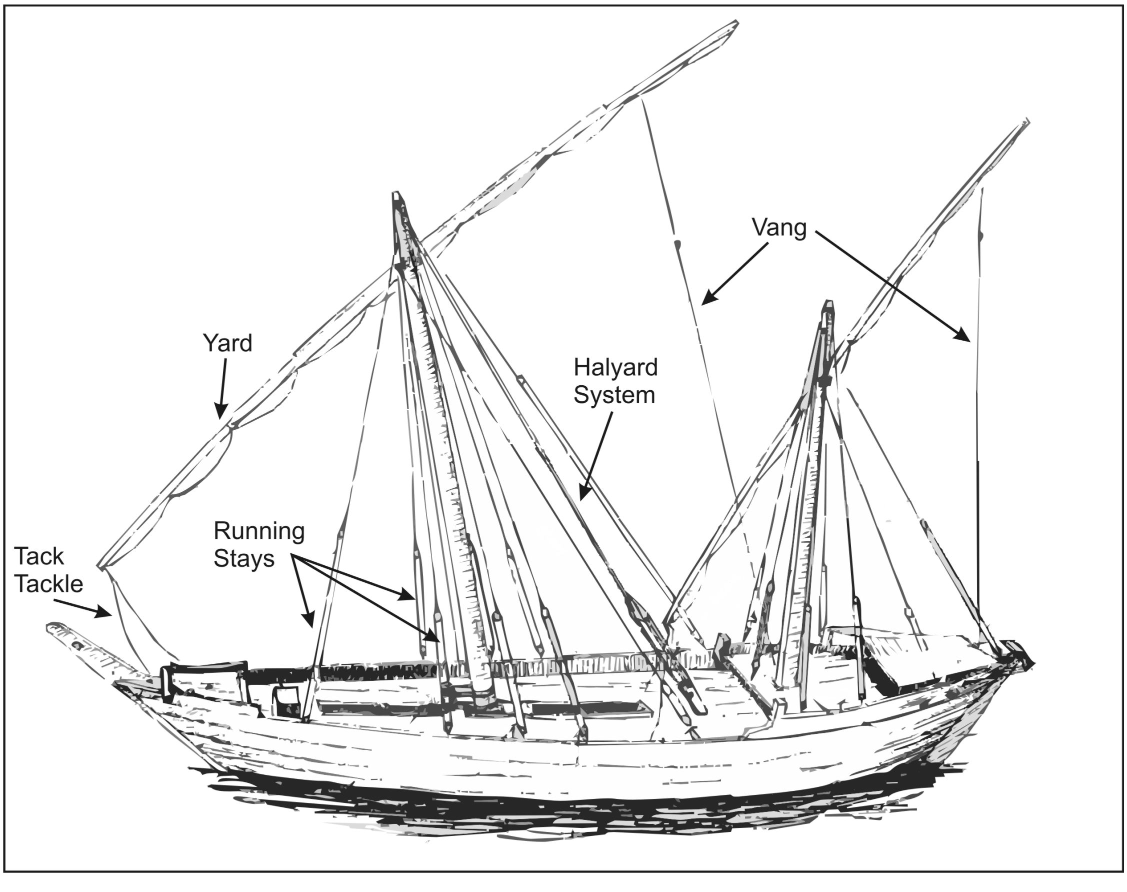

Figure 2-19. Generic rigging of a settee rigged Kuwaiti Boom (after Johnstone & Muir 1964: Fig. 3).

The Kuwaiti boom *Bayen*, upon which Villiers sailed, had three such running stays to each side (Villiers 1962a: 122) although larger vessels could easily have more and smaller ones fewer (c.f. Figure 2-19). The settee rigged vessels of Lamu observed by Prins (1965: 106), were generally smaller than Bayen and were rigged with two running stays per side. When under sail the running stays on the windward side are always set up (*ibid*), so as to provide support to the mast in the manner of shrouds on a western European sailing vessel. Meanwhile the running stays to leeward, which would obstruct the sail if left set up, are instead allowed to lie up and down the mast on the windward side of the yard (Dimmock 1946: 40). This is significant. By remaining to windward of the yard, the lee running stays remain free to be set up once the process of wearing ship begins (2.2.6). In the meantime they do not inhibit the movement of yard and sail by being rigged on the side of the vessel where they are not currently required. One of the running stays can be set up forward of the mast to assume the role of the forestay (Moore 1925: 130). All the running stays are shifted from place to place according to the relative direction of the wind and the position of the yard, consequently there is some variation in the precise role that each plays (Johnstone & Muir 1964: 315). Villiers (1962a: 121) notes that there is no gear dedicated to handling the sail itself. All the rigging is there to support the mast and handle the yard

Some idea of the schematic appearance of an Indian Ocean settee rigged vessel and the likely position of its running stays can be gained from Figure 2-19. This diagram can be usefully compared to some of the early iconography of lateen/settee rigged vessels from the Mediterranean (V35-37). In these depictions rigging similar to the running stays used by Indian Ocean craft is shown supporting the vessels mast. On the same theme it is worth recording that Moore (1925: 109) in his description of settee rigged Maltese vessels notes that their masts are "supported on each side by a runner and tackle, and abaft it by a shroud set up with a tackle." This infers that the lateral supports of the masts were not permanently rigged in the manner of shrouds with deadeyes, but with temporary lines, blocks and tackles which could be moved around the vessel. The Mediterranean method of providing lateral support to a lateen/settee rigged vessel's mast may not have been very far removed from the technique used in the Indian Ocean in recent times.

Forestays

As well as lacking a dedicated backstay, Indian Ocean settee rigged ships also lack a dedicated forestay. On points of sailing where a forestay is required (such as sailing to windward) one of the running stays is utilised in that position. A permanently rigged forestay is not compatible with the technique used for handling the yard and sail when going about (2.2.6). Consequently a forestay is only set up if required and *after* the yard has been transferred to the leeward side of the vessel. Early Mediterranean lateen/settee rigged vessels (V32-34) are all depicted with an obvious forestay running from the masthead to the bow of the vessel. This mirrors the forestays seen on earlier depictions of Mediterranean square-sail vessels (ch. 2.1.3).

It is difficult to ascertain whether this feature was permanently rigged or set up once the vessel was under way. Only in V33 in which the yard is lowered and the forestay is still depicted can we conclude that the forestay may have been rigged permanently. Even then, the artist may have chosen to include the forestay at a moment when it would not normally have been rigged (with the yard lowered). The three later examples (V35-37) all have lines running from the masthead to a forward position (although not right to the bow of the vessel) also suggesting the use of a forestay. In the five examples where a forestay is shown with a raised sail, the forestay and halyard/backstay are both shown on the windward side of the sail. Iconographic evidence indicates that forestays were rigged on early lateen/settee rigged ships in Mediterranean waters. What remains unclear is whether or not these stays were rigged permanently or only when the sailing course required it. It is important to differentiate between a permanent and temporary forestay because of the subsequent implications regarding sail handling techniques (2.2.6).

Running rigging

The rigging components described above all operate to support the mast at the same time as fulfilling other functions, such as raising the yard. Their observed function on recent Indian Ocean and Mediterranean lateen/settee rigged craft seem to correlate with the current evidence for early Mediterranean lateen/settee rigged vessels. Although the evidence for the latter is currently derived mainly from iconographic evidence. In conjunction with the rigging which supports the mast, lateen/settee rigged vessels from all periods are rigged with components to facilitate control of the yard and sail which can be described as true running rigging. Foremost amongst these are the sheets, attached to the clew of the sail and crucial to its control, trim and efficient use. Although fundamental to the operation of the vessel they are often omitted from iconographic depictions or occur in areas of the vessel not depicted or hidden from view (e.g. V32, 35 & 37). However, the presence of sheets can be safely assumed due to the impossibility of operating a sailing rig without them.

Vangs

Frequently depicted rigging components in the iconographic record of the Mediterranean square-sail are the braces used to control the position of the yard relative to the wind (ch. 2.1.4). This part of the rig appears on nearly every documented example of a square-sail from all over the world and is crucial to the operation of the rig. The lateen/settee rig also requires a means to control the upper end of the yard, but because of the asymmetric plan of the sail only one brace is required. Although fulfilling the same function as the brace of a square-sail it is usually referred to as a *vang* when operated on a lateen/settee rig (Johnstone & Muir 1964: 310; Moore 1925: 98, 117 & 132; Villiers 1962a: 122). It is convenient to retain this nomenclature as a way of distinguishing between the brace of a square-sail and the vang of a lateen/settee sail (c.f. Johnstone & Muir 1964: 310).

On modern Indian Ocean vessels the vang is attached to the yard about halfway between the peak of the sail and the halyard (Figure 2-19) (Johnstone & Muir 1964: 310; Villiers 1962a: 122). Reference to images of 19th century lateen rigged ships in the Mediterranean confirms that vangs were attached in a similar position there (Gillmer 1994: Fig. 4-51; Roberts 1855-56: pl. 17). Such an attachment point can also be seen on V35 where a double vang is clearly visible roughly midway between the masthead and the peak of the sail. The use of a double vang is also consistent with modern Mediterranean lateen/settee rigged vessels observed by Moore (1925: 98). The lateen rigged ship from Kellia (V34) is drawn with line running from the yard to the deck of the vessel which strongly suggests the presence of a vang on this depiction. Like the brace on a square-sail vessel, the main function of the vang was to maintain control of the yard from the deck of the vessel, especially during manoeuvres (below 2.2.6). It is also recorded by Johnstone & Muir (1964: 310) as helping to prevent the yard falling away to leeward when under sail. In these respects, but especially the former, it is fundamental to the operation of the vessel and it is hard to see how a large ship could have sailed successfully without it. Like the sheets and braces of Mediterranean square-sail vessels (chapter 2.1.4), the presence of a vang can probably be safely assumed, especially on large vessels, even if it is not shown in every iconographic depiction (e.g. V32 & 37).

Tack-tackles

The lower end of the long lateen/settee yard also requires a form of control. This comes in the form of a set of block and tackles attached to the bottom end of the yard on a lateen and to the tack of the sail on a settee (Figure 2-19) (Johnstone & Muir 1964: 306). Known as tack-tackles they are visible on V35 and V37. Interestingly in V37 and contrary to Johnstone and Muir's distinction between the attachment points of lateen or settee sails, the tack-tackle is attached to the yard, rather than the sail. The tack-tackle itself operates to provide the crew with extra purchase when moving the lower end of the yard around the foredeck of the vessel. It also provides the means to secure the forward end of the yard and sail to the vessel. Its position is not fixed, but alters in accordance with the course being sailed (below 2.2.6). In smaller vessels the tack-tackle may comprise only a single rope, while on larger ships the weight and cumbersome nature of the yard, due to its great length dictates that a set of block and tackles will be used. While not always depicted (e.g. V32 & 34) some form of tack-tackle must have been used in order for the rig to operate successfully.

2.2.6 Sail handling

In order to complete this investigation into the characteristics of early Mediterranean lateen/settee rigged vessels, a study of the potential techniques and practices used to handle the rig must also be undertaken. Evidence from the ancient Mediterranean is limited to three iconographic depictions (V32-34) dating between the mid 5th century AD and the early 7th century AD and three comparative depictions from the 9th century AD (V35-37). This evidence was important in drawing conclusions regarding the component parts of the ancient lateen/settee rig (above). Without knowing what the constituent parts of a sailing rig are, it is impossible to speculate how such a rig may have been used and what its potential performance may have been. The investigation into the rigging of these vessels (above) indicates a high correlation between the components found on modern vessels and those depicted in the iconography. The sparse nature of the evidence from the ancient world regarding sail handling means that recent observations of lateen/settee rigged vessels from the Mediterranean and Indian Ocean regions must again be utilised. Combining this with the known characteristics of the ancient lateen/settee rig presents the best opportunity for understanding the operation of this particular sailing rig in the ancient world.

Downwind sailing

Moore (1925: 100-101) notes four different ways to set a lateen/settee sail when sailing downwind. All result in a different appearance to the vessel from the perspective of an external viewer (Figure 2-20). Images of Mediterranean lateen/settee rigged vessels from the medieval period show ships unmistakeably sailing on downwind courses with the yards seemingly squared across the vessel in a manner similar to Figure 2-20b. In this example (V38) the yard is peaked and the tack-tackle runs to the stern of the vessel to aid in the control of the lower half of the yard. In another example (V39), a vessel with a hook-shaped masthead and nearly triangular sail has a horizontally set yard. The horizontal position of the yard combined with other characteristically lateen/settee rig features infers a vessel running downwind. In both of these examples the sail is set before the mast The combination of lateen/settee rig and horizontal yards, indicative of a downwind course also occurs in medieval Islamic depictions of lateen/settee rigged vessels of Mediterranean origin (see Nicolle 1989: fig. 13, 18, 19 & 22). The practice is also referred to by Ibn Jubayr with reference to the Genoese ship that he sailed on from Acre to Messina in the winter of AD 1184/5 (tr. Broadhurst 1952: 313 & 332).

It is clear from reference to Figure 2-20 that when running downwind the sail is set across the vessel and is handled in the manner of a square-sail (Dimmock 1946: 40). To do this the tack of the *sail* has to be brought aft from the bow and the clew allowed to go forward until both are nearly amidships (Johnstone & Muir 1964: 306-8). As the vessel changes course and sails closer to the wind the tack is taken forwards and the clew is moved aft. This process continues until the vessel is close-hauled when the tack and clew are at their maximum distance apart and the sail lies nearly along the fore-and-aft line of the vessel. Although the lateen/settee is classified as a fore-and-aft rig at least some of the practices and techniques used in its operation, such as downwind sailing, would be familiar to both lateen/settee sailors and square-sail sailors (c.f. Figure 2-12).

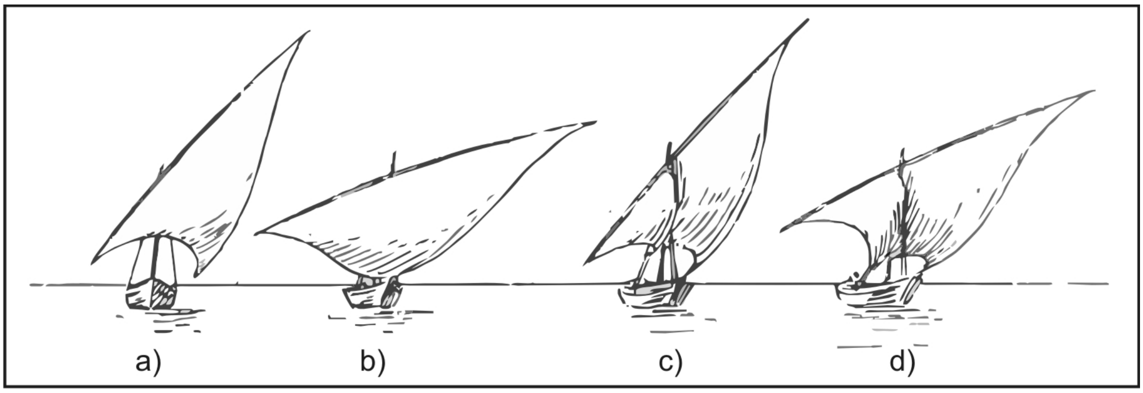

Figure 2-20. Lateen/settee yard positions when sailing downwind. a) Yard and sail before the mast with the yard peaked. b) Yard and sail before the mast and the tack eased until the yard is nearly horizontal. c) Yard and sail abaft the mast with the yard peaked. d) Yard and sail abaft the mast and the tack eased (after Moore 1925: Fig. 105).

Going-about

Sail-form has the greatest impact on the practice and techniques used to operate a sailing rig when the vessel changes course. Particularly when it changes from a port tack to a starboard tack (and vice-versa), bringing the wind to bear on the opposite side of the vessel than before. A modern fore-and-aft sail, such as gaff, gunter or bermudan sail is easy to use in this situation. These sails are all attached to the mast at their forward end and pivot about this point, consequently they can be moved easily across the vessel to the other side. The square-sail also represents a relatively simple solution to the problem. Because it is symmetrical it can be swung around the front of the mast as the vessel goes through the wind. What was the clew on one course becomes the tack on another. The lateen and the settee rig both share common characteristics which complicate their use; they are asymmetrical, so clew and tack have to retain their functions, they cannot be swapped over in the manner of a square sail. Instead the sail must be moved to the other side of the mast and still retain its orientation, the tack must remain as the tack and the clew as the clew (c.f. ch. 3.6). The transfer from one side to another is the point at which modern Mediterranean and Indian Ocean lateen/settee sail handling practices diverge.

The technique used in the Indian Ocean would seem to be unique to vessels of that region. Furthermore the same technique is consistently reported, despite differing cultural backgrounds and beliefs amongst sailors from different locations. The Indian Ocean settee is generally rigged on the leeward side of the mast (Moore 1925: 117). When the vessel changes tack the sail is transferred to the opposite side of the vessel, thereby remaining to leeward of the mast. Vessels are invariably 'worn about' (gybed) away from the wind rather than being tacked through the wind (c.f. Figure 2-13) (de Monfried 1935: 127; Moore 1925: 132; Villiers 1940: 30). The main reason for this is to prevent the large mainsail from being taken aback against the mast. The permanent nature of the halyard/backstay system dictates that the sail has to be transferred around the front of the mast. The presence of a forestay would greatly hinder this operation so it is easier to remove it while the yard is moved. The absence of the forestay and presence of a backstay means that it makes far more sense to turn the stern of the vessel through the wind (wearing ship) rather than the bow. The lack of a permanently rigged forestay means that the pressure of the sail on an unstayed mast could easily damage the mast. Once the operation is complete, one or more of the running stays can again be rigged in place of a forestay.

Both Dimmock (1946: 41) and Villiers (1940; 1962a) record the sequence of events for a Kuwaiti vessel to wear, while Prins (1965: 237-238) recounts an identical sequence for vessels from Lamu. This seemingly generic technique is illustrated in Figure 2-21. As the vessel bears away, the yard is brought to a vertical position and the sail is bundled and secured to the mast with the clew (Figure 2-21b&c). The running stays on the lee side of the vessel which until now have been unused are set up to act as shrouds. This cannot be done until the sail is made up to the mast. The yard is then swung around the front of the mast, facilitated by the forward rake of the mast (Figure 2-21d). At this point the parrel has to have been loosened to allow the yard to swing freely about, while remaining hoisted. The yard twists on its loosed parrel and the whole sail 'throws itself over' (Villiers 1962a: 123), this process is aided by the three or four men who 'gallop around with the mainsheet' (*ibid*). Further help is given by three more men who man the vang, as the peak of the yard rolls over to leeward they haul the vang to help swing the yard across (*ibid*). Once the yard has swung across, the sail can be unfurled and the tack made fast, the clew and the sheet can then be set to the desired position for the new course (Figure 2-21e). Moore (1925: 135) and Villiers (1961: 253) both observe that surprisingly little ground is lost by wearing the vessel around in this fashion. Occasionally, when only very short tacks have to be made the sail is left to windward and sailed aback the mast (Dimmock 1946: 40; Johnstone & Muir 1964: 307). Although this leads to the sail working less efficiently on one tack than the other it reduces what little ground might be lost while wearing ship (Dimmock 1946: 40).

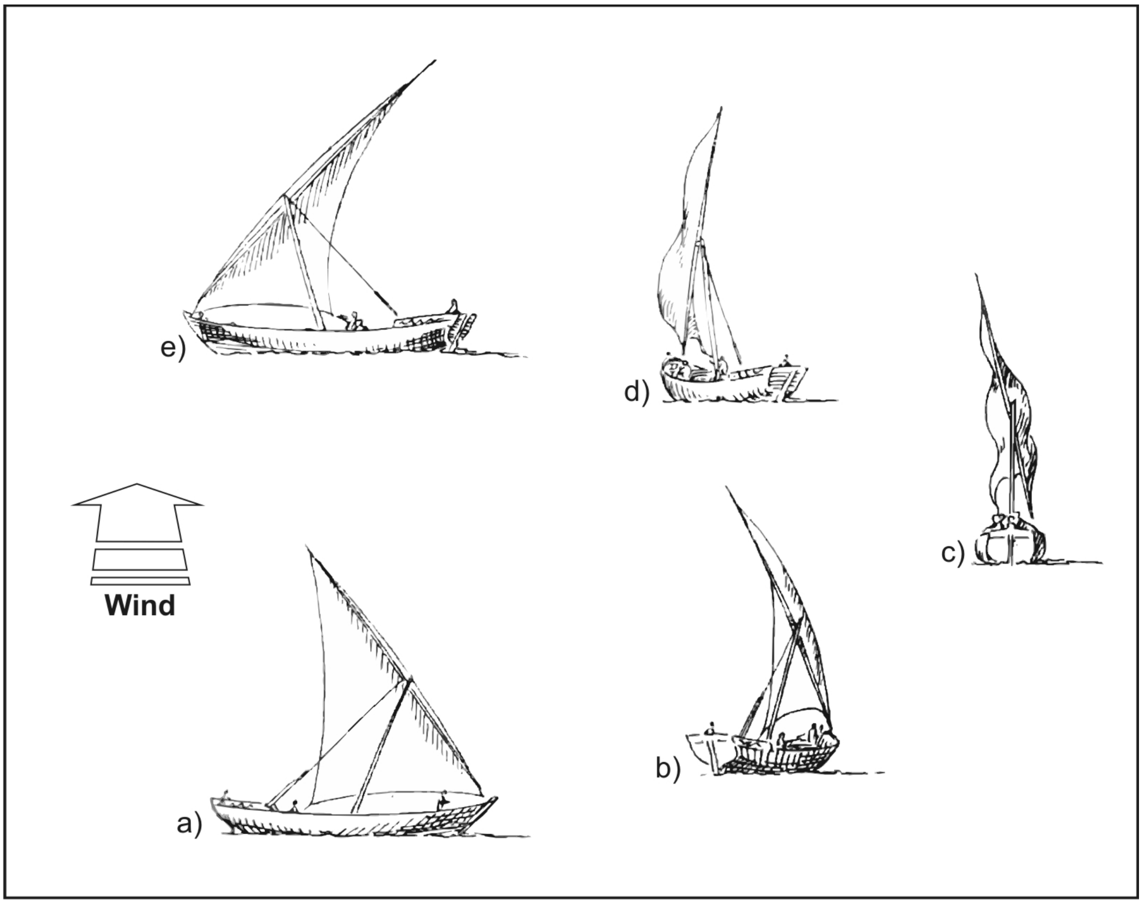

Figure 2-21. Lateen/settee rigged vessel wearing ship using the Indian Ocean technique. a) Reaching on a starboard tack. b) Bearing away. c) Yard brought to the vertical position. d) Yard transferred across. e) Sail unfurled and sheeted home on a port tack (rig positions derived from Moore 1925: Fig 131).

Modern Mediterranean lateen/settee rigged vessels use a distinctly different technique when going about. The yard and sail is only ever hoisted on one side of the mast. When the vessel goes about, either through tacking or wearing the yard and sail remain on that side. The sail is therefore to leeward of the mast on one tack and to windward of it on the other (Moore 1925: 217). One easily observable result of this is that the portion of the sail forward of the mast becomes much less efficient than it would usually be. If a vessel is two-masted it may well have the two sails hoisted on the opposite side of the mast. Two-masted, settee-rigged Maltese boats always hoist the foresail to port and the mainsail to starboard (Moore 1925: 109), this ensures that one sail is always potentially operating at it most efficient. Another result of not transferring yard and sail is that they can be set up inside any standing rigging, i.e. between the shrouds and the mast. Shrouds and forestays can be permanently rigged because the yard does not need to travel around the front of the mast.

Setting the sail inside the standing rigging potentially allows the sail to be sheeted closer to the centre-line of the vessel because there are no shrouds to interfere with the foot of the sail. The problem of shroud interference is bypassed in the Indian Ocean technique through the use of running stays; those to leeward lie along the mast and so do not interfere with the sail, they are set up when needed. It is informative that the practice of sailing with the forepart of the sail deliberately aback the mast is known amongst Indian Ocean sailors, but is only used in specific circumstances. When sailing on downwind courses the Mediterranean practice of setting the yard on only one side of the mast dictates that on one tack the yard and sail will be set across the vessel but behind the mast, in the manner of Figure 2-20c&d. On the other the yard will be free to swing in front of the mast, however it will be inhibited from lying fully across the vessel by the leeward set of shrouds.

The lateen/settee sail in the ancient Mediterranean

Two different techniques for operating a lateen/settee rig exist in the two regions where the sail has remained in commercial use; the Mediterranean technique of sailing with yard and sail aback the mast on one tack and the Indian Ocean technique of swapping sides by transferring yard and sail around the front of the mast. The question of whether or not either of these techniques is applicable to the lateen/settee rigs of the ancient Mediterranean, or if an alternative technique was in use in late-antiquity must now be addressed.

The strongest indication of the sail handling used in antiquity comes from observing the correlation of known lateen/settee characteristics with identifiable sailing courses in medieval Mediterranean iconography. In the instances where vessels can be identified as sailing downwind (e.g. V38-39) the yards are clearly shown in front of both mast and any rigging set up to support the mast. In both instances the vessels are also shown with the hook-shaped masthead characteristic of late-antique lateen/settee rigged ships. The significance of this is not obvious until attention is paid to the mastheads and yard position of late-medieval lateen/settee rigged vessels. Depictions dating to the 14th century AD clearly show vessels sailing downwind with the yard and sail aback the mast or with the sail hoisted *between* the mast and its supporting shrouds (Landstrom 1978: 54-59, fig. 123,125 & 133; Pryor 1994: 71, 73). In each case the hook-shaped masthead has been replaced with a barrel like structure more reminiscent of a traditional ‘crows-nest’. The implication of this is that the hook-shaped masthead is associated with a sail-handling technique which places the sail outside the running stays, in front of the mast when sailing downwind and which would allow the yard and sail to swing around the front of the mast when wearing ship. The approach corresponds with the technique used in the Indian Ocean. Vessels depicted with yard and sail inside the shrouds and aback the mast are associated with vessels with barrel-topped mastheads. A technique which seems to be continued in the Mediterranean to the present day. The continuity of hook-shaped mastheads between medieval and late-antique lateen/settee rigged vessels suggests that the latter also shared a sail-handling technique with the former. In which case it can be concluded that late-antique and early-medieval lateen/settee rigged vessels were sailed using similar techniques to modern Indian Ocean lateen/settee rigged vessels

The possibility that the hook-shaped masthead facilitated the transfer of yard and sail around the front of the mast by allowing the yard to hang clear of the mast has been noted by some scholars (Pryor 1994: 71; Villain-Gandossi 1994: 169). Such a system has far more in common with the Indian Ocean technique of sail handling than the one currently used in the Mediterranean which the iconography suggests was used from the 14th century AD. The idea that the hook-shaped masthead allows the yard to hang clear of the mast is also vindicated by the Indian Ocean technique. The same effect is achieved on modern Indian Ocean vessels by raking the mast forwards. The presence of hook-shaped mastheads on the earliest known examples of Mediterranean lateen/settee sails implies continuity in the form of rigging components between the late-antique and medieval periods. It is not unreasonable to assume that the same sail handling practice seen in medieval depictions of vessels with hook-shaped mastheads was similar to that used on their late-antique counterparts. The invention of a new system for shortening sail, using a reefing band, also fits this assumption. The invention of reefing points as a means to shorten sail corresponds with a method of sail handling in which yard and sail are fully mobile to move around the mast and for the windward and leeward faces of the sail to invert when on different tacks. Utilising reefing points incorporates the system for shortening sail *into* the sail, unlike brails which are an *additional* system attached and restricted to one face of the sail. By contrast, the Mediterranean system of brails would simply have been too unwieldy to transport around the mast with the yard because such a system would also need to be inverted on every other tack between the windward and leeward face of the sail. However, it could have been used with the modern Mediterranean lateen/settee sail-handling technique because the yard is not transferred around the mast when tacking/wearing

In terms of rig-use, there seems little reason to believe that a settee rigged vessel would have been used any differently to a lateen rigged vessel. An Indian Ocean settee sail with a long luff is handled using the same rigging equipment and practices as a settee with a short luff. The early lateen and settee rigged vessels depicted in the Mediterranean consistently show the same set of rigging components, the assumption must be that they were operated in largely the same way. Certainly there is no reason, at the present time, to believe that they were operated using different techniques, practices and components from one another during antiquity. The currently available evidence suggests that lateen/settee rigged sailing ships in the late-antique Mediterranean were handled in a similar way to Indian Ocean settee rigged vessels observed in the 20th century. The modern Mediterranean technique of sailing with a standing yard, rather than transferring yard and sail around the mast seems to have developed in the late-medieval period and is reflected by identifiable changes to the rigging components depicted in the iconography of lateen/settee rigged vessels.

2.2.7 Conclusion

This chapter has set out to analyse the way in which the ancient lateen/settee sailing rig was used, as well as identifying its constituent rigging components. Such an approach allows a clearer comparison to be made with similarly analysed contemporary Mediterranean square-sail vessels (chapter 2.1). A series of identifiable features can be set out as defining the lateen/settee sail in early iconographic depictions and can predict the likely form of rigging components which may be excavated in the future. The most notable of these is the hook-shaped masthead which appears on all examples of lateen/settee rigged ships well into the medieval period (e.g. V32-39). This feature may be representative of reality or it may simply be a widely used artistic convention for distinguishing lateen/settee rigged vessels from square-sail vessels. The *ramshead* block halyard system is also clearly depicted on early images (V32-34), present in the archaeological record of the 11th century AD and still in use, virtually unchanged, on modern lateen/settee rigged ships in both the Mediterranean and the Indian Ocean. Analysis of the two relevant surviving techniques for using a lateen/settee rig in conjunction with a comparison of features and techniques visible in the iconographic record indicates that late-antique lateen/settee rigged ships utilised a technique similar to that used in the Indian Ocean in the 20th century AD. Finally, depictions of lateen/settee rigged vessels are usually shown with a distinctive sail-form, although this is not consistently the same. Sails can be trapezoidal (with both a short or long luff) triangular with a horizontal foot, or triangular with a horizontal yard, the inclination of the yard may vary in all cases. The variation reflects the concurrent use of two different forms of sail; the lateen and the settee, which can be set in a variety of different ways on different courses.

2.3 The Sailing Potential of Ancient Rigs

"There is no ideal type of sail that is superior on all points of sailing."

- Marchaj (1996: 149).

An often repeated statement in the maritime literature relating to the ancient Mediterranean is that the lateen/settee sail superseded the square-sail because of the superior upwind performance, manoeuvrability and overall speed of the lateen/settee rig in comparison to the square-sail (e.g. Basch 2001: 72; Campbell 1995: 2; Casson 1995: 243; Castro *et al* 2008: 347-8, 351; Hourani 1951: 101; Kingsley 2004a: 78; Kreutz 1976: 81-2; Le Baron-Bowen 1949: 95; Lopez 1959: 71; Makris 2002: 96; McCormick 2001:458; Polzer 2008: 242; Pryor 1994: 67-8; White 1984: 143-4). This assumption, based upon the notion of technological determinism, neatly fits within the theoretical framework which has been widely adopted by maritime scholars who have studied the ancient Mediterranean and Indian Ocean regions (ch. 1.1). Chapters 2.1 and 2.2 characterised the antique square-sail and lateen/settee rig respectively, from the perspective of their rigging components and practical usage. In order to complete the picture of the ancient sailing rig and to establish the validity of claims relating to the superior performance of the lateen/settee rig, an investigation into the potential performance of both the Mediterranean square-sail and lateen/settee sail is required.

2.3.1 Measuring sailing performance

The modern, global yachting industry has accrued a large body of knowledge relating to the bermudan rig currently favoured by most classes of yacht involved in organised racing (Marchaj 1996: 152). In contrast to this, little or no systematic research has been conducted which addresses the relative performance of other, more traditional sailing rigs (*ibid*) including the single-square or lateen/settee rig. Palmer (1986: 178) has observed that the performance of a sailing rig can be measured in three different ways, each of which are subject to different considerations and problems, either generally or in the specific context of the present study:

- Method One - Model experiments in a wind tunnel.
- Method Two - Absolute measurement of the full-scale performance of a vessel.
- Method Three - Comparative measurements of the performance of two identical hulls, each fitted with a different rig.

Problems

Wind tunnel tests are prone to several problems arising from the use of scale models which reduce the reliability of any subsequent predictions relating to full-scale performance (*ibid*). The scaling problems are both structural and aerodynamic. Structural problems arise from characteristics such as stretch of sail cloth and rigging (which have a profound effect on rig performance) being very difficult to reproduce and control at model scale (Palmer 1986: 179).

Likewise, wind tunnel tests utilise constant wind, both in terms of speed and direction. Real wind is far from constant, either in speed or direction (Palmer 1986: 185-7), effects which are very difficult to reproduce in a wind tunnel (Palmer 1986: 178). Smitt (1986: 172) notes that wind tunnel tests always represent optimum conditions, factors such as wave action, variable wind and non-optimum sail setting means that real performance is always less than the test-derived performance.

Method Two, the measurement of the full-scale performance of a sail powered vessel would seem, at first glance, to be the best way to measure vessel performance. The issues of scaling, outlined above, obviously do not apply and it should be possible to test the vessel in a variety of different conditions. However, making reliable measurements of a vessel under full sail is very difficult and plotted results of criteria such a 'speed', 'heading' or 'leeway' tend to exhibit a wide scatter, performance data can often not be deduced to an accuracy of much better than ±25% (Palmer 1986: 180). This obviously reduces the reliability of such tests. The first two methods are also interlinked to a certain extent because the first method relies upon the results obtained in the second method as a form of verification (*ibid*). Palmer (1986: 179) identifies the Method Three, using different rigs on identical hulls in back-to-back tests, as the only practical approach remaining to assess the sailing potential of different rigs. However, this approach requires a substantial investment in capital, time and expertise in order to satisfactorily create and sail a variety of rigs, back to back in a scientifically rigorous fashion.

Existing work

Despite the problems outlined above, a body of work exists which has derived data from all of three different methods. Wind tunnel testing (Method One) has obviously provided the basis for the ongoing refinement of the bermudan rig, but analysis of other rigs is far more limited. Comparative back-to-back wind tunnel tests on a variety of rigs (bermudan, lateen, sprit, gunter, dipping lug and crab-claw) was conducted by Marchaj (1996: 152-176) as a means to compare the performance of different sailing rigs. Unfortunately a square-sail was not included within the tests and the sprit-rig was rigged with a jib, a sail-plan unknown in the ancient world. Consequently, although the tests are revealing, particularly with regard to the fact that the modern bermudan sail is not the supreme rig it is commonly cited as (Marchaj 1996: 158-161), their relevance for this specific study is limited. Wind tunnel tests were conducted at the University of Southampton in 2007 which compared a square-sail and a settee sail (Posnett 2007: 37-39) as part of a wider investigation into predicting the performance of traditional sails (Posnett 2007). These tests concluded that the square-sail could achieve a higher heading angle to the wind, but that in doing so created more drag and would not be as fast as the settee rig at angles above 90° (Posnett 2007: 39). Palmer (pers.comm.) has questioned the validity of the results because the performance figures for the square-sail do not match the expected figures derived from other wind tunnel tests of square-sails (e.g. Matsuyama *et al* 2005). It should also be observed that different fabrics were used for the manufacture of each sail and that this may have affected the results.

A growing body of evidence has recorded the performance of a range of replica vessels rigged with single-masted square-sails (Method Two). The majority of these are north-west European vessels from Anglo-Saxon (Gifford & Gifford 1996), Viking (Englert 2006; Vadstrup 1986; Vinner 1986), Slavic (Gülland 2003) and Hanse (Brandt & Hochkirch 1995) contexts, although trials have also been conducted on two replicas of the Kyrenia shipwreck (S024) (Cariolou 1997; Katzev 1990) and the trireme replica *Olympias* (Morrison *et al.* 2000). A single replica lateen/settee Arab vessel has been built, sailed and published by Severin (1991). Conducting assessments of sail performance has not usually been the primary purpose of replica ships and the voyages of such vessels have not always been measured or completed in a scientifically rigorous or satisfactory fashion. Despite these problems, which are obvious when reading the resulting literature, these vessels have produced a range of data which is of use to this study and which is considered further below. Finally, comparative trials (Method Three) were undertaken by Gifford Technology in 1983 and compared Bermudian, Sprit, Gaff and Lateen rigs in a manner which was both reliable and repeatable (Palmer 1986: 188-193). Unfortunately the tests are of little use to this study because a square-sail was not included. From the antique perspective of this study the results for the lateen and sprit are of questionable use because both rigs included a jib, a sail-plan unknown in the ancient Mediterranean.

2.3.2 Historical voyage analysis and Vmg (velocity made good)

The lack of data relevant to the specific nature of the problem addressed in this study necessitates that a different approach must be used to assess the relative potential performance of the single square-sail and the lateen/settee rig. This study identifies the concept of *velocity made good* (Vmg) as being central to the comparative assessment of appropriate full sized sailing ships, replica or otherwise. Put simply, Vmg is the relative speed of a vessel over a direct course between two points (Figure 2-22). Analysis of Vmg allows the relative performance of two vessels to be compared, independent of factors which are often the source of subjective observation such as leeway or crew efficiency. It is of particular value when attempting to measure the effective speed of a vessel to windward (Englert 2006: 39; c.f. Vinner 1986: 221), an area of particular importance in the context of the present study because of the traditional explanation for the adoption of the lateen/settee sail. Recently, the application of Vmg derived from historical sources has allowed a reassessment of the capability of Roman sailing vessels in the northern Red Sea to be carried out (see Whitewright 2007a). Such an approach is expanded in this study, the data derived for square-sail and lateen/settee rigged vessels is detailed in a series of historical voyages contained in Appendix Four. The results of this analysis are summarised in the remainder of this chapter.

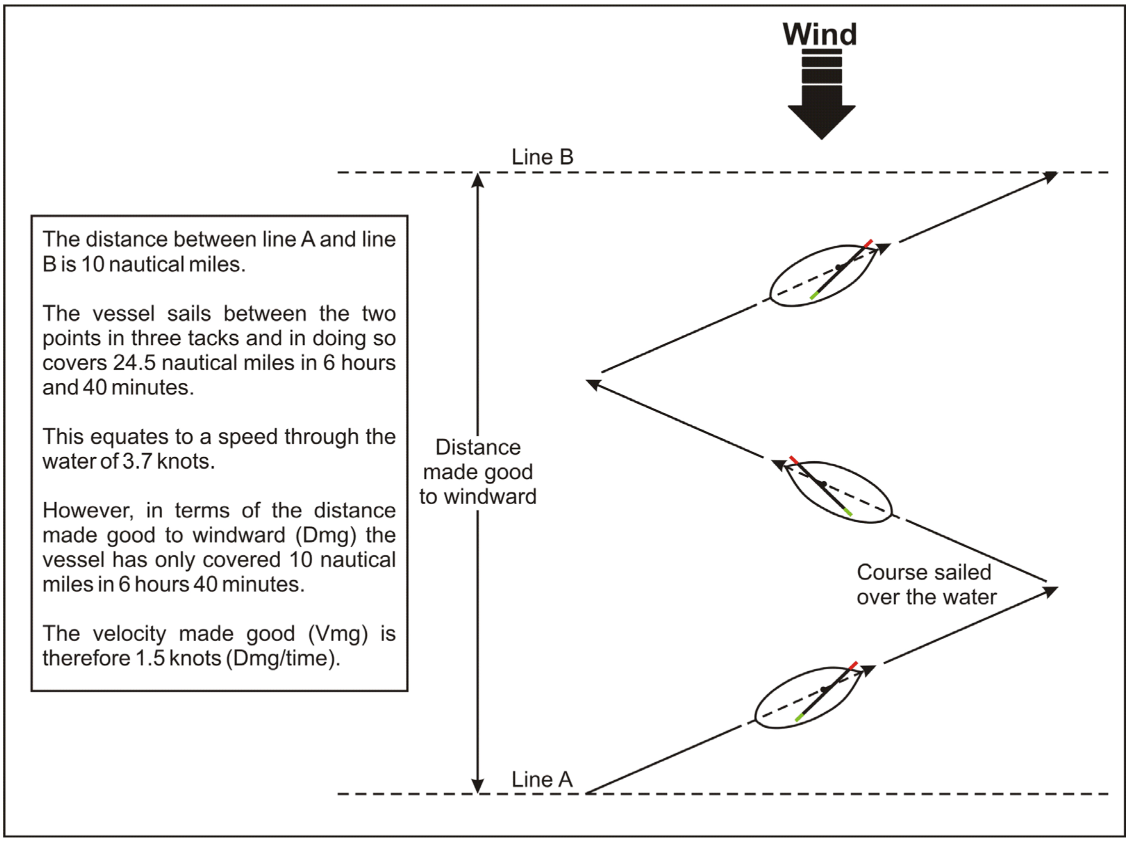

Figure 2-22. Diagrammatic explanation of *Velocity Made Good* (Vmg) (J.Whitewright).

One of the advantages of using velocity made good to compare the performance of different sailing vessels is that only a relatively small amount of information is required;

- The rig-plan of the vessel (square-sail or lateen/settee).
- The start and finish point of the voyage.
- Whether or not the voyage was non-stop.
- The time taken to complete the voyage.
- The over-riding weather conditions.

Rig-plan

It is obviously important to establish the type of sailing rig used by a vessel on a given voyage. With modern voyages this is usually a simple matter due to the survival of photographs, log books or other detailed records made at the time. Historical voyages present more of a problem because they are usually only recorded in general terms, by people who have no motive to record details such as the shape of the sail. In these cases it is necessary to assume that a vessel is rigged in a generic way for a particular period. For example a ship of the early Roman

Imperial period would most likely have been rigged with a Mediterranean square-sail rig (ch. 3.1). From the late 12th/early 13th century AD the Northern European Cog, rigged with a single-masted, square-sail began to be built and used in the Mediterranean (Adams 2003: 64; Pryor 1994: 78). Prior to this, Mediterranean vessels would probably have been rigged with a lateen/settee sail (ch. 3.3). It is usually impossible to know if a vessel was rigged with two or more masts, so Vmg can only be calculated for vessels rigged with an overall rig-plan; either square-sail or lateen/settee, rather than for variants within these general types.

It is useful at this point to mention hull-form, which has a large influence on the performance of a sailing vessel, particularly on upwind courses. Put simply, the deeper in the water and more developed the keel of a vessel is, the better the performance of the vessel will be to windward (Palmer 2008b: 3-5). The projection of the keel helps to resist the lateral forces imposed upon the vessel during sailing and which manifest themselves as leeway, causing the vessel to drift sideways while sailing forwards. Flat-bottomed vessels will generally experience far more leeway, and a corresponding reduction in performance than vessels with substantially projecting keels. Evidence of the potential effect of increasing the depth of keel on a vessel of non-optimum shape comes from the sailing trials of the half-scale models of the Sutton Hoo and Graveney boats (Gifford & Gifford 1996; c.f. Palmer 2008b: 3-5). The addition of a false keel to the Graveney boat reduced the leeway by half to c.10° (Gifford & Gifford 1996: 139). Similarly on the reconstruction of the Sutton Hoo ship, the increase of the keel projection from 20mm to 40mm reduced leeway from c.20° to 12° (Gifford & Gifford 1996: 150).

It is practically impossible to determine the underwater hull shape of a vessel referred to in a literary source and even more complicated to compare the effects any differences may have had. However, shipwreck remains from the Mediterranean indicate that a wide variety of hull-forms existed, including flat-bottomed vessels and those with significant underwater profiles (Figure 2-23). The assumption must therefore be accepted that historically recorded voyages represent a cross-section of this shipping because of the impossibility of distinguishing between hull-form on the basis of a literary reference. The variation in hull-form within a corpus of contemporary ship types gives some indication as to the importance of specialisation for various environmental or economic reasons. Hulls more suitable for windward sailing were constructed regularly during antiquity, their failure to become ubiquitous gives an indication of the relative importance of the ‘need’ for windward performance when set against other social, economic or environmental factors contributing to hull shape.

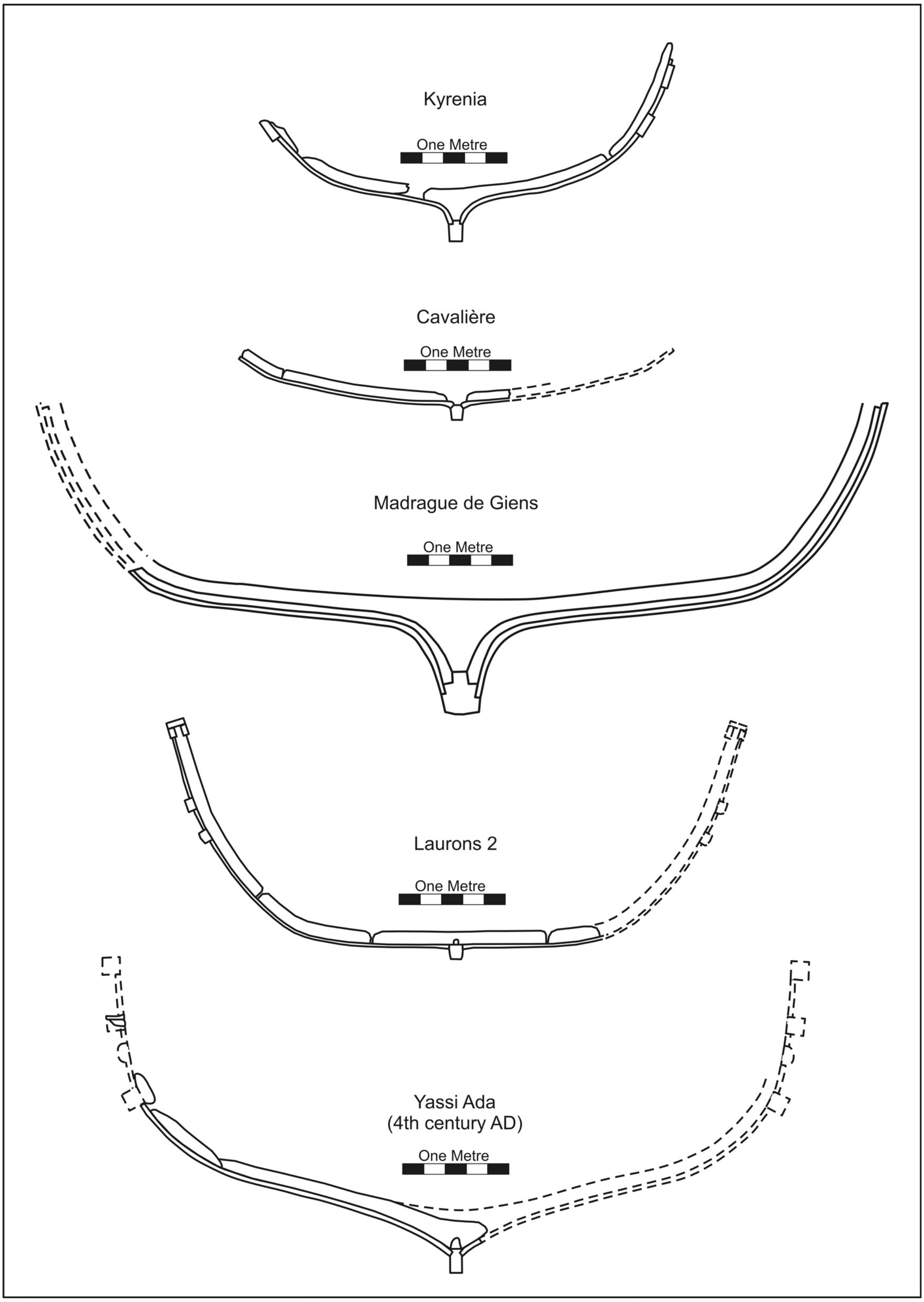

Figure 2-23. Five Mediterranean sailing vessels from Classical, Roman and late-antique contexts. The different cross-sectional forms constructed by ancient shipwrights, range from flat-bottomed to relatively deep-keeled. Redrawn by author from: Kyrenia (S024) (Steffy 1985: Il.6), Cavaliére (S011) (Charlin *et al* 1978: Fig. 34), Madrague de Giens (S029) (Rival 1991: Fig. 62), Laurons 2 (S026) (Gassend *et al* 1984: Fig. 17c), Yassi Ada (4th century) (S048) (Bass & van Doorninck Jr 1971: Fig 5).

Voyage details and weather conditions

The details of the voyage under analysis are obviously of great importance in establishing a comparable Vmg figure. The start point and finish point of the voyage must both be known in order to calculate the distance made good at the end of the voyage. It is also important to establish that the voyage did not include any stops en-route as these may greatly increase the time taken to complete the voyage, without adding to the distance travelled. The duration of voyages is rarely measured with accuracy greater than half a day, a voyage might also be recorded as taking '2-3 days' in such an example a compromise figure of 2½ days may be used (e.g. Voyage 02). Finally, the type of weather encountered during the voyage must also be considered. Ancient sources, while not specific about the nature of the weather encountered do provide some significant information. If the wind direction is such that a vessel can sail on a reach or a run to its destination the wind may be considered favourable, and referred to as such (e.g. Voyage 08). Contrastingly, wind from an unfavourable direction is usually described as 'foul' wind. In the context of ancient sailing a 'foul' or unfavourable wind may be taken to mean that the wind is coming from the direction of the destination, or that the voyage has to be made in generally upwind conditions. Where details of the winds are not given it is often possible to reconstruct the most likely wind to have been encountered based on charts of the prevailing wind in specific areas.

Weather conditions are obviously of prime importance in determining the speed of a sailing vessel. A vessel travelling a relatively short distance may experience ideal conditions and record a record run. Likewise a captain and crew may be unlucky and have to sail a long voyage in adverse conditions, leading to an exceptionally long journey time. The weather encountered on a voyage is not always recorded. However, if the start point and destination point are known, then the most likely weather conditions which may have been encountered may be estimated via comparison with the wind patterns for the prevailing and seasonal winds in the region. Similarly, data derived from ethnographic observation or from the trials of replica vessels with comparable rigs may give an indication of the likely performance in certain weather conditions, or when the wind was from a certain relative direction. [17]

Sea-state

One of the major determinants of the extent to which a vessel rigged with any type of sail-plan makes positive ground to windward is the state of the sea (de Monfried 1935; Gillmer 1979:

[17] An example of the effect of weather conditions on journey time can be seen in the experimental voyage of *Ottar*, the replica of Skuldelev 1, to Norway in 2002 on which the author crewed. With steady, favourable winds of moderate strength, *Ottar* achieved an average speed of 4.4 knots over 146 nautical miles. With lighter variable winds *Ottar* was only able to make an average of 1.9 knots over 106 nautical miles (Englert 2006: Table 6.5).

179; Heikell 1989: 23; Smitt 1986: 172; Vinner 1986: 222). Generally speaking, the calmer the water the better the vessel will perform in a windward direction. This is because of the reduction in the strength of the wind-associated wave action. Waves stop the progress of the vessel through the water and lead to an increase in the leeway generated by the vessel. In certain conditions even modern vessels with a hull and rig specifically designed for windward performance struggle to make ground because of the influence of wave action (e.g. Heikell 1989: 23). It may be the case in some of the voyages noted above that although a vessel encountered wind from an unfavourable direction it remained light enough to enable the vessel to make progress to windward in calm seas. It must also have been part of the skill of navigation in the ancient world to select courses which led to sailing in sheltered waters, unaffected by significant wave action and where speed could be maximised. Island groups and archipelagos have been cited as slowing down passage time (Casson 1995: 288; McGrail 1998: 264), the reality may have been that they actually allowed vessels to speed up by providing calm waters in which to sail to windward. This approach was used by de Monfried (1935) in 1916 in his passage up the entire length of the Red Sea into the prevailing wind at an unfavourable time of year. He made constant use of every offshore island group or reef system available and constantly commented on his preference for sheltered water in which to sail, for example;

"on the starboard tack I ventured in among the reefs of the inner sea which stretches to the north-west. There I could work profitably to windward in these waters which are always calm, despite the strong breeze blowing." *- (de Monfried 1935: 135).*

2.3.3 The Square-Sail

The potential performance of the single square-sail rig of the ancient Mediterranean and similar rigs in north-west Europe has long been the source of speculation amongst scholars of the subject, who have largely focused on the ability of vessels to sail to windward (e.g. Casson 1995: 273-4; Gillmer 1979; Rice Holmes 1909; Roberts 1995; Rougé 1981: 22; Tilley 1994). All have concluded that the single-masted square rigged vessel, such as those of the Roman period, had some ability to sail above 90° to the wind. The consensus being that vessels were able to steer a course of between 65°-80° off the wind[18]. This correlates with the range of close-hauled heading angles reported from the sailing trials of traditional square-sail vessels which are

[18] Casson (1995: 274) cites a course of no closer to the wind than 7 points (78¾°), Rice Holmes (1909: 38) infers a course of 6 points (67½°), Le Baron Bowen (1960: 130) estimates a course of 75°, Kahanov (2006: 436 & 442) a course of 80° including leeway and McGrail (1998: 262) concludes a course of 7 points including leeway for square-rigged Viking age vessels but broadens his analysis to include classical Mediterranean vessels (1998: 264), Gillmer (1979: 179) approaches the subject from a scientific perspective and suggests a course of 55°, but does not say how he derives this figure.

listed in Table 2-2. It should be observed that these figures almost certainly represent the 'best' results produced by a particular vessel.

Vessel	Angle	Reference
Hanse Cog (Bremen)	67°- 75°	(Brandt & Hochkirch 1995: 7-8)
Roar (Skuldelev 3)	65°- 72°	(Vinner 1986: 224)
Imme Aros (Ellingå)	70°	(Vadstrup 1986: 87)
Imme Skinfaxe (Skuldelev 3)	63°- 68°	(Vadstrup 1986: 91)
Bialy Kon & Dziki Kon (Slavonic)	60°-65°	(Gülland 2003: 361)
Kyrenia II (Kyrenia)	c. 61°	(Cariolou 1997: 92)
Olympias (Trireme)	65°- 72°	(Morrison, et al. 2000: 262)
Ottor (Graveney)	70°	(Gifford & Gifford 1996: 139)

Table 2-2. Heading angle, relative to wind direction of replica vessels rigged with square-sails. Leeway was included in all cases, but was often an estimate, rather than a measured quantity.

There are numerous passages from ancient sources which inform us of a great deal of the practice of sailing with a contrary wind and can leave no doubt that sailing close-hauled was practiced in antiquity. The most notable of these is probably the passage from Aristotle, dating to the 4th century BC, cited in chapter 2.1 but repeated here;

"Why is it that [sailors], when the wind is unfavourable and they wish to run before it, they reef the sail in the direction of the helmsman, and slacken the part of the sheet towards the bows? Is it because the rudder cannot act against the wind when it is stormy, but can when the wind is slight and so they shorten sail? In this way the wind carries the ship forward, but the rudder turns it into the wind, acting against the sea as a lever. At the same time the sailors fight against the wind; for they lean over in the opposite direction."

- Aristotle, Mechanical Problems. 851b.7 (tr. W.S. Hett, 1955).

This passage represents a concerted effort by the ancient mariner to balance the rig of his vessel (cf. 2.1.1) while sailing on a close-hauled course. It is only on this course that the need to balance the CE and CLR of the vessel becomes most critical, the inference therefore being that such an action would be unnecessary if the vessel was only sailing on offwind courses. The following passage from Pliny will be familiar to anyone who has ever helmed a boat upwind in a confined waterway

"Vessels by means of slacking the sheets can sail in contrary direction with the same winds, so that collisions occur, usually at night, between ships on opposite tacks"

- Pliny, Natural History, 2.48. (tr. H. Rackham, 1938).

Pliny's observation that the sheets are slackened may suggest that the ships are sailing downwind. However, it should be remembered that in order to sail close-hauled one of the sheets must be slackened off enough for the tack of the sail to be secured in the bow of the vessel, while the other sheet remains led aft. Achilles Tatius dramatically describes a ship encountering a wind shift which causes headwinds and, as a result, an extended period of tacking into the wind;

"On the third day of our voyage, the perfect calm we had hitherto experienced was suddenly overcast by dark clouds and the daylight disappeared, a wind blew upwards from the sea full in the ship's face, and the helmsman bade the sailyard be slewed round. The sailors hastened to effect this, bunching up half the sail upon the yard by main force, for the increasing violence of the gusts obstructed their efforts; for the rest, they kept enough of the full spread [of the sail] to make the wind help them to tack. As a result of this the ship lay on her side, one bulwark raised upward into the air and the deck a steep slope, so that most of us thought that she must heel over when the next gale struck us. We transferred ourselves therefore to that part of the boat which was highest out of the water…the wind suddenly shifted to the other side so that the ship was almost sent under water, and instantly that part of the boat which had be down in the waves was now violently thrown up…all changed their station, running, with shouts and cries, to the position in which they had been before they moved; and the same thing happened a third and a fourth, nay, many times, we thus imitated the motion of the ship"

- Achilles Tatius, Leucippe and Clitophon. III.1-2 (tr. Gaselee 1917).

The appearance of the *artemon* and *mizzen* sails as part of the ancient sailing rig is also equally instructive about the type of courses being sailed in antiquity. As outlined in 2.1.1 these sails add relatively little to speed on downwind courses. However, both can play a crucial role when attempting to balance and steer a vessel on close-hauled courses. Because of the forward position of the CLR, the *artemon* is crucial for the sailing balance of vessels rigged with the mainmast amidships. In the light of the reassessment of the position of CLR carried out in 2.1, both the use of an *artemon* and the forward position of the mast-steps on those vessels not rigged with them, point towards ancient vessels being regularly sailed on courses above 90° to the wind. A similar point can be made in respect of the use of bowlines on Mediterranean ships in the Roman period. This particular rigging component had no function other than to maintain the tension on the luff of the sail when sailing close-hauled. One of the likely reasons that vessels in the Bronze Age could not sail to windward effectively was the probable lack of developed standing rigging, most notably shrouds (Whitewright 2000: 47), needed to support the mast when sailing close-hauled. Reference to chapter 2.1 illustrates that Roman shipping suffered from no such deficiencies, vessels being fitted with a full set of shrouds and stays providing lateral and longitudinal support to the rig on all points of sailing. In short the rigging components, mast-step position and technical practice described in literary sources relating to

Mediterranean square-sail ships indicates that such vessels were regularly intended to be sailed on courses above 90° to the wind from at least the 4th century BC onwards.

The Vmg of square-sail vessels

Prior to analysing a series of voyages made with square-sail vessels it is useful to be able to establish some parameters which results might be expected to fit within. This is especially useful when it is not known if a voyage was made with 'fair' or 'foul' winds (downwind or upwind respectively). The performance of replica square-sail vessels (Table 2-3), in known conditions, can give an indication of the possible conditions experienced by ancient vessels where the actual conditions are not mentioned by the author. Such trials are often carried out in good conditions and by a crew who are actively trying to achieve the best performance, either upwind or downwind, available to them. As such they provide an 'optimal yardstick' by which the data from historical voyages can be measured. Analysis of these results indicates that vessels rigged with single square-sails can be expected to achieve up to 2 knots Vmg when sailing close-hauled (c.f. Crumlin-Pedersen 1984: 32-3). Such figures are only likely to be achieved by a vessel with a relatively efficient hull shape and weather conditions of moderate winds and calm seas. Vessels lacking a substantial keel, such as the Graveney, Sutton Hoo and Hanse Cog replicas may only achieve up to 1 knot Vmg. In some cases where conditions are unfavourable (strong wind and rough sea) ground may be lost to windward.

Vessel	Vmg	Reference
Roar (Skuldelev 3)	1.5 - 2 knots	(Vinner 1986: 224)
Imme Skinfaxe (Skuldelev 3)	1.5 - 2 Knots	(Vadstrup 1986: 91)
Ottor (Graveney)	1 knot	(Gifford & Gifford 1996: 140-1)
Sæ Wyfling (Sutton Hoo)	1 knot	(Gifford & Gifford 1996: 149-150)
Hanse Cog (Bremen)	0.63 knots	(Brandt & Hochkirch 1995: 7)
Hanse Cog (Bremen)	-0.1 knots	(Brandt & Hochkirch 1995: 7)

Table 2-3. The Vmg to windward of replica vessels rigged with single square-sails.

Potential Mediterranean square-sail performance

A range of literary sources provide commentary on the time taken to sail on a number of different routes on vessels rigged with the Mediterranean square-sail. The majority of these voyages occur in the Mediterranean, but some are referred to which took place in the Indian Ocean and Red Sea. Details of the voyages used to document the performance of the Mediterranean square-sail can be found in Appendix Four (5.4.1 & 5.4.2). Analysis of these voyages can give a reasonable indication of the Vmg of sailing vessels rigged with the Mediterranean square-sail rig on upwind or downwind courses. Analysis of these historical voyages suggest that vessels rigged with a Mediterranean square-sail rig could attain up to 2 knots Vmg in suitable conditions when sailing on close-hauled courses (see 5.4.1). This tallies closely with the likely performance suggested by the trials of replica vessels (above).

As well as providing as indication of the potential speed of sailing ships when attempting to sail to windward, literary sources can also supply information relating to the speed of shipping on other courses. Marchaj (1996: 147, 149, figs 127 & 131) has demonstrated that on these courses the square sail is amongst the best performer, all other things being equal. Specifically, on running courses with the wind coming over the vessel's quarter a low aspect ratio (AR) sail represents the optimum sail plan while on broad reaches a sail plan with an AR of c.1 is the best performer (*ibid*). The fastest average speed recorded in ancient sources is a voyage from Corinth to Puteoli during which a vessel averaged 6.2 knots (Voyage 16). The combined information indicates that with wind from a favourable direction, average speeds of 4-6 knots could be achieved on reaching and running courses (see 5.4.2). Speeds which tally with the observations of replica square-sail vessels on similar courses (Englert 2006: 41; Katzev 1990: 245, 246 & 248). Maximum speeds can also be indicated by data from replica voyages and these suggest speeds in excess of 10 knots.[19] In some cases a record exists of the outbound voyage made with the prevailing wind and the homeward voyage made against it. In each case the speed (and journey time) against the prevailing wind is double the respective figure for the reverse voyage with the prevailing wind. This correlates with the overall difference between the Vmg of voyages made into the wind and those made with the wind.

Accurately quantifying the speed at which ancient shipping could travel under sail is difficult. The combination of archaeological, experimental, literary and iconographic evidence can give an indication of the potential performance of Mediterranean square-sail vessels. Vessels rigged in this way could attain average speeds over long distance of 4-6 knots with much higher speeds possible over short distances in strong winds. Less well documented is the ability of such ships to sail to windward. The rigging and technical practice used would have allowed windward sailing in suitable conditions of moderate wind and relatively calm seas. The available data from replica trials of comparable vessels and ancient literary sources for the square-sail is summarised in Table 2-4. It indicates that on close-hauled courses in optimum conditions a vessel could achieve a heading of 60°-65° with a *potential* Vmg of up to 2 knots (c.f. Crumlin-Pedersen 1984: 32-3 for Viking age square-sail performance). On reaching and running courses average speeds of 4-6 knots might be attained with maximum speed in excess of 10 knots.

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[19] The maximum speed reached by Kyrenia II was an estimated 12 knots before shortening sail (Katzev 1990: 252). I have experienced speeds of 7.5 knots when triple reefed in strong winds (force 6-7) on the Skuldelev 1 replica *Ottar*.

Potential Square-Sail Performance	
Possible maximum heading angle (close-hauled)	60°-65°
Maximum Vmg to windward	2 knots
Likely average speed range on reaching & running courses	4-6 knots
Maximum speed on reaching & running courses	+12 knots

Table 2-4: Summary of potential ancient Mediterranean square-sail performance in optimum conditions.

2.3.4 The Lateen/settee Sail

Assessing the potential performance of ancient vessels rigged with a lateen/settee sail plan presents a similar set of problems (2.3.1) to the assessment of the square-sail carried out above. The process of analysing the potential performance of the lateen/settee sail of late-antiquity must therefore take a similar path to that chosen for the Mediterranean square-sail. The lack of replica lateen/settee rigged vessels and corresponding lack of data was noted above. This is largely compensated by the data available from ethnographic observations of commercial lateen/settee rigged sailing vessels in the Red Sea and Indian Ocean in the last century (e.g. Prins 1965; de Monfried 1935; Villiers 1940). As well as providing quantifiable data relating to the lateen/settee rig, these accounts also recount personal observations about the advantages, limitations and general use of the lateen/settee rig. In 2003 the author was also able to interview fisherman at the Egyptian Red Sea port of Marsa Alam regarding the use and performance of their sailing vessels, also rigged with a lateen/settee sail. These modern voyages, along with medieval voyages described by Arab navigators or recorded in literary sources provide further, historically contextualised evidence for rig performance (Appendix Four – 5.4.3 & 5.4.4). This approach also has the advantage of producing a picture of the potential performance of lateen/settee rigged vessels from a set of sources of comparable nature to those used to assess the Mediterranean square-sail.

Medieval sources for windward performance

Valuable information regarding the use and by inference, performance of lateen/settee rigged vessels can be derived from the writing of the Arab navigators of the late-medieval period. With specific regard to the Red Sea, Tibbetts (1961) singles out two navigators as giving the most valuable information about windward sailing in these waters; Ibn Mājid and Sulaimān al-Mahrī. Of particular interest is the practice of *takkiya* which was used when vessels sailing northwards up the Red Sea encountered the prevailing northerly winds above the eighteenth parallel (Tibbets 1961: 326). *Takkiya* seemed to entail the practice of turning from a northerly course in the centre of the Red Sea to sailing toward either the Arabian or African coast. A manoeuvre consistent with having to alter course upon meeting the prevailing northerly wind. Tables of *takkiyat* described which islands or coastal landmarks would be sighted first if a vessel steered for the coast from a known position (observed via star altitude) in the centre of the sea. Sulaimān al-Mahrī also gives the sailing courses for two sets of conditions, a strong northerly wind and a weak northerly wind.

The northerly winds in the Red Sea generally blow from between north and north-west (Davies & Morgan 1995: 29) so it seems reasonable to take north north-west as a compromise direction between the two. Sulaimān al-Mahrī tells us that in a strong wind a vessel steers east by north or due east for the Arabian coast and west south-west or south-west by west for the African coast (Tibbets 1961: 327). In a weak wind the courses are north-east or north-east by north and due west respectively (*ibid*) (Figure 2-24). The close-hauled heading in strong winds equates to 101¾°, rising to 56¼°-67½° in weak winds. Ibn Mājid also gives bearings for *takkiya* from the island of Bahr al Zihār on the approaches to the harbour of al-Lith. When the wind is blowing weakly from the north-west the bearing is north by east or north north-east which equates to a heading angle of 5-6 points off the wind. When the wind is blowing hard then the ship must bear north-east or further east, giving a bearing of 8 points or more. Both of these courses are consistent with those given by Sulaimān al-Mahrī. Taken together, the *takkiya* headings provide an indication of the windward performance of lateen/settee rigged vessels in the Red Sea during the late-medieval period. This equates to a sustainable course of between 5 and 6 points (56¼°-67½°) off the wind in ideal conditions, diminishing to 9 points (101¾°) off the wind in strong winds. Severin (1991: 238) notes that the settee rigged sewn vessel *Sohar* could achieve 65°-70° off the wind when close-hauled, including leeway.

This information re-emphasises the point made above that windward performance is adversely affected by sea-state. Strong winds result in rougher seas and decrease the ability of a vessel to hold a course to windward due to a subsequent increase in leeway. In the case of late-medieval vessels in the Red Sea the difference is as much as 3 points (33¾°) in terms of the course sailed over the ground when compared to a vessel sailing in weaker winds (Figure 2-24). Further evidence for such problems can be found in the writings of Ibn Mājid, who describes the effect of an increasing north wind on landfall when sailing toward the Arabian coast from the centre of the Red Sea (Tibbetts 1971: 253 & 386). He describes the strength of the wind in four ways; 'weak', 'moderate', 'of medium size' and 'foul and blowing hard'. With each increase in wind strength, landfall is made further to the south. Ibn Mājid also describes the sailing seasons around Socatra and notes that sailing from Fartak and Hairij [on the Yemen coast] to Socatra is difficult because one does so at that season with a wind of two sails (Tibbets 1971: 229). He goes on to state that the journey is contrary to the wind and is not attempted unless the wind is light (*ibid*). The term 'wind of two sails' is used to describe travelling to a destination that lies

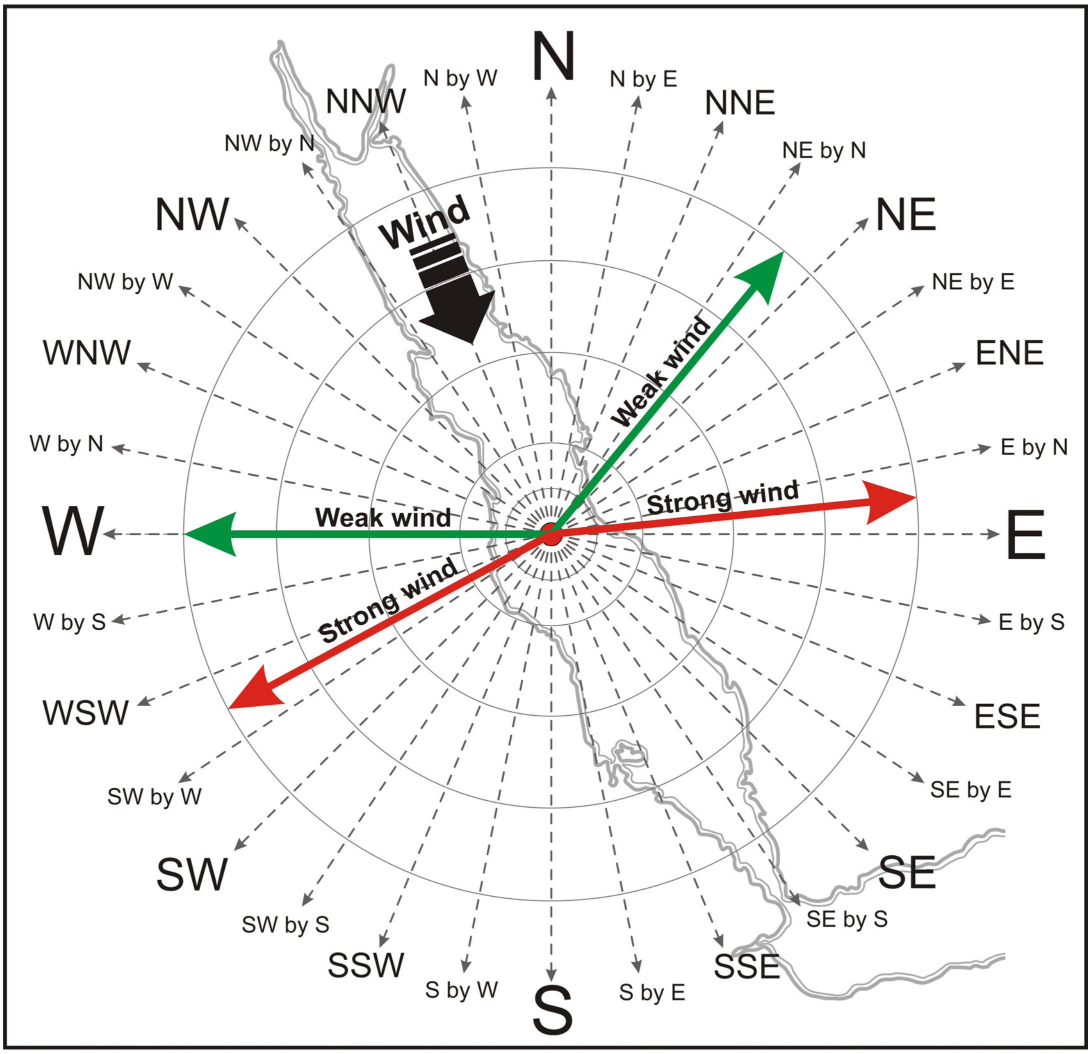


Figure 2-24. Illustration of the *takkiya* headings given by Sulaimān al-Mahrī. These give a good indication of the effect of different wind strengths on close-hauled heading angles of medieval lateen/settee rigged ships in the Red Sea according to contemporary accounts. Some inaccuracy is inevitable because of the need to take an average wind direction of NNW. The variable wind direction is reflected in the fact that a range of courses are given by Sulaimān al-Mahrī (J.Whitewright).

to windward. The vessel in question sails two tacks to complete the trip, one with the sail(s) on one side of the vessel and one with them on the other, hence the 'two sails'. The term was recently still in use in East Africa and was noted in the same context by Prins (1965: 252) in his ethnography of Lamu. The same technique is used by fisherman in the northern Red Sea when sailing to windward (personal observation). Villiers also notes the effect which sea state might have on a vessels performance, both in terms of the ground made to windward and in dictating which course was sailed. Returning home from the annual voyage to East Africa, the Kuwaiti Boom he sailed on met persistent strong headwinds at the entrance to the Persian Gulf and was able to make little ground to windward (Villiers 1940: 313, 317-8). In his earlier voyage in a Red Sea Zaruq, Villiers notes that a pair of sambuks, in order to beat to windward had sailed 'the inside passage' between the coast and the offshore reefs in order to take advantage of the flat water there (Villiers 1961: 251). Such an approach was also adopted by de Monfried (1935) in his voyage up the Red Sea from Djibouti to Suez.

In his records of his travels Ibn Jubayr (tr. Broadhurst 1952), describes in some detail the voyages which he undertakes. The ships on which he travels generally attempt to sail in favourable conditions with the wind from astern or abeam, even if this means waiting in port for several days (e.g. Broadhurst 1952: 326, 361-2). Such an approach has strong echoes of earlier practices on vessels rigged with square-sail when waiting in port for a fair wind was a common occurrence. Once at sea, in some instances when encountering headwinds, the Ibn Jubayr's vessel is able to continue on its course (e.g. Broadhurst 1952: 327 & 364), suggesting relatively calm conditions. At other times the wind is to strong for the ship to make headway and the vessel is forced downwind (e.g. Broadhurst 1952: 331-2 & 362).

The Vmg of lateen/settee rigged vessels

The medieval texts relating to Arab navigation indicate that in optimum conditions of light/moderate winds and calm seas a lateen/settee rigged vessel could achieve a close-hauled course between 56¼°-67½° off the wind. This figure is largely corroborated by observations on the sewn vessel *Sohar* which could achieve 65°-70° off the wind. Medieval and modern sources suggest that Vmg on close-hauled courses could have reached nearly 2 knots (ch. 5.4.3). In stronger winds, with an associated increase in wave action, modern observations and historical sources both indicate that lateen/settee rigged vessels would experience difficulty in making meaningful ground to windward. On courses with a more favourable wind (running and reaching courses), it would seem that lateen/settee rigged ships were capable of achieving a Vmg of 4-6 knots (ch. 5.4.4). The maximum speed which lateen/settee rigged vessels could attain remains open to speculation. Villiers (1940: 336) records the Kuwaiti boom *Bayen* reaching speeds of 10 knots. Similarly, Severin (1991: 238) records *Sohar* achieving speeds of 8-9 knots. Of further interest is the fact that the speeds and sailing practices given in the medieval period tally closely with those recorded during the 20th century, suggesting little change in overall performance during the intervening period.

Potential Lateen/settee sailing rig performance	
Possible maximum heading angle (close-hauled)	56¼°-67½°
Maximum Vmg to windward	1.9 knots
Possible average speed range on reaching & running courses	4-6 knots
Maximum speed on reaching & running courses	+10 knots

Table 2-5: Summary of the potential performance of late-antique Mediterranean lateen/settee rigged ships in optimum conditions.

2.3.5 Conclusion

The Mediterranean square-sail rig and the lateen/settee rig which replaced it during the late-antique period share certain characteristics in their potential performance. Using the data derived from the voyages of full-sized vessels in conjunction with historical sources, a series of conclusions can be reached which outline the performance of either rig. These are summarised in Table 2-6 and visualised in Figure 2-25 and 2-26. This indicates that vessels rigged with lateen/settee sails may have been able to attain a slightly higher heading angle on close-hauled courses in optimum conditions than vessels rigged with a Mediterranean square-sail. Emphasis was placed on the measurement of *velocity made good* (Vmg) as a way of determining the performance of vessels described in historical sources as well as those of full-size ships. In unfavourable conditions, assumed to represent upwind sailing, the sources suggest that vessels rigged with a Mediterranean square-sail could achieve up to 2 knots Vmg. This figure is matched, but not exceeded by sources relating to lateen/settee rigged vessels. The potentially higher close-hauled heading angles of the latter rig do not result in a better Vmg. In favourable conditions both rigs could achieve a Vmg of 4-6 knots. Total maximum speeds of 10 knots or more might be achieved by both forms of rig in ideal conditions and with a suitable hull shape.

The evidence currently available would therefore seem to indicate that there is very little difference in the overall performance of a sailing vessel rigged with a Mediterranean square-sail rig when compared with a similar vessel rigged with a lateen/settee rig from the late-antique, medieval or modern era. Reference to Figure 2-25 illustrates the Vmg given by recorded voyages in favourable or unfavourable conditions from antiquity to the present day. It is notable that there is no improvement in the Vmg on unfavourable courses as a result of the introduction of the lateen/settee rig. Likewise, the Vmg in favourable conditions remains confined within a reasonably limited range. Such a conclusion has obvious implications for our understanding of the processes and motives which lead to the adoption of the lateen/settee rig in late-antiquity. The development and adoption of the lateen/settee rig, at the expense of the established square-sail, did not lead to a subsequent increase in the windward performance or overall speed of sailing vessels in the Mediterranean.

Potential sailing rig performance	Square-sail	Lateen/settee
Possible maximum heading angle (close-hauled)	60°-65°	56¼°-67½°
Maximum Vmg to windward	2 knots	1.9 knots
Possible average speed range, reaching & running courses	4-6 knots	4-6 knots
Maximum speed on reaching & running courses	+12 knots	+10 knots

Table 2-6: Combined summary of the potential performance of Mediterranean square-sail and late-antique lateen/settee rigged sailing vessels.

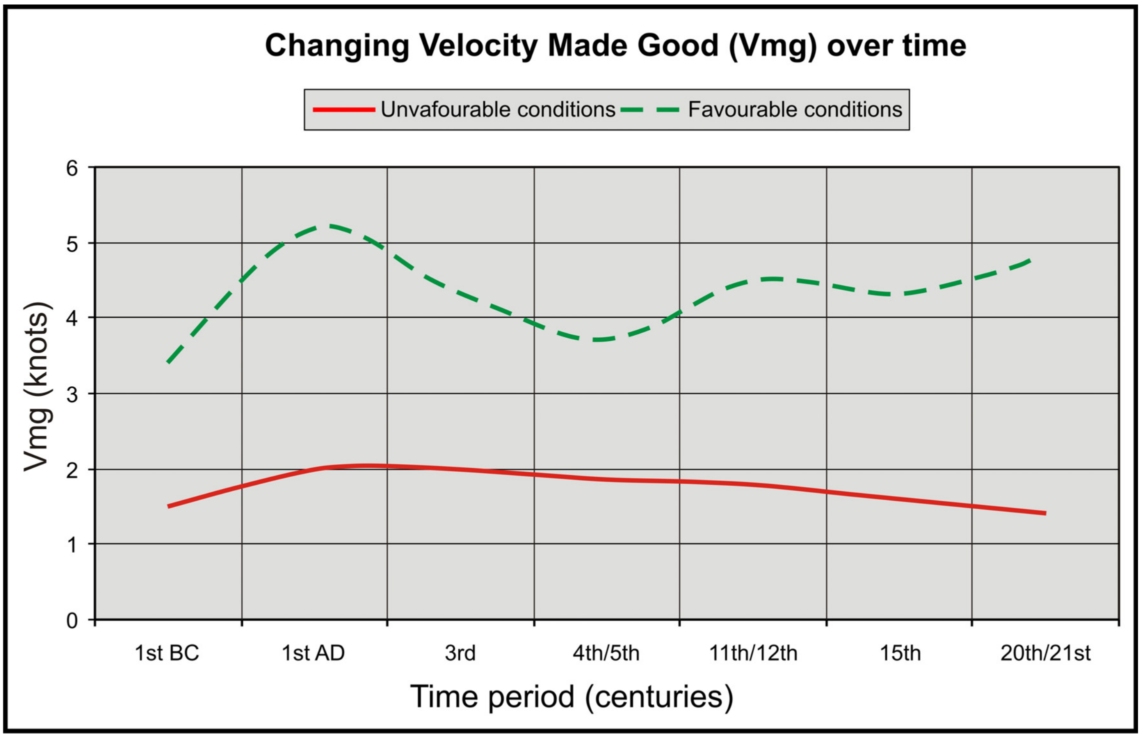


Figure 2-25. Chart plotting changing Vmg over time, as documented in recorded voyages. Data is derived from averaging voyages assumed to have been undertaken in square-sail vessels (1st century BC to 4th/5th century AD) and lateen/settee rigged vessels (11th/12th century AD to the present). Details of voyages can be found in Appendix Four, however it is clear that there is no dramatic improvement in vessel performance resulting from the adoption of the lateen/settee rig.

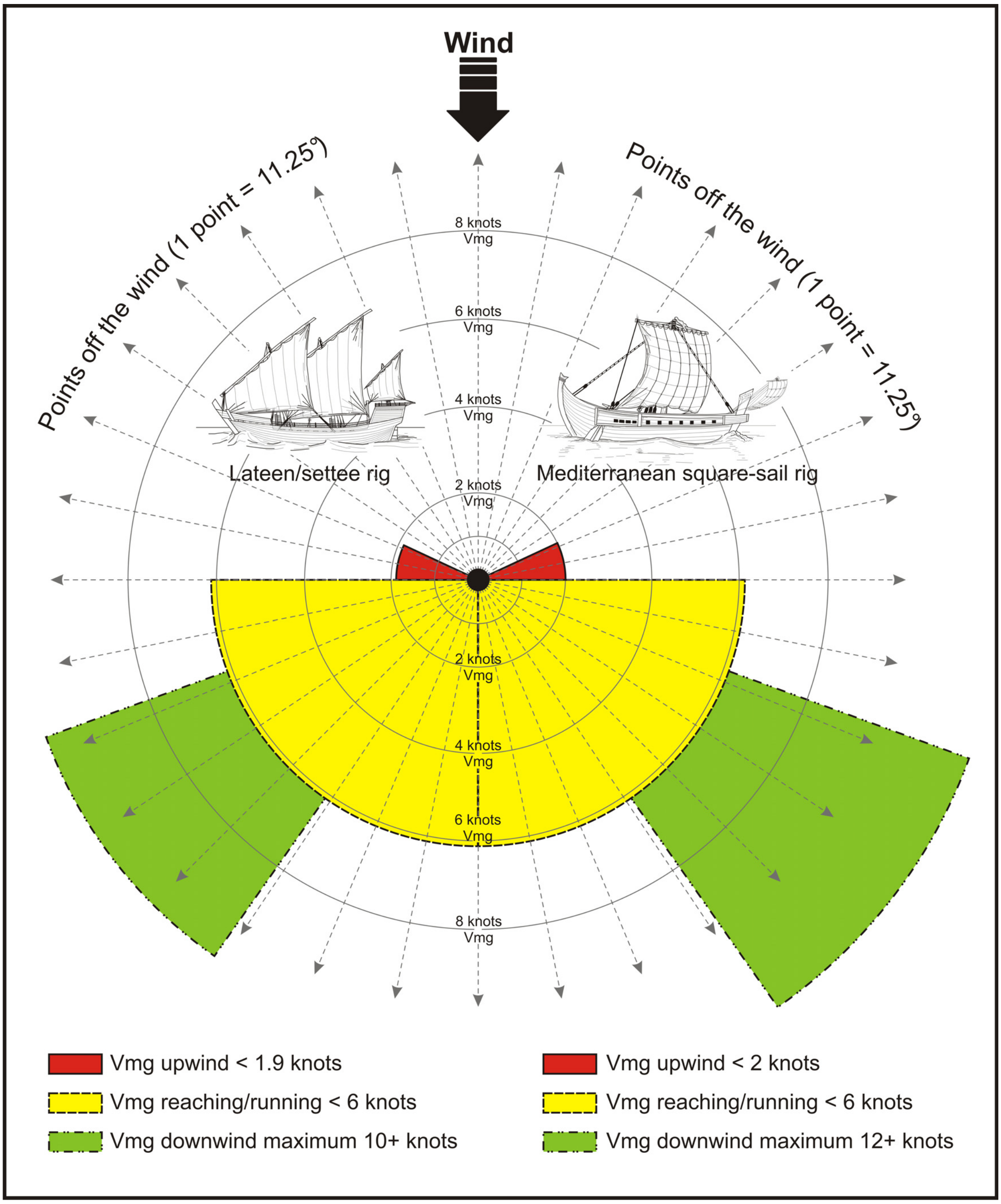


Figure 2-26. The potential performance of Mediterranean square-sail and lateen/settee rigged ships on upwind and downwind courses. Relative speeds are expressed in terms of velocity made good (Vmg) and the fastest maximum speed is assumed to occur on a broad reach.

Part Three: Maritime technological change in the ancient Mediterranean and Indian Ocean.

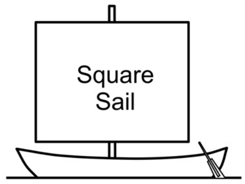
Part Two covered the principle sailing rigs (square-sail and lateen/settee) used in the ancient Mediterranean from a technical perspective, including an assessment of their potential performance. This produced a detailed characterisation of the rigging components, the inter-relationship between those components and the technical practice required to use the rig. In conjunction with such an approach, it is necessary to address the broader picture of maritime technology in the ancient world. What is being used, where and when? Do sailing rigs exhibit temporal and spatial variation or do they remain uniform in their characteristics? An assessment of other, closely related, technological processes, such as hull-construction, is required for completeness. Changes or alteration to these traditions, where archaeological evidence is often more extensive may indicate wider processes of change affecting maritime technology.

The following section sets out the maritime technological change apparent in the ancient world, during the period covered by this study, based on the currently available evidence. As a result of the detailed component study conducted in Part Two, archaeological as well as more traditional forms of evidence (literary or iconographic sources) can be utilised. This represents a new methodology for studying ancient sailing rigs over long time periods. The two rig types which form the focus of this study, the square-sail and the lateen/settee sail are covered in 3.1 and 3.3 respectively. As well as addressing the sailing rigs, it is important to incorporate the hulls upon which they were rigged. Mediterranean shipbuilding traditions underwent significant change during late-antiquity and it is important that these changes are acknowledged and documented. A general overview of ancient Mediterranean shipbuilding traditions currently identified through archaeological evidence is provided in chapter 3.4.

As well as addressing general trends in the distribution and use of sailing rigs, a return is made to the individual components of the ancient sailing rig to assess the extent of any change/stasis in form or function (ch. 3.5). Part Two also elucidated the technical practices needed to operate the two forms of rig and their respective set of components. This included an assessment of the potential performance of each type of rig based on a variety of evidence. Chapter 3.6 sets out the conclusions which can be made regarding the observable differences in technical practice and performance between the two sailing rigs in question. Finally, chapter 3.7 draws together the different themes of rig type, hull construction, component analysis and technical practice to provide an overview of the nature and character of the maritime technological change concerned.

3.1 The Square-sail rig

3.1.1 Single-masted vessels



The single-masted square-sail rig represents the oldest documented form of sailing rig. Drawings on pots from the Gerzean period in Egypt allow its use to be acknowledged from at least 3100 BC (Casson 1995: 12, n. 6; Landstrom 1978: 6; Le Baron-Bowen 1960: 117; McGrail 2001: 19). Earlier sailing vessels almost certainly existed in Egypt and other parts of the world, they lie outside the scope of this study. Suffice to say that the single-masted square-sail rig has provided the basic sailing propulsion for Mediterranean ships since the earliest times for which there is reliable evidence. The single-masted rig developed throughout the Bronze Age until about 1200 BC when it assumed a form which would have been recognisable to Mediterranean sailors of the 1st millennium BC. This consisted of a loose-footed sail, trimmed with sheets and braces and shortened with brails (Casson 1995: 37; Jones 1995; Landstrom 1978: 23; McGrail 2001: 46; Vinson 1993; 1994: 41-2; Whitewright 2000: 35). During the middle of the first millennium BC a developed system of shrouds was added to the standing rigging to create a strong, easily adjustable sail-plan capable of operating on all points of sailing.

The basic characteristics of the single-masted square-sail rig (ch. 2.1) remain unchanged throughout the Roman period and such vessels were still being consistently depicted in the early 7th century AD. A clear example (V26) comes from the monastic site of Kellia in Egypt, a contemporary, although less detailed depiction of a square-sail can be found on a pilgrim flask from the site of Abu Mena in Egypt (Vikan 1982: Fig. 11). The problems surrounding iconographic interpretation were set out in chapter 1.3 and included the possibility that rig types may be depicted long after they have fallen out of use. This can certainly be the case with mosaics or manuscripts where artists are known to have drawn upon older pattern books for their inspiration. In the case of V26 the image in question is a graffito and the artist is far more likely to be drawing upon personal experience or observation. The ship depicted in the graffito may well have been seen by the artist in the course of their life. In this case it seems reasonable to state that on the basis of iconographic evidence the single-masted, square-sail rig was still in use in the Mediterranean until the late 6th or early 7th century AD.

From an archaeological perspective the Mediterranean square-sail rig can be most easily traced through the presence of brail rings. Relatively large numbers of brail rings were discovered during excavations at the Roman Red sea port of Myos Hormos (S034) (Whitewright 2007b).

Many of these, along with other components associated with the square-sail, were made from materials derived in India or East Africa rather than the Mediterranean. This indicates that the Mediterranean square-sail was definitely in use on the Indian Ocean during the first half of the first millennium AD; certainly by sailors of a Mediterranean origin, but also on ships of an Indian Ocean origin (Blue *et al* In press; Whitewright 2007b). Regarding the Indian Ocean iconographic sources, a graffito on a pot sherd from the port of Alagankulam in Tamil Nadu (V44) seems unequivocal in its depiction of a single-masted vessel rigged with a square-sail. The dating of the piece is difficult but it probably dates to the early first millennium AD (Sridhar 2005: 67-73), contemporary with the square-sail rigging components found on the Red Sea. Literary sources also indicate the use of square-sails in the Indian Ocean during the Roman period. Pliny (VI.24.82-3) notes that the voyage from the Ganges to Sri Lanka takes place in local reed vessels which have 'the rigging used on the Nile'. This must indicate the use of square-sail vessels, presumably with brails.

Single-masted square-rigged vessels, probably from the Indian Ocean or Persian Gulf are depicted on an illustration of "Argo" in *Suwar al Kawakib (Book of Fixed Stars)* from Mardin[20] and dating to AD 1134/5 (V48). This probably indicates that the square-sail was in use in the Indian Ocean in the Medieval period. Graffito of ships from East Africa (V49), dating to the 15th and 16th century AD (Garlake & Garlake 1964: 200) also show vessels which seem to have hulls of a distinctly Indian Ocean type but which are rigged with square-sails. These geographically disparate sources indicate that the square-sail was still widely used in the Indian Ocean in the middle of the 2nd millennium AD.

Hornell (1942: 14) refers to the 18th century traveller James Bruce's accounts of his travels in Egypt who describes a vessel at the port of Kosseir (modern Quseir);

"Our vessel had one sail, like a straw mattress, made of the leaves of a kind of palm tree, which they call Doom. It was fixed above and drew up like a curtain but did not lower with a yard like a sail; so that, upon stress of weather, if the sail was furled, it was so top heavy that the vessel must founder or the mast be carried away. But by way of indemnification, the planks of the vessel were sewed together and there was not a nail nor a piece of iron in the whole ship; so that when you struck upon a rock, seldom any damage ensued" *- (Bruce 1813: 107)*

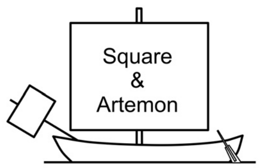
Such a sailing rig has nothing in common with the lateen/settee rig of the Red Sea and Indian Ocean, but perfectly fits the characteristics of a square-sail fitted with brails. Modern Quseir is

[20] The city of Mardin is far from the sea in ancient Mesopotamia, midway between the Tigris and Euphrates rivers (Nicolle 1989: 175). The use of these rivers to service the trade leading to the Persian Gulf and the Indian Ocean leads Nicolle to conclude that the ships depicted at this time were originally from the Gulf or the Indian Ocean (*ibid*).

located only 7km to the south of the Roman port of Myos Hormos where vessels rigged with brailed square-sails are known to have operated in the Roman period (Whitewright 2007b).

In the 20th century, ethnographic observers have reported on the *Mtepe* dau of Lamu which was traditionally rigged with a single-masted, square-sail (Gilbert 1998; Hornell 1941; Lydekker 1919; Prins 1965). The survival of the *Mtepe* with a square-sail in East Africa perhaps corroborates the iconographic evidence from 15th century AD East Africa noted above. The square-sail has also been used on traditional Indian watercraft in recent times and assumed to be a survival from earlier periods (Hawkins 1965: 147; Hornell 1946a: 212; 1946b: 241-253). It is important to bear in mind the continuity of the square-sail in the Indian Ocean when assessing the extent to which the lateen/settee rig was used in these waters (ch. 3.3).

3.1.2 Main sail and artemon



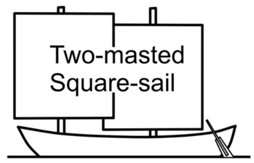
The use of an *artemon* with the square-sail rig represents the earliest visible variation of the single-masted square-sail rig. The *artemon* should not be viewed as a sail which was developed to provide a vessel with extra power. Instead its primary function was to aid the helmsman in steering the vessel, particularly when sailing close-hauled (ch. 2.1.1). The earliest current evidence for this practice comes in the form of two iconographic depictions from Etruria. The later depiction, dating to the early 5th century BC (Casson 1995: 70, Fig. 97) is reasonably unambiguous in its depiction of a vessel rigged with both mainsail and *artemon*. The earlier of the two images dates to the mid 7th century BC (MacIntosh Turfa & Steinmayer Jr 1999a) but is far more ambiguous in its content. Either way, the mainsail and *artemon* rig was in use by the middle of the first millennium BC. Beltrame (1996: 135) notes that reliefs, mosaics and graffiti show that it became common in the Roman age and that the *artemon* mast was usually inclined at 45° over the bow of the vessel. The association of the *artemon* with close-hauled sailing indicates that attempts to sail to windward were also being seriously undertaken from this time. Associated developments to the standing rigging of large sailing vessels, particularly shrouds, may also have begun to occur from this time.[21]

Following its introduction in the mid-first millennium BC it is unlikely that the *artemon* ever fell completely out of use, providing that ships were rigged with square-sails. Iconographic depictions of vessels rigged with mainsail and *artemon* are visible in the Mediterranean in the

[21] Shrouds are systematically absent from the ship iconography of the Late Bronze Age (Whitewright 2000: 20, 35 & 38-9) and first half of the first millennium BC. However heart blocks, probably used as deadeyes (indicating the presence of shrouds) were excavated from the Kyrenia shipwreck (suggesting their introduction prior to, or during the 4th century BC).

4th century AD (V22) and equivalent sails can be seen on European square-sail shipping from the medieval period onwards.

3.1.3 Two-masted vessels



The full two-masted rig represents another variation on the ancient square-sail rig. It is important to clarify the difference between a two-masted rig and the mainsail and *artemon* rig which also carries two masts. While the *artemon* is a relatively small sail set in the bow of a vessel, usually at an angle of around 45°, the two-masted rig employs two sails of nearly equal size. Although the foremast may be canted slightly forward, its much larger size and position slightly aft of the bow area distinguishes it from an *artemon* (compare V08 or V20 with V06 or V09). In the Mediterranean the earliest example of a two-masted ship is a relief from Utica dating to AD 200 (V08), archaeological evidence of a two-masted ship also exists in the mid-2nd century AD in the form of the Saint Gervais 3 shipwreck (S044). The latest iconographic depiction is on a mosaic from Tabarka in Tunisia (V23) dating to the 5th century AD. A similar date occurs in the textual record in a letter written by Bishop Synesius of Cyrene dating to the beginning of the 5th century AD.[22] Synesius writes of his voyage from Alexandria to Cyrene, at one point the ship is out of sight of land and Synesius remarks that the ship has “come into the track of the double-sailed cargo vessels, whose business does not lie with our Libya; they are sailing on quite another course” (tr. Fitzgerald 1926: 82). Casson (1995: 268) translates the phrase as “two-masted freighters” while Meijer and Van Nijf (1992: 172) prefer “double-masted freighters”. The picture Synesius paints is of large ocean-going vessels sailing out of sight of land and rigged with two masts. These may be ships rigged with a mainsail and *artemon* or with a full two-masted rig. A coin of Diocletian dating to AD 306 carrying a depiction of a two-masted ship (V20) may be significant in understanding what type of ships carried full two-masted rigs. Coinage was as much an expression of imperial power as a form of currency, with this in mind it is unlikely that Imperial currency would depict a small, or minor class of ship. The Emperor is more likely to have wanted to be associated with large, impressive and prestigious vessels.

The two-masted rig is not confined to Mediterranean waters during antiquity. Several iconographic examples exist from the Indian Ocean showing two-masted vessels. These occur mainly on southern Indian coins (V46) dating to the 2nd century AD and as a graffito on a pot

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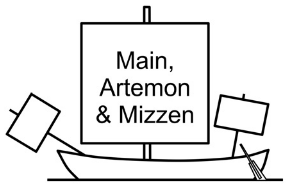
[22] Attempts to calculate the exact date of Synesius’ letter have been carried out by several authors on the basis of astronomical, climatological and chronological data. All conclude a different date for the start of the voyage, ranging from; 28th May or the 22 Oct AD 401 (Long 1992: 375), January AD 402 (Meijer 1986: 67), 28th January AD 404 (Fitzgerald 1926: 80 n.4), April 26th AD 404 (Kahanov 2006: 436).

sherd from Alagankulam (V45) dating to the 1st or 2nd century AD. All of these vessels share a similar set of characteristics. The masts are of equal height, distributed evenly between the bow and stern of the vessel and supported by a forestay and backstay. In all cases the vessels are steered by either one or two steering oars. No indication of the type of sail is included on any of the depictions, although the general assumption has been made that they were rigged with square-sails (Rajan 2002: 84; Schoff 1912: 244; Sridhar 2005: 69-70). The square-sail is known to have been used in the Indian Ocean at this time (above) and the lack of any evidence suggesting an alternative rig, such as the lateen/settee (below), makes it the most likely possibility. The presence of steering oars, the archaeologically documented existence of Mediterranean style rigs in the Indian Ocean and the presence of contemporary two-masted vessels in the Mediterranean increases this likelihood.

The two-masted, square-sail rig seems to have fallen out of use in the Mediterranean sometime in the 5th century AD. The Indian Ocean witnessed two-masted sailing vessels, as early as the 1st century AD and certainly in the 2nd century AD, which were likely to be rigged with square-sails. The extent to which such vessels remained in use in the Indian Ocean is impossible to tell and two-masted ships may only have been utilised for a short period of time in the early first millennium AD.

3.1.4 Main, artemon and mizzen



The final variation on the single-masted square-sail rig is to set a mainsail, *artemon* and *mizzen*. Like the *artemon*, the primary purpose of the *mizzen* sail (rigged at the stern of a vessel) is to further improve the manoeuvrability of the vessel (ch. 2.1.1). The earliest evidence for a three masted rig in the Mediterranean may be the description by Athenaeus (5.206d-209b) of Hiero II's superfreighter constructed by Archimedes in the mid 3rd century BC (Casson 1995: 191-199; c.f. MacIntosh Turfa & Steinmayer Jr 1999b). Torr (1895: 89, n.194) however believes that Athenaeus is actually describing a ship of Caligula's time which he professes to belong to Hiero II and that the *mizzen* sail did not come into use until the 1st century AD (Torr 1895: 89). Basch (1987b: 473) prefers a date of 240 BC in keeping with the description of Athenaeus. The passage from Pliny (XIX. 5), cited at the head of chapter 2.1 also provides direct reference to the use of a ship rigged with a mainsail, *artemon* and *mizzen* in the 1st century AD. A mosaic from Ostia (V10) dating to AD 200 shows a sailing vessel with the three-masted rig and Lucian (Navigium 14) refers to a three-masted merchant ship in the mid 2nd century AD. The available evidence suggests that the three-masted ship is absent from the Mediterranean from the 3rd century AD until its re-development in the medieval period.

3.1.5 Conclusion

Archaeological and iconographic sources indicate that the square-sail rig was in continuous use in the Mediterranean until at least the early 7th century AD. After which there is an absence of iconographic depictions of sailing vessels of any sort until the 9th century AD, when lateen/settee rigged craft seem to have replaced the square-sail (ch. 3.3). Rigging components associated with the Mediterranean square-sail are absent from the archaeological record in the Mediterranean after the early 3rd century AD and after the early 5th century AD on the Red Sea. Although not totally conclusive, the trend in the iconographic and archaeological evidence suggests that the square-sail fell out of widespread use in the Mediterranean by the 7th century AD. Furthermore, the failure of the characteristic system of brails to be utilised when the square sail regains widespread use in the late-medieval period suggests extinction rather than marginalisation.

In contrast to this is the situation in the Indian Ocean, where the use of the square-sail has not been widely acknowledged. In this region, survey of the archaeological, iconographic, historical and ethnographic evidence suggests that there has been widespread use of the square-sail in some form, from at least the Roman period until the present day. As well as the single-masted rig, ancient mariners also employed several variations in sail-plan to the standard square-rig. From roughly 500 BC onwards the Mediterranean square-sail witnessed a prolonged period of development in which different variations on the basic rig-plan of a single-masted vessel were used. These included the addition of an *artemon*, the development of a fully two-masted rig and the combination of mainsail, *artemon* and *mizzen*. The relative time-lines of the square-sail and its variations in both the Mediterranean and Indian Ocean are illustrated in Figure 3-1.

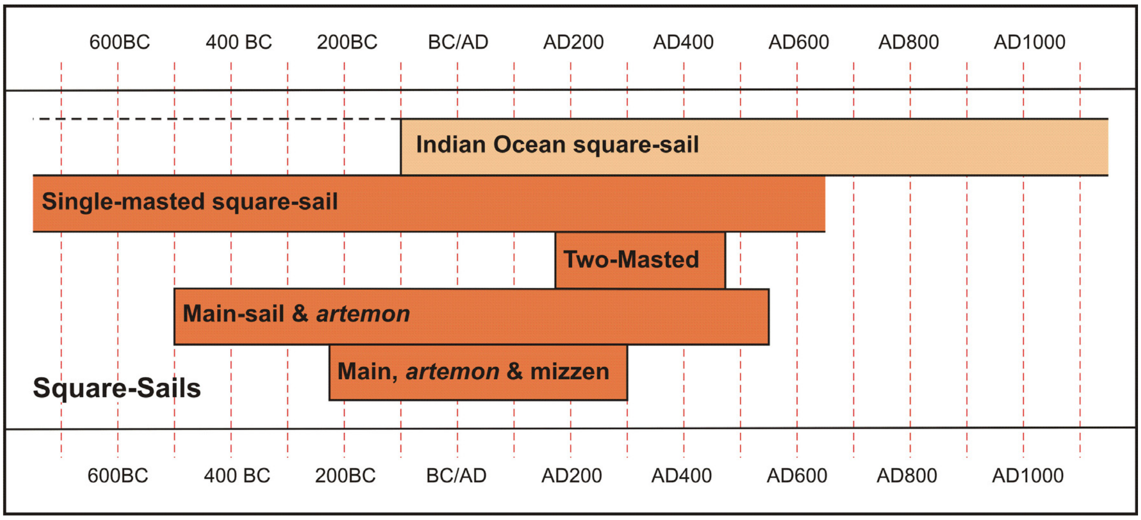
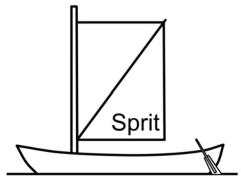


Figure 3-1. The time-lines of the square-sail in the Mediterranean and Indian Ocean during antiquity.

3.2 The Sprit-rig

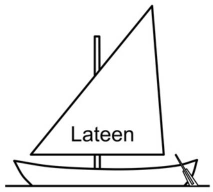


Spatial constraints dictate that the sprit-rig remains outside the scope of this study. However, this section provides the opportunity to briefly discuss this form of sailing rig within the wider context of maritime technological change in the ancient world. The use of the sprit-rig in the ancient world was first identified by Casson (1956; 1960) in a series of reliefs from Thasos (V27), Çemberli-Taş (V28) Lampsacus (V29), Ostia (V30) and Thessaloniki (Casson 1956: Fig. 1). The reliefs date between the 2nd century BC and the 3rd century AD. There is no archaeological or textual evidence for the use of the sprit rig in antiquity, so its use rests entirely on the iconographic evidence cited. These depictions are unambiguous in their depiction of the sprit rig and Casson's conclusion regarding the use of the rig in antiquity has become widely accepted.

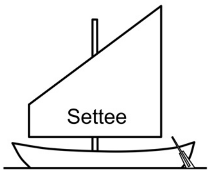
The sprit-rig consists of a quadrilateral sail set fore-and-aft with the sail rigged entirely aft of the mast. Rather than being set from a yard, the sail is set on a diagonal pole (the sprit) attached near the tack and peak of the sail. The simplicity and efficiency of the sprit rig means that it has remained common on small craft which often have to operate in confined waterways. It has also been used on larger cargo vessels since the late-medieval period (Moore 1925: 147-166).

From the perspective of the study of maritime technological change in the ancient world, the significance of the sprit rig has been largely overlooked by academics. The sprit-rig represents a unique form of sailing rig, technologically unrelated to contemporary square-sail rigs and later fore-and-aft rigs such as lateen/settee rig. This fact is tacitly acknowledged in the maritime literature by the fact that the sprit-rig is largely ignored in any description of the technological progression from square-sail to fore-and-aft rig. However, the very existence of the sprit-rig indicates that innovation could occur in the maritime technology of the ancient world which did not draw upon existing technology or influence later technology. The technological distinctiveness of the sprit-rig has led to its exclusion from the 'unilinear progression' usually favoured by maritime scholars (ch. 1.1.2). Ironically it is the exclusion of the sprit-rig which renders the 'unilinear progression' unsustainable in the context of the ancient Mediterranean due to the presence of an alternative but unrelated line of technological development (c.f. Whitewright In Press-a). The rejection of the 'unilinear progression' by this study means that while the space to study the sprit-rig in detail is lacking, it can at least be rehabilitated into the overall chronology of fore-and-aft rigs in the ancient world.

3.3 The Lateen rig



The date of the introduction of the lateen/settee rig into the Mediterranean is a central concern of this study. Accurately identifying the earliest date at which such a sail became widespread in the region is crucial if the relationship between technological change and the wider causal factors (ch. 1.1) is to be fully understood. Identification of early examples of lateen/settee rigged vessels is reliant, to a large extent, on the iconographic record. At present the archaeological record is not complete enough, or well-documented enough to identify lateen/settee rigged vessels while literary sources seldom provide accurate enough accounts of the required rigging details. Where details have been given by the ancient author, modern scholars have found fault with the exact language of subsequent translation, provoking further disagreement. The iconographic record, while far from perfect (ch. 1.2.1) is at least free from linguistic dispute. At the present time it probably represents the best source of information regarding the emergence of the lateen/settee sail in the Mediterranean and Indian Ocean.



3.3.1 Mediterranean iconographic sources

The depiction of a sailing vessel from a 5th-6th century AD mosaic found at the site of Kelenderis in southern Turkey (V32) provides a starting point. The mosaic has been at the centre of debate revolving around whether or not a square-sail (Friedman & Zoroglu 2006) or settee sail (Pomey 2006; In Press) is depicted. Analysis of the mosaic and the rigging components depicted by the artist strongly indicates that a settee rig is depicted and the mosaic should be unequivocally accepted as such. A contemporary graffito of a ship from Corinth (V33) (Basch 1991b) shows a ship with a lowered yard, but sharing many of the rigging characteristics present on the vessel from Kelenderis (Pomey 2006: 327-8). The similarity in rigging components present on both vessels suggests that the vessel from Corinth is likely to have been rigged with a lateen/settee sail. A Graffito from the monastic site of Kellia in northern Egypt dates to AD 600-630 (V34) (Basch 1991a) and shares many rigging components with the depictions from Kelenderis and Corinth (Pomey 2006: 327-8) which are characteristic of the lateen/settee rig. The Kellia depiction carries a fully triangular sail and is clearly a representation of a lateen sail.

The settee sail was therefore in use in the Mediterranean from the late 5th century AD and the lateen sail from at least the late 6th/early 7th century AD. Furthermore, this group of early depictions of lateen/settee rigged vessels all share similar characteristics which can be positively identified in the iconographic record (c.f. Pomey 2006: 327-8), these include;

- A multi-block halyard system running from the masthead to a large block and tackle at the stern of the vessel. The absence of a backstay suggests the halyard system also fulfils this function.
- Hook-shaped masthead which facilitates the halyard system running to the yard.
- A long yard, which is roughly the same length (or slightly longer) than the vessel itself.
- The presence of a small upright projection in the bow of the vessel, also surmounted with a hook-shaped fitting. This may be a small foremast, or it may be a spar designed to take bowlines, tack-tackles etc.
- The presence of vertical supports and lashing around the base of the mast to provide additional support.

As well as being common to this early group of lateen/settee rigged vessels, many of these rigging components or features are also characteristic of depictions of Mediterranean lateen/settee rigged vessels from the wider medieval period (e.g. V35-39) (Chapter 2.2). This correlation suggests that the Mediterranean lateen/settee rig remains relatively unchanged from the 5th century AD until the late-medieval period (c.f. Whitewright In Press-c).

Other iconographic sources

Although the lateen/settee rig can be traced with some certainty to the 5th century AD, a series of depictions exist from earlier centuries which are more ambiguous, either in terms of the contents of the iconography or its dating, than those cited above. These earlier depictions have been cited by scholars as providing further evidence of the lateen/settee rig in the ancient Mediterranean and so must be investigated. The first example is a north Italian mosaic dating to the 4th century AD which is cited by Casson (1995: Fig. 182), Pryor (1989: 273) and Kreutz (1976: 83) as depicting a relatively small craft rigged with a lateen sail. Basch (1987b: 492, n.61) observes that the mosaic has been restored past the point at which it can be considered as viable evidence. This has prevented the mosaic being included within the appendices of this study and it shall not be considered further. Another example cited by Casson (1966; 1995: 244) is the graffito of a lateen rigged ship scratched onto a pot sherd found on the island of Thasos. There can be no doubting the artists depiction of a vessel rigged with a lateen sail. However, the dating and origin of the pot sherd remains very uncertain (Basch 1971) and should not be considered as dateable evidence for the development of the lateen sail in the Mediterranean (c.f. Basch 1971: 330).

Two other examples of lateen/settee rigged vessels published by Basch (2001) must also be referred to. These are a fresco from Eboda (V41; Basch 2001: Fig. 19) and a graffito from the site of el-Auja (V42; Basch 2001: Fig. 17), both in Israel. Both of these depictions are unequivocal in their depiction of vessels rigged with lateen sails, however, there are problems surrounding their dating. The graffito from el-Auja probably dates to the late-antique or early medieval period, but this cannot be certain. The graffito is portrayed with a pair oversize steering oars reminiscent of those visible on lateen/settee depictions from Kelenderis (V32) and Kellia (V34) and which may further suggest an earlier date. The depiction from Eboda is in the form of a fresco and is clear in its depiction of vessels rigged with a lateen sail. However, the dating of the fresco can not be refined with any certainty, although Basch (2001: 71) is of the opinion that it probably dates to the 6th century AD. Although the exact date of both the el-Auja graffito and the Eboda fresco is uncertain, the clarity of their depiction and their rough date range reinforces the presence of the lateen/settee rig in the Mediterranean during the late-antique period. Attention may now be turned to earlier iconographic examples.

Alexander of Miletus

Casson (1956; 1995: Fig. 181) also cites a relief carved on a tombstone, belonging to Alexander of Miletus, at Piraeus dating to the 2nd century AD (V31). This shows a vessel with a heavily inclined, slightly curving yard set on a forward raking mast. The sail has a short luff and the tack is held down in the bow of the vessel, while the peak is high above the head of the skipper. He is depicted holding a stick which leads towards the yard arm in the manner of a vang. It is observed by La Roërie (1956a: 239) that such a stick was a common substitute for a brace in many contemporary depictions. If the direction of the stick is continued to the yard in the manner of a brace it would have connected midway between the peak of the sail and the mast. Such a location is in keeping with the attachment position of the vang of a lateen/settee rig, but not of the brace for a square-sail rig which are normally attached at the end of yard. The hull of the vessel is purely Roman in its representation of a goose-headed stern post and enclosed steering oars.

The rig depicted in the relief satisfies most of the criteria required of a lateen/settee rigged vessel (chapter 2.2), especially with regard to some of the details of the rig; unequal luff and leech lengths, raked mast, inclined and curved yard and vang position. The relief failed to be widely accepted by scholars as a depiction of a settee rigged vessel at its time of publication. The explanation given for this is that the relief represents a poorly executed square-sail confined by the spatial limitations of the surrounding archway (Basch 1989: 332, n.13; La Roërie 1956a: 239; Le Baron-Bowen 1956: 240; Moll 1929: 21). There have been exceptions with some scholars accepting Casson's interpretation more readily (e.g. Kreutz 1976: 82; Moore 1957: 241). A simple interpretation of the relief hinges on whether or not the viewer believes the sail has been deliberately misshaped to fit it within the confines of the archway. Reference to Figure 3-2 indicates that a square-sail could have been illustrated within the space available, had the artist so wished. During the discussion following a recently presented conference paper the relief was again categorised as ambiguous and problematic.[23] In the most recent edition of 'Ships and Seamanship in the Ancient World' Casson (1995: 244) maintains his view that the relief represents the earliest example of a lateen/settee rigged vessel. Certainly, newcomers to the field of maritime archaeology, have accepted Casson's conclusions. In a rig development chronology published on the world-wide-web by the Nautical Archaeology Program, Texas A&M University, the tombstone of Alexander of Miletus is cited as representing evidence of the lateen/settee rig in the 2nd century AD.[24] Other recent publications gloss over the issue by accepting that the lateen/settee rig was in use on small craft (such as that assumed to be depicted in V31) as early as the 2nd century AD but was not widely used on larger vessels until the Byzantine period (e.g. Kingsley 2004a: 79).

When originally published (Casson 1956), V31 was separated chronologically from the nearest unequivocal depictions of a lateen/settee rig (V35-37) by seven centuries. It also required the total abandonment of the belief that the lateen/settee sail originated in the Indian Ocean before being spread to the Mediterranean by the 7th century AD Arab invasion. The depiction of a settee rigged ship at Kelenderis has reduced the chronological gap to three or four centuries. In conjunction with this the 7th century AD Arab invasion is no longer viewed as being the point when the lateen/settee rig was brought to the Mediterranean because of the depiction of a lateen sail from Kellia. If the tombstone of Alexander of Miletus was published today, as a new discovery, against the background of depictions from Kelenderis and Kellia, it seems likely that it would be accepted as earlier evidence for the use of the lateen/settee rig in the Mediterranean. The features and form of the sail, shown by the artist strongly suggest that the vessel depicted on the tombstone of Alexander of Miletus was rigged with a settee rig. Features which become characteristic of the lateen/settee sail in later periods, most notably the hook-shaped masthead, are absent from the depiction. This might suggest that the vessel was depicted when such rigging components had not been developed or were not used as standard on lateen/settee rigs. Viewing the evidence in its broader context, the tombstone of Alexander of Miletus should be considered as a depiction of a sailing vessel rigged with a settee sail dating to the 2nd century AD. Furthermore, it may represent an early example of the rig, in which features characteristic of later depictions have not been developed or incorporated.

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[23] The paper presented (Whitewright In Press-a) outlined the problems of the current theories of technological change which have been utilised to understand the emergence of the lateen rig. Casson's relief (V021) was cited as a possible example of the lateen/settee rig dating to the 2nd century AD. In the discussion following the paper, P. Pomey and Y. Kahanov both agreed with one another that the relief should not be considered as a reliable source.

[24] The chronology of rigging development can be found at http://nautarch.tamu.edu/shiplab/index-chrono.htm

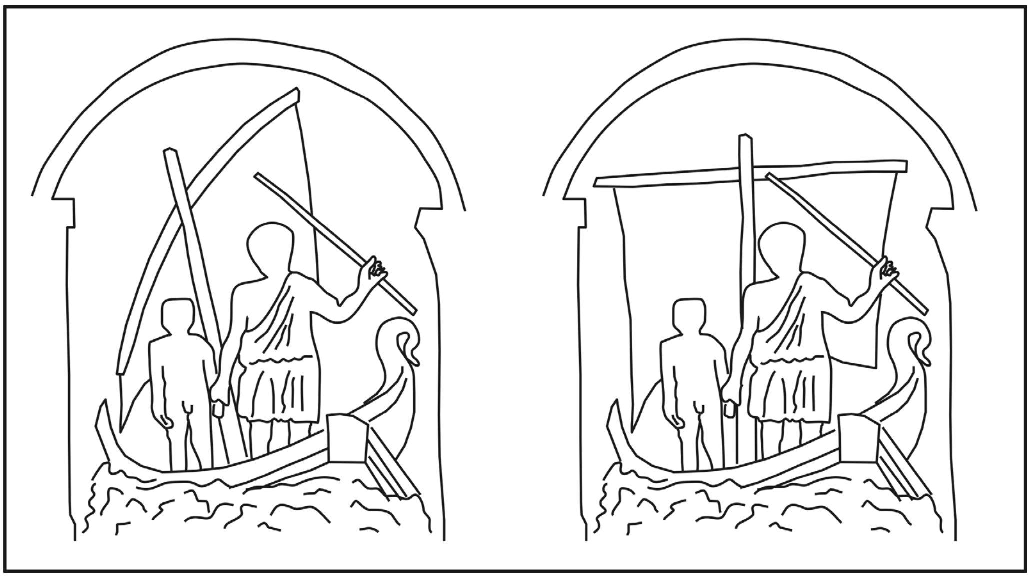

Figure 3-2. The tombstone of Alexander of Miletus, square or lateen/settee sail? Academic interpretation of the relief has hinged on the belief that the artist has depicted a square-sail, altered to fit into the confines of the surround. The diagram illustrates the ample space in which the ancient artist could have depicted a square-sail (right) rather than a lateen/settee rig (left), had they so wished.

Anfouchy

A second, potentially earlier but equally problematic depiction (V40) has been identified by Basch (1989: 332, Fig. 8) as depicting a vessel rigged with a lateen sail. The vessel is a simply drawn graffito scratched in the plaster of hypogeum No.2 of the Necropolis of Anfouchy in Alexandria. Other depictions of ships are also present in the same hypogeum which has been dated to the 3rd century BC (Basch 1989: 328). One of these vessels (V03) has been given a *terminus ante quem* by Basch (*ibid*) of the Augustine period because of the style of the ram associated with the vessel. On this basis all the vessels have been dated to between the 3rd century BC and the Augustine period. In the case of V40, Basch (1987b: 474) cannot be sure that the graffito was not added after the other vessels. It may therefore be of a later, unknown date. Despite the simplicity of the graffito, he draws stylistic comparisons with the other vessels in the hypogeum in order to assign the vessel a similar date between the 3rd century BC and the Augustine period. Basch (1989: 332) concludes that V40 is representative of a small sailing boat rigged with a lateen sail and dating to the 3rd or 2nd century BC. It is his opinion (*ibid*) that such vessels remained absent from other forms of iconographic evidence because they were "small craft which were judged to be unworthy of being shown in the 'official' iconography." In an earlier commentary on the graffito, Basch (1987b: 474) notes the similarities between the bow projection on V40 and those seen on Nile vessels in the 18th century. Such similarities, combined with a time difference of c.2000 years and the impossibility of accurately dating the depiction cast considerable doubt on its dating to the 3rd and 2nd centuries BC.

First-hand inspection of the graffito does not resolve the question. The vessel undoubtedly takes the form of a lateen rigged vessel of some sort. However, there is no obvious way of distinguishing the order in which the ships present in the tomb were drawn, or at what date. It may be that different ships, representing those familiar to different visitors have been added at different times over the centuries. This appears to be the case at a rock art site in the Egyptian eastern desert where a depiction of a two-masted lateen rigged ship appears in conjunction with vessels from Pharonic Egypt (Van Rengen*, et al.* 2006). While the latter site is in a very different context, it illustrates the point that people will add graffiti from their own period to graffiti from earlier periods. It is perhaps significant that since the initial publication of the Anfouchy graffito it has not become widely adopted as an early depiction of a lateen rigged vessel. The problems with its dating preclude the inclusion of the graffito as dateable evidence within this study.

Lateen/settee iconography: Conclusions

Mediterranean iconographic evidence regarding the earliest use of the lateen/settee sail is mixed. From the 5th century AD there are unequivocal depictions of lateen/settee rigged vessels which exhibit an identifiable set of characteristics. These characteristics, such as the hook-shaped masthead continue to be depicted on lateen/settee rigged vessels until the 13th or 14th centuries AD (chapter 2.2). Prior to the 5th century AD the picture is more complex. Analysis of the lateen/settee rig carried out in chapter 2.2 suggests that the sailing vessel depicted on the tombstone of Alexander of Miletus (V31) has a settee rig. This sailing rig was therefore in use in the Mediterranean from at least the 2nd century AD. An earlier depiction from Alexandria has sufficient doubt surrounding its date for it not to be considered as reliable evidence. From the 5th century AD onwards, lateen/settee rigged ships are depicted with a consistent and identifiable group of rigging components. These components continue to be associated with the lateen/settee rig in the Mediterranean until the late-medieval period suggesting that the appearance and use of the rig remains exhibits little change between late-antiquity and the late-medieval period.

3.3.2 Mediterranean textual sources

Procopius

Mediterranean literary sources provide somewhat ambiguous evidence regarding the earliest use of the lateen/settee rig. Sottas (1939: 229-230) identifies a passage from Procopius referring to the year AD 533 in which Procopius observes

"So, at the sailing of the expedition, he [Belisarius], on careful consideration, gave an order that the three ships carrying the officers in chief command should have almost as much as a third of the upper angles of their sail painted red."

- Procopius, de bello Vandalico 1.13.3 (tr. by J. Haury. 1905).

This passage has been widely accepted as indicating that the peak of a lateen/settee sail was painted red in order to identify the commanders' ships (c.f. Carr Laughton 1939: 441; Casson 1995: 245, n.82; Kreutz 1976: 83; La Roërie 1956a: 238; Moore 1957: 241; Percival Kaeyl 1956: 154). Intriguingly, lateen/settee rigged vessels still exist in the south-eastern Mediterranean where the upper angle of the sail is coloured (Moore 1925: 96; Percival Kaeyl 1956: 154). The definitive iconographic evidence from the 5th/6th century AD serves to confirm Sottas' original theory, derived from literary evidence, that the lateen/settee sail was in use by the Byzantine period.

Synesius

An earlier textual source which has been interpreted as referring to a vessel rigged with a lateen/settee sail is a letter written by Synesius of Cyrene to his brother in Alexandria (tr. Fitzgerald 1926). Synesius describes in some detail a voyage taken from Alexandria, westward along the coast to the port of Azarium in the early years of the 5th century AD (ch. 3.1.3, note 20). His description of weather conditions and directions sailed en-route, has allowed a theoretical reconstruction of the route taken by the vessel to be carried out (Kahanov 2006). In one passage Synesius describes the efforts of the crew and passengers to shorten sail while running before a storm;

"Now what made death gape at our feet was the fact that the ship was running with all sails spread, and that there was no means of taking them in, for as often as we attempted this we were thwarted by the ropes, which stuck in the pulleys; and again we had a secret fear lest in the night time, even if we lived out the sea, we should approach the land in this sorry plight.

But day broke before all this had time to occur, and never, I know, did we behold the sun with greater joy. The wind grew more moderate as the temperature became milder, and thus, as the moisture evaporated, we were able to work the rigging and handle the sails. We were unable, it is true, to replace our sail by a new one, for this was already in the hands of the pawnbroker, but we took it in like the swelling folds of a garment"

- Synesius, Epist. 4 (tr. Fitzgerald 1926: 85-86).

Casson (1995: 268-269) maintains that this passage indicates that Synesius sailed a lateen rigged vessel. He offers an alternative translation of the final sentence as "We weren't able to substitute another, bastard sail since it was in pawn" He concludes that in this context the phrase *nothos* "bastard" referred to a smaller sail. He believes that the crew of the vessel would have swapped the mainsail for a smaller one, if it had been available. The practice of substituting one sail for another, smaller sail, is consistent with the practice used to shorten sail on Indian Ocean lateen/settee rigged ships (ch. 2.2.3). This is central to Casson's theory that Synesius' vessel was lateen rigged. A few days later the ship again runs into a storm and "again the sail was intractable and defied all our efforts to take it in" (tr. Fitzgerald 1926: 87). Casson (1995: 269) also offers an alternative translation to this line as “Again the sail was hard to handle, and it couldn’t be made to move for lowering”. Casson correctly observes that the practice on a Mediterranean square-sail ship is to shorten sail by *brailing up* the sail while on an Indian Ocean lateen/settee rigged vessel the sail must be lowered in order to change it. Casson’s conclusion that Synesius sailed upon a lateen/settee rigged vessel hinges, in both cases, on his own alternative translation of the text.

An alternative interpretation is offered by Meijer (1986: 67-8) and Kahanov (2006: 435-6) who both conclude that the vessel was rigged with a square-sail in the conventional Mediterranean fashion. Meijer (1986: 67-8) notes that the Greek phrase *pasin histiois* is used which signifies the presence of more than one sail, Fitzgerald translates this as ‘running with all sails spread’. Such a configuration is inconsistent with our knowledge of early lateen/settee rigged vessels in the Mediterranean which are consistently depicted with a single mainsail (ch. 2.2). The second sail may have been an *artemon* or simply a topsail, it is not mentioned again, suggesting it is of secondary importance to the mainsail which becomes the focus of Synesius’ description. Meijer (1986: 68) agrees with Casson that the yard was lowered during the second storm, but he points out that this was done because the yard had broken, there was no alternative but to lower it. Synesius’ description of the sail being taken in ‘like the swelling folds of a garment’ is consistent with the observed use of brails on the *Kyrenia Liberty* replica.

The only remaining point of ambiguity is the point accepted by all three authors, that the mainsail would have been swapped for another, if such a sail had not been at the pawn brokers. In the context of a square-sailed vessel that must be explained as indicating that the mainsail was damaged during the storm and needed to be changed. This would not be unsurprising in light of the fact that the sail was left at full-size for the duration of the night. Earlier in the letter Synesius notes that the screen which separated the male and female passengers was the ‘suspended fragment of a recently torn sail’ (tr. Fitzgerald 1926: 81). This suggests that damage to sails was relatively common. The spare sail may well have been pawned in order to pay for the replacement for the torn sail serving as a screen. The rig of Synesius’ vessel remains unresolved and somewhat ambiguous, with the evidence broadly favouring a square-sail vessel.

Summary

Literary evidence does little to refine our understanding of when the lateen/settee rig became widely utilised in the ancient Mediterranean. The passage from Procopius has gained widespread acceptance. Although it is only contemporary (at best) with the iconographic depiction from Kelenderis, it does serve to highlight the increasing adoption of the lateen/settee rig in the Mediterranean at that time. Meanwhile the passage from Synesius remains open to discussion and analysis regarding the type of rig described and further serves to reinforce the translation problems associated with literary evidence (ch. 1.2.1). The tombstone of Alexander of Miletus, recognised by this study as an example of a settee rigged vessel, considerably pre-dates Synesius. If Synesius' vessel is interpreted as carrying a lateen/settee rig it does not improve our understanding of when this rig was introduced to the Mediterranean.

3.3.3 The lateen/settee rig in the Indian Ocean

Direct maritime archaeological remains in the Indian Ocean are rare, consequently a limited iconographic and literary record is relied upon for information. The significance of Portuguese navigation to the Indian Ocean from 1498 should not be overlooked. Following this event, Indian Ocean maritime cultures seem to have rapidly adopted western European shipbuilding techniques such as the use of transom sterns (Hornell 1946b: 237). Evidence coming from after 1498 will always be under suspicion with regard to the origin of the vessels which are represented. Evidence dating to before 1498 is usually seen as representative of Indian Ocean cultures rather than any outside influences. This stance tends to ignore the fact that Mediterranean peoples were actively trading on the Indian Ocean from the late first millennium BC for several hundred years (ch. 1.3). There is direct archaeological evidence from this period that at least some sailing vessels used on the Indian Ocean were rigged with Mediterranean sailing rigs (Whitewright 2007b). Likewise, following Arab expansion into the Mediterranean from the 7th century AD there was ample opportunity for technological transfer between the two regions. The Indian Ocean is therefore not devoid of external influences to maritime technology prior to 1498 and should not be viewed as a sealed technological vacuum before this time.

Iconographic sources

Scholars have traditionally assumed that sailors of the Indian Ocean have always used the lateen/settee rig (e.g. Boxhall 1989: 290; Hourani 1951: 100-101), without stating why this is the case. Others have been more conservative and restricted its use to the last thousand years (Villiers 1952: 73). Reference to the survey by Nicolle (1989) of 'Shipping in Islamic Art' is revealing with regard to the Indian Ocean. The Mediterranean witnesses the consistent depiction of lateen/settee rigged vessels from the mid-first millennium AD onwards, in keeping with the comparative non-Islamic sources which Nicolle draws upon. In contrast to this, the earliest examples of lateen/rigged vessels in the Indian Ocean do not appear until c. AD 1564 when three Ottoman galleys (V50) taking part in the battle of Cape Musandam (AD 1544) are depicted on a Portuguese manuscript (Nicolle 1989: 189 & Fig. 79). The Ottoman Empire occupied Egypt, Syria and western Arabia in AD 1516-17 (Hourani 2002: 215) and expanded to the shores of the Persian Gulf soon after. The Ottoman historian Haji Khalifeh (tr. Mitchell 1831: 26-27) recorded that the Ottomans did not enter the Indian Ocean before AD 1525 but from then on successful advances were made. Conflict with the Portuguese was perhaps inevitable and Ottoman sources record the fitting out of warships on the Red Sea and the Persian Gulf. It seems likely that these vessels were similar to Ottoman warships in the Mediterranean; oared vessels with a single lateen sail. In this case the vessels have a lateen mainsail and a square-sail *artemon* set in the bow of the vessel. The naval context in which these vessels appear suggests that they would have had close parallels with their counterparts in the Mediterranean. The expansion of Ottoman land power to the shores of the Indian Ocean provides a reason for the introduction of this type of vessel to the Indian Ocean direct from the Mediterranean. However, the artist may simply have drawn a form of Mediterranean galley with which they were familiar. Nearly contemporary Portuguese depictions of 'Arab Ships' on a map of the Indian Ocean dating to AD 1519 show vessels with characteristically Arab hull shapes but rigged with square-sails (Nicolle 1989: 189 & Fig. 80). Again, the artist may simply be illustrating a Western European ship with which they were familiar rather than Indian Ocean reality.

Another 16th century AD depiction of a lateen rigged vessel (V51) comes from the East African site of Gedi (Garlake & Garlake 1964: Fig 4.3). The authors note that they find it strange that the rig does not appear in earlier East African ship graffitos (Garlake & Garlake 1964: 203) which are mainly of square-sailed vessels (chapter 3.1). Like the square-sailed vessels the image is scratched in the plasterwork of buildings. Its association with other vessels which are obviously Indian Ocean in origin suggests that the vessel is indigenous to the Indian Ocean, rather than a depiction of a newly arrived Portuguese vessel. Ship depictions from this time onwards tend to illustrate more lateen/settee rigged ships than square-sailed vessels, although examples of the latter still appear.

Textual sources

The principal textual source on medieval Arab navigational and sailing practice is undoubtedly the work of Ibn Mājid, a *mu'allim* or master navigator, writing in c. AD 1490 (ch. 1.2). Ibn Mājid refers to the sailmaking practice used by Arab sailors and its relationship to the star constellation of Pegasus. He states that

"the two southern ones [stars] being further apart than the two northern ones in the same proportion as the dāmān [leech] of a ship to its jawsh [luff]. The ratios being 10:13⅓ whereas the jawsh is ¼ to the dāmān ⅓. This is sufficient on this point concerning the mathematics of sail construction for the sails of ships are constructed according to these figures" - *(tr. Tibbets 1971: 116).*

This formula produces a sail which is nearly square in shape (Tibbets 1971: 52), albeit with an inclined yard. The difference between the luff:leech proportion of 3:4 of Ibn Mājid's sail and those recorded by Johnstone and Muir (1964: 313 & Fig. 9) on a Kuwaiti vessel of 1:6 (Figure 3-3) causes Tibbetts (1971: 52) to state the need to re-read the passage with a modern sail in mind. This is achieved by taking Ibn Mājid to mean the distance of the *dāmān* from the *jawsh* rather than their relative proportions as Ibn Mājid actually states. Tibbetts does this in order that the sail of Ibn Mājid should be similar in shape to that in modern use on Arab vessels. He concludes that such an approach, producing a sail in which the proportion of the foot of the sail to its head of 3:4 fits more closely with modern observations of settee sails.

Such a solution does not fix the ratios of the luff and the leech which are actually referred to by Ibn Mājid. Figure 3-4 shows three sails which all fit Tibbets' foot:head ratio, all have very different luff:leech ratios. Tibbets manipulates the textual evidence to fit the modern, western observations of what a settee sail should look like. A better solution is simply to accept Ibn Mājid's description of sail dimensions. Tibbets' approach neglects the fact that the Arab sails of the medieval period may easily have been a different shape to those of the 20th century. Basch (2001: 68) asserts that the shape of the settee sail has only assumed its nearly triangular shape during the 19th century. That there was a difference in shape over a 450 year period is proved by the different proportions recorded by Ibn Mājid in the late 15th century AD when compared to ethnographic observers in the mid 20th century (e.g. Johnstone & Muir 1964: 313 & Fig. 9). It is telling that some of these recent observations (e.g. Le Baron-Bowen 1953b: 185-6) record a variety of different luff:leech ratios in concurrent use within the Indian Ocean region (c.f. Figure 1-2).

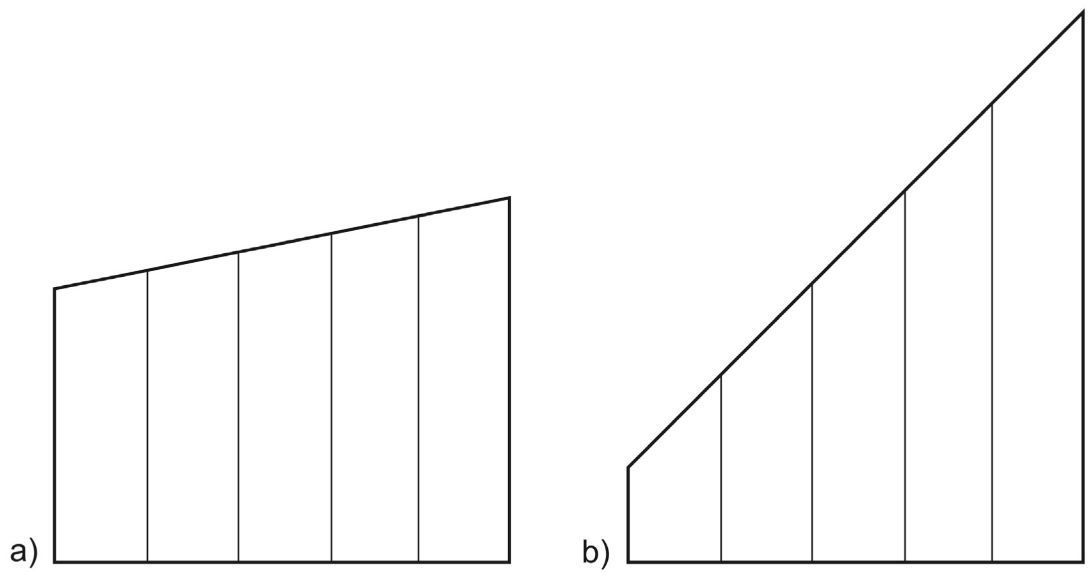

Figure 3-3. Settee sail luff:leech ratios. a) Described by Ibn Mājid in the late 15th century AD, ratio of 3:4. b) Observed by Johnstone and Muir (1964: 313) in the mid-20th century, ratio of 1:6. In both cases the foot of the sail has been kept at the same length.

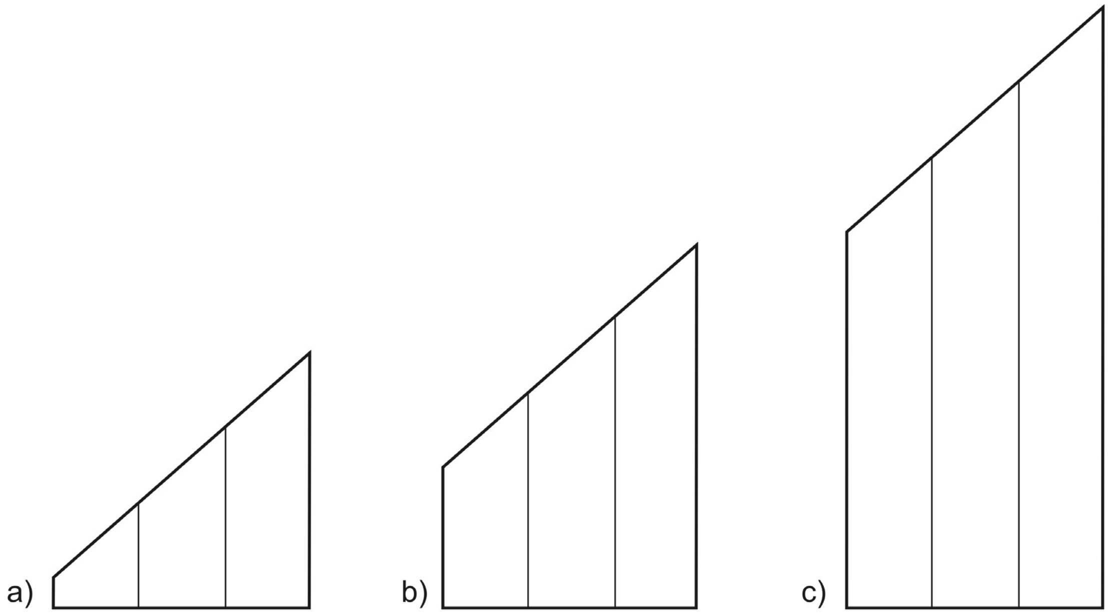

Figure 3-4. Three settee sails with the foot:head ratio of 3:4 as interpreted by Tibbetts (1971: 52). All have very different luff:leech ratios; a)1:8.3, b) 1:2.6, c) 1:1.6.

The passage from Ibn Mājid is still of critical importance to this study. If Ibn Mājid's ratio's are accepted at face value they produce a sail which, although much squarer than a modern Indian Ocean settee sail, still has a leech which is longer than the luff. The important point is that the asymmetrical nature of such a sail dictates that it cannot be rigged and used like a square-sail, it must be set and used as a fore-and-aft sail (ch 3.6). Ibn Mājid was describing a settee sail, simply one with a longer luff than those in use on many present day Arab ships. This conclusion is borne out by many of the rigging details and sail handling practices described by Ibn Mājid and earlier Arab navigators[25] (Tibbets 1971: 52-58) being consistent with those noted on present day Indian Ocean settee rigged vessels. At no time in these works is mention made of a different type of sail and rig being used other than the one described by Ibn Mājid. There is therefore a strong case to be made that the rig with which Ibn Mājid was familiar was in use by the earlier navigators. Likewise the dangers of sailing listed by Ibn Mājid; being caught with the sail aback

[25] Ibn Mājid himself acknowledges the history of Arab navigation in the beginning of his own work. He cites "three well-known men"; Muhammad ibn Shādhān, Sahl b. Abbān and Laith b. Kahlān who are dated to around AD 1100 (Tibbets 1971: 5, 71). The earliest navigator referred to by Ibn Mājid is Khawāshir b. Yūsuf b. Sabāh al-Arīkī who was sailing in around AD 1009/10 (*ibid*). Ibn Mājid's work represents one of the last great treatises on the Arab technique of Navigation which stretches back through a series of earlier works to the tenth century (Hourani 1951: 107-8). The *Kitab ajaib al-hind* or 'Book of the Wonders of India' (tr. Freeman-Grenville 1981), a collection of 10th century sea stories also describes maritime practices and terminology strongly associated with those described by Ibn Mājid and more recent 20th century observers.

the mast, or with the largest sail hoisted at night or in a squall are roughly the same problems as those recently observed on Indian Ocean vessels (e.g. Villiers 1940).

Archaeological remains

A rare example of archaeological evidence relating to the settee rig was excavated from the medieval Islamic port of Quseir al-Qadim. The lower element of a running stay from a small sailing vessel, was identified following its excavation from a context in a building dating to the Mamluk period of the site (Flatman & Thomas 2006). This probably relates to the late 13th and 14th century AD based on current analysis of the Islamic ceramics from the site (Bridgeman pers.comm.). The nature of the find is consistent with the foot of a running stay (*saghla)* observed by the author on a modern Arabic sailing vessel on the Red Sea coast. In each case an identical knot was used to secure the *saghla* to the rope of the stay.

Summary

The settee sail familiar to Ibn Mājid may have had a more squarish form, with a longer luff than more recent settee sails. Textual and archaeological sources indicate that it was still rigged and handled in the manner of a modern Indian Ocean settee sail. It is this final point which is the most important. The sail of the medieval Indian Ocean can be partially identified and classified according to the way in which it was used as well as its basic shape. The use of the settee sail and its associated rig by Ibn Mājid and probably by his forerunners is of further significance because it predates the Portuguese discovery of a route to the Indian Ocean in AD 1498 and the arrival of Ottoman warships from AD 1525 onwards. Both of these cultures had extensive knowledge and use of the lateen/settee sail in the Mediterranean prior to their eastward expansion. The textual evidence cited above indicates that the settee sail was already in use in the Indian Ocean by the end of the 15th century AD. The navigational tradition within which Ibn Mājid was writing suggests that the lateen/settee sail was used in the Indian Ocean at least as early as the 9th or 10th century AD. Iconographic evidence from East Africa illustrates a lateen sail dating from the 15th century AD. Archaeological evidence, although slim, attests to its use on the Red Sea in the 13th or 14th centuries AD.

3.3.4 Conclusion

The conventional view of the use of the lateen/settee sail in the Mediterranean and Indian Ocean is that the rig was developed in the Indian Ocean before spreading to the Mediterranean via the Arab invasions of the 7th century AD. Depictions of lateen/settee rigged ships from the Mediterranean which predate this indicate that the rig must have been in use in the Mediterranean prior to the 7th century AD. Although depictions of lateen/settee rigged ships are still rare, the iconographic and literary sources suggest that they became more widespread from the 5th century AD. It is difficult to identify the earliest date at which the lateen/settee rig was used in the Mediterranean. The currently available evidence suggests that an early form of the settee rig was in use from the 2nd century AD.

More instructive with regard to an origin for the lateen/settee rig is its appearance in the Indian Ocean. Far from being the universal sailing rig of this region, evidence for it is hard to find. Iconographic depictions restrict its use to the 15th century AD onwards. The slim archaeological evidence suggests its use from the 13th or 14th centuries AD. Textual sources corroborate this date but may be traced further back to the 9th or 10th centuries. What is clear is that the lateen/settee rig is far from universal across the Indian Ocean and that evidence for the use of the rig in the Mediterranean is both clearer and earlier in its date. Although overly simplistic to argue a Mediterranean origin for the lateen/settee rig on this basis alone, the evidence currently available indicates that the lateen/settee rig was in widespread use in the Mediterranean at least 700 years before similar use in the Indian Ocean. It should be further noted that throughout the use of the lateen/settee rig in the Indian Ocean there is also a strong tradition of using square-sail vessels. In contrast to the Mediterranean, where use of lateen/settee rigs appears to signal the abandonment of square-sail rigs, in the Indian Ocean both rigs are used contemporaneously over an extended period of time.

The relative time-lines of fore-and-aft rigs in the two regions are outlined in Figure 3-5. This draws further attention to the sprit-rig as an alternative form of fore-and-aft rig which precedes the lateen/settee rig in the Mediterranean but which has no technological relationship to it. The presence of the sprit rig highlights the inadequacy of an approach to technological change founded on a 'unilinear progression' of technology and indicates the potential for original maritime technological development in the ancient world.

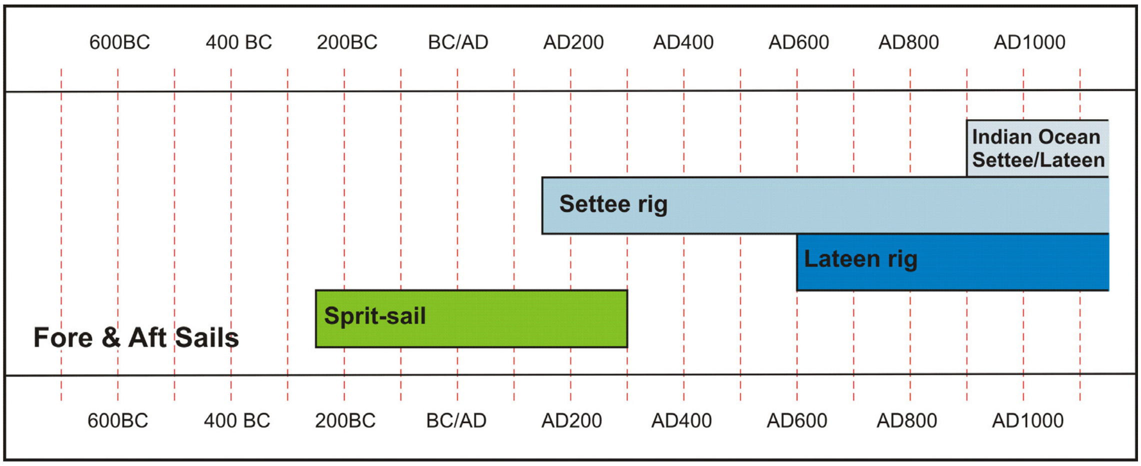

Figure 3-5. The relative time-lines of fore-and-aft sailing rigs in the Mediterranean and Indian Ocean during antiquity.

3.4 Hull Construction

3.4.1 Mediterranean hull construction

Although the principal subject of this study is the introduction of the lateen/settee sail to the ancient Mediterranean, attention must also be given to the hulls on which such sailing rigs were placed. Alteration or changes to hull form or construction would have had implications for the type of sailing rig to be set. Furthermore, the relatively high survival of hull remains in the archaeological record of antiquity may provide a clearer indication of the nature, scope and intensity of any technological change/stasis than is available through the more limited sources relating to sailing rigs. The availability of well-excavated shipwreck evidence has meant that ancient hull construction has been the subject of extended, detailed study and analysis (e.g. Rival 1991; Steffy 1994; Pomey 2004). This has led to the observation of a clear change in the construction technique utilised in the shipping of the ancient Mediterranean during the first millennium AD. In simple terms, hull construction moves from a technique based upon the planks of the vessel (shell-first) to one in which the frames of the vessel dictate the form of the hull (frame-first) (McGrail 2008: 623-4; Steffy 1994: 83-5).

This process of technological change is not straightforward and is not yet clearly understood. However, several trends can be observed. Shell-first Mediterranean ships are constructed by joining the planks together via a series of closely set mortice and tenon joints, secured with pegs, along the edges of the planks. The result is a strong, rigid shell into which frames and cross-beams can be inserted. The use of pegged mortice and tenon joints in this fashion has been observed as early as 1327 +4/-7 BC on the Uluburun shipwreck from southern Turkey (Manning *et al* 2001: 2535; Pulak 1998: 210-214). The same construction technique was used on the hull of the Kyrenia ship (S024) (Steffy 1985), dating to c.310 BC and has been widely observed on other shipwrecks dating to the late first millennium BC and early first millennium AD (for examples see Beltrame & Gaddi 2007; Gassend*, et al.* 1984; Pomey 2004; Steffy 1994: 42-72). A notable addition to the Kyrenia wreck, not present on the Uluburun wreck is the use of lead sheathing to cover the hull below the waterline. This feature becomes common, although not universal, on Mediterranean ships during the Roman period. Lead sheathing appears to fall out of use by the 3rd century AD (Hocker 1995; Parker 1992: 27).

Mediterranean ships are often assumed to be the symmetrical, double-ended vessels represented in the archaeological (e.g. Laurons 2 (S026) (Gassend*, et al.* 1984) and Dramont E (S017) (Santamaria 1995) shipwrecks) and iconographic (e.g. V05, 06, 09, 14-16, 18, 20, 22, 25 & 26) record. However, both the archaeological and iconographic sources also inform us of another hull form which was built concurrently by Roman shipbuilders. These are vessels depicted in the iconographic record with a concave stem post and cutwater (e.g. V10, 12, 13, 23). Such vessels have also been identified in the archaeological record by the remnants of their concave stemposts (e.g. Madrague de Giens (S029) (Pomey 1982; Rival 1991: 148-244; Tchernia & Pomey 1978)). Reference to the hull remains of these shipwrecks reveals a characteristic angular scarf between the keel and endposts of the vessels. This contrasts with double-ended vessels where a smoother, more continuous join is present (compare S026 with S029). The difference between the two hull forms, both built shell-first using mortice and tenon joined planks, is illustrative of the variation in hull-form and conception within a single shipbuilding tradition usually viewed as 'Mediterranean' in character (c.f. Figure 2-23).

Technological change

The initial alteration to the long held shell-first construction tradition is a change to the spacing of the mortice and tenon joints used to hold the planks together (Bass & van Doorninck Jr 1982: 312; van Doorninck Jr 1976: 123 & Fig. 7). Later wrecks, such as those from the 4th century AD site at Yassi Ada (S048) (Bass & van Doorninck Jr 1971; van Doorninck Jr 1976) or the mid 5th century AD Dramont E shipwreck (S017) (Santamaria 1995: 131-174) have mortice and tenon joints more widely spaced (20cm centres) than on earlier shipwrecks (10cm centres). Eventually the locking pegs are dispensed with and the tenons are simply loosely located in the mortices. In conjunction with this, the framing system becomes heavier and is set slightly closer together. The transition then sees the abandonment of edge-joined planking in favour of planks which are attached directly to the pre-erected frames of the vessel (Steffy 1994: 84). It is now the shape of the frames which dictate the form of the hull, rather than the planks. Such a change requires an alteration in the mindset of the shipbuilder in terms of the way they conceive the shape of a ship, prior to its construction, because of the need to pre-shape the frames (c.f. Pomey 2004). A series of shipwrecks were utilised to sketch out a logical progression from shell-first to frame first (e.g. Steffy 1994: 83-91). This was illustrated by an ever diminishing number of mortice and tenon joints and a reduction in their importance in maintaining the integrity of the hull. The linear nature of this progression is evident in Steffy's (1994: Fig. 4-8) widely used diagrammatic expression of the relevant shipwrecks spanning from the 4th century BC to completion of the process by the 11th century AD (Figure 3-6).

The orderly, logical nature of this transition has been dramatically altered by the discovery and excavation of a series of shipwrecks which do not fit the chronology set out above. An entirely frame-first built ship dating to the late 5th/early 6th century AD and referred to as Dor 2001/1 (S016) has been excavated from the site of Dor on the coast of Israel (Mor & Kahanov 2006). A contemporary wreck from the same site, Tantura A, was also built using a frame-first technique

(Kahanov*, et al.* 2004: 113-118; Mor & Kahanov 2006: 286). Both wrecks date to within half a century of the fully shell-first Dramont E ship illustrating a likely chronological overlap between the two building traditions. The Saint Gervais B shipwreck (S043), from southern France and dating to AD 600-625, utilised only a limited number of loosely located mortice and tenons in the bow and the stern. The main method of construction was frame-first, based on attaching the planks to the frames with iron nails (Jézégou 1989; Pomey 2004: 32). The situation is further confused by the presence of vessels of 'mixed construction' (Pomey 2004: 28), utilising elements of both techniques in the 5th century AD; Ravenna (S042) (Medas 2003), mid 5th - 6th centuries AD; Dor D (Kahanov & Royal 2001; Royal & Kahanov 2005), the 7th century AD; Yassi Ada (S048) (Bass & van Doorninck Jr 1982) and Pantano Longarini (Throckmorton & Throckmorton 1973) and as late as the 9th century AD Bozborun vessel (Harpster 2005). These vessels used both the shell and the frame of the vessel to determine its shape at different stages of construction. Vessels were still being constructed using at least some elements of the shell-first technique some four centuries after the earliest known example of a frame-first built ship.

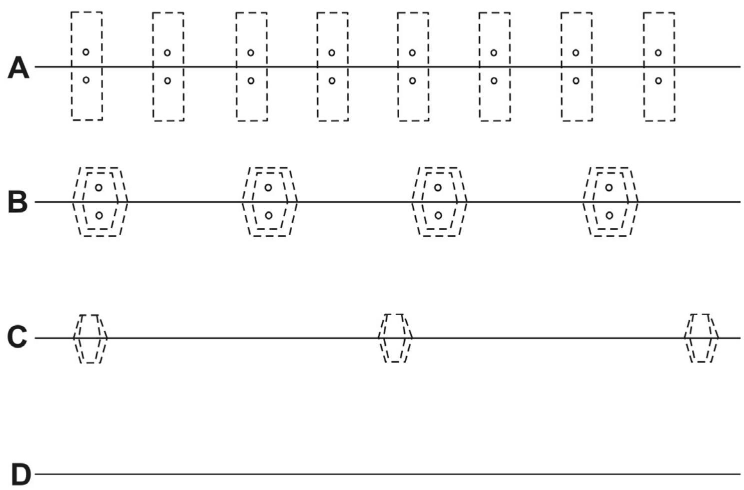

Figure 3-6. Illustration of the linear transition of edge-joinery over time from shell-first to frame-first construction in Mediterranean shipbuilding. A) Kyrenia. B) Yassi Ada, 4th century. C) Yassi Ada, 7th century. D) Serçe Limani (Steffy, 1994: Fig. 4-8).

The chronological deficiencies of the unilinear scheme have led to a recent reappraisal of the transition in Mediterranean shipbuilding traditions. It is now widely accepted that the change from shell-first to frame-first was not a unilinear process (Harpster 2005: 88; Kahanov & Royal 2001: 265; Mor & Kahanov 2006: 288; Royal & Kahanov 2005: 312). The development of the frame-first technique was more rapid, while the earlier shell-first tradition endured over a far longer period of time than formerly acknowledged. The discovery of the late 5th/ early 6th century AD, frame-first built vessels at Dor places the earliest completion of the transition at a much earlier date than previously thought. Meanwhile the Saint Gervais B shipwreck indicates that the early introduction of frame-first building techniques was not confined to a single local or regional tradition but encompassed the whole of the Mediterranean.

3.4.2 Alternative Mediterranean shipbuilding

It is also worth briefly noting the existence of a distinct shell-first tradition of Mediterranean shipbuilding utilising edge-joined sewn construction. Instead of using mortice and tenon joints to secure the planks a system of sewing is used (McGrail 2008: 618-620). Archaeological examples of Mediterranean sewn vessels fall into two groups. The first group generally dates to the mid-first millennium BC and includes shipwrecks from Bon Porté (530-525 BC) (Pomey 1981), Giglio (600-590 BC) (Bound 1985), Place Jules-Verne (2) (late 6th century BC) (Pomey 1999), Gela (late 6th/early 5th century BC) (Parker 1992: No 441) and the Ma'agan-Mikhael wreck (c. 400 BC) (Kahanov & Linder 2004). The second group of wrecks date to the Roman Imperial period and are centred on the northern Adriatic region of the Mediterranean. This includes the sewn vessels from Nin (S035) (Brusic & Domjan 1985), a partially sewn ship from Comacchio (S013) (Berti 1990), as well as many partial pieces of hull from the Venetian lagoon (Beltrame 2000). It is outside the scope of the present study to consider the Mediterranean sewn tradition further other than to acknowledge its presence as a form of technological variation.

3.4.3 The Indian Ocean

In contrast to the Mediterranean, the Indian Ocean witnesses very little change in shipbuilding techniques, for which there is evidence, during the period covered by this study. Although direct archaeological evidence is limited, it is possible, in combination with other sources to build up a picture of the nature and longevity of Indian Ocean shipbuilding techniques. The principle technique used in the Indian Ocean seems to have been sewn hull construction. Planks are edge-joined by stitching them together to form the shell of the vessel prior to the insertion of a framing system. The earliest textual reference to sewn vessels comes from the Mediterranean author of the *Periplus* who records the use of sewn vessels at *Rhapta* in East Africa (passage 15-16, tr. Schoff 1912) and also the building of sewn vessels known as *madarata* by the town of *Ommana* in Persia (passage 36, tr. Schoff 1912). Sewn vessels are referred to by Procopius in the 6th century AD, by a pre-Islamic 7th century AD Arab poet (Boxhall 1989: 289), by nearly every other medieval Arab or European traveller in the Indian Ocean (Hourani 1951: 89-98; McGrail 2001: 71-72,) and by the crew of Vasco de Gama at the end of the 15th century AD (Ravenstein 2000: 16). Iconographic examples of sewn vessels come from 2nd century AD Indian sources (Deloche 1996) and from medieval Islamic manuscripts (Hourani 1951: pl. 7; Nicolle 1989: Fig. 23, 24a & 24c). Archaeological evidence for sewn vessels can be found in the 9th century AD Arab/Indian vessel excavated in Indonesia (Flecker 2000) and the remains of a sewn vessel reused in a non-maritime context at the medieval Islamic port of Quseir al Qadim on the Egyptian Red Sea (Blue 2006). This technique is characteristic of the western Indian Ocean region (Chittick 1980: 297) and is still in use there in the present (e.g. Chittick 1980; Gilbert 1998; Hourani 1951: 93 & pl. 8; Lydekker 1919; Prins 1965: 121-2) and would seem to have considerable antiquity.

Following Portuguese expansion into the Indian Ocean, the use of sewn vessels diminishes in favour of iron fastenings (McGrail 2001: 77). The reasons for the continuous use of sewn construction over other forms remains unclear, although alternative methods of construction were certainly known. Evidence from the Roman Red Sea ports of Myos Hormos and Berenike indicates that mortice and tenon construction was present in the Red Sea. Hull-plank remains from both sites were excavated from contexts in which they had been re-used in building construction. These remains featured characteristics consistent with the contemporary shell-first construction technique in use in the Mediterranean. Despite the presence of Roman shipping in the region for several centuries, Mediterranean construction techniques do not seem to have been widely adopted. In the Islamic period there was similar movement between Mediterranean and Indian Ocean coasts, both on the Red Sea and Persian Gulf. Again, Mediterranean techniques do not seem to have been adopted as a result of this movement. The conclusion must therefore remain, that throughout the period with which this study is concerned, the Mediterranean and Indian Ocean employed distinctive methods and traditions of shipbuilding technology.

3.4.4 Materials and technology

Shipbuilding and rigging materials

In the context of the present study, the investigation of materials is concerned with the abundance and availability of shipbuilding supplies for hull construction and rigging components. There is no evidence to suggest that there was any alteration in the availability of material for sailmaking between the Roman Imperial and late-antique period. The use of cotton for sailmaking is attested at the Red Sea ports of Myos Hormos (S034) and Berenike (S002) with regard to Indian Ocean shipping (Whitewright 2007b; Wild & Wild 2001), but it is unclear if this was used in the Mediterranean as well. It seems more likely that linen remained as the main material for sailmaking throughout both periods and that it was freely available during this time. The same scenario is likely to hold true for the various different types of material used for cordage in the ancient Mediterranean (ch. 2.1).

The main material required for shipbuilding is obviously timber. This can be extended to the rigging of a vessel when the need to acquire timber for masts, yards, blocks, deadeyes, brail-rings, toggles, bitts and the like is also considered. The majority of these rigging components can be manufactured from relatively small pieces of wood, so supply is unlikely to have been an issue. In contrast to this, masts and yards would have required relatively long, strong and straight lengths of timber. As such any shortage of supply in shipbuilding timber in general may have manifested itself in these components as well as in the more obvious area of hull construction. Although evidence for timber prices exists from the reign of Diocletian, the inconsistency of the evidence and the lack of comparable material, either earlier or later, means that it is unclear of there was a specific increase in price (Meiggs 1982: 364-369). Prices probably increased during the 3rd century AD, but not in a disproportionate way in comparison to other goods (*ibid*).

The general assumption regarding Mediterranean timber supplies in the ancient world is that they were under continuous and increasing pressure from the industrial demands of the Roman Empire. Either from shipbuilding, or other uses; construction, mining, agriculture or military. One conclusion drawn by maritime archaeologists is that shipwrecks where a wide range of wood types are used may represent a shortage of timber (e.g. Guibal & Pomey 2003: 41; Parker 1992: 204). It follows that the use of a fairly homogenous range of timbers must be indicative of an abundance of the preferred species for shipbuilding. Assessment of the available evidence suggests that supplies were fairly stable across the Mediterranean as a whole. Any shortages were simply regional or local fluctuations in the availability of timber, often dependant as much on environmental factors such as fire or flood as human activity (Burnet 1997: 61; Horden & Purcell 2000: 182-6 & 327-338; Meiggs 1982: 371-403). In general, timber for shipbuilding would have been as available in late-antiquity as it was in the Imperial or late Republican period (Parker 1992: 26). Meiggs (1982: 377) records that there are virtually no literary sources which express alarm at the [supposedly] rapidly dwindling timber stocks of the ancient Mediterranean. Likewise, Meiggs (1982: 381) draws attention to the fact that, despite the apparent stripping of Cypriot forests by the Hellenistic kings of Syria and Egypt, by the 4th century AD Ammianus Marcellinus writes that Cyprus was so rich in materials that a ship could be built and fully equipped there (*Amm. Mar.* 14.8.14). Regions which may have experienced a shortage of supply over the short-term were well able to recover over the longer-term (c.f. Burnet 1997: 67).

Technology

In the context of this study, *Technology* represents the woodworking and fastening technology available to Mediterranean shipwrights and riggers for the construction and rigging of ships. Significant alteration to the tools available may have led to changes to the way in which ships were constructed or rigged. For example, the development of iron working technology allows the forging of longer, more efficient saws, than those available during the Bronze Age (Arnold 1982: 115). The best example of Mediterranean maritime woodworking tools comes from the range of carpentry tools recovered during the excavation of the 7th century AD Yassi Ada shipwreck (Bass & van Doorninck Jr 1982). These tools included axes, adzes, hammers, chisels, gouges, caulking irons, punches, a carpenter's compass, bitts for a bow drill, an awl, files and the possible remains of a saw (Katzev 1982). This represents an almost complete set of woodworking tools required to make major repairs to the ship during its voyage (Katzev 1982: 265). It seems likely that such items would be similar to those used in contemporary shipyards. The Yassi Ada shipwreck therefore provides a clear picture of the range of shipbuilding tools available during late-antiquity.

No other shipwreck from antiquity provides such a clear indication of the tools available to Mediterranean shipbuilders. However, woodworking tools, or evidence for their use, comes from range of sites and other sources of evidence (iconographic and textual). These can indicate the extent to which such technology changed over time. There is unequivocal evidence from the Roman period for adzes and axes (Casson 1995: 206, n.24 & Fig. 163; Goodman 1964: 23-27; van Holk 2006: 298), bow drills (Goodman 1964: 161-2; Weeks 1982: 166), chisels (Goodman 1964: 196), compasses or dividers (Goodman 1964: 200-201; Ximénès & Moerman 1990: 24 & Fig. 23), planes (Goodman 1964: 43-53) and saws (Goodman 1964: 115-122; van Holk 2006: 298). Generally speaking there seems to have been little change in woodworking tools between the early Imperial period and the 7th century AD (c.f. Ulrich 2008b: 439-464).

The second area of technology which has a direct impact on ship construction and rigging is the type of fastenings available. The earliest examples of frame-first built ships from the Mediterranean (Dor 2001/1 and Tantura A) utilised iron nails to fasten the endposts to the keel, the frames to the keel and the planks to the framing elements (Mor & Kahanov 2006: 275-6, 279 & 286). The use of iron nails does not represent the presence of a new form of fastening to the Mediterranean. Other fastening methods which have been associated with frame-first shipbuilding, such as bolts, are also present in the archaeological record well in advance of the earliest examples of frame-first built ships. The evidence indicates that there is little change in the woodworking or fastening technology of the ancient Mediterranean which might have subsequently influenced either the shipbuilding or rigging traditions in the region.

3.4.5 Conclusion

The Mediterranean and Indian Ocean provide contrasting pictures regarding shipbuilding in antiquity. The Indian Ocean tradition of sewn vessels is documented through textual sources such as the *Periplus* and such vessels continue to be used in the region until the present day. There seems to have been little impact on this building tradition by the presence of ships built in a Mediterranean tradition operating in the Indian Ocean during the early centuries AD. In contrast, Mediterranean shipbuilding traditions undergo a period of change during the late-antique period. The shell-first tradition is replaced by a frame-first tradition. This transition was previously considered to be orderly and linear in nature, recent archaeological evidence now indicates that the process witnessed overlap between different techniques and that the transition to frame-first construction was completed in some areas far sooner than previously thought (Figure 3-7). It should also be re-emphasised that within the Mediterranean shell-first tradition of shipbuilding there was variation in both the fastening technique and the final hull-form.

Hull and rig comprise the two principle technological systems of a sailing ship and are to some extent reliant upon one another; a hull must be capable of absorbing the forces generated by the sailing rig. As maritime technological systems, both hull and rig are likely be similarly susceptible to alterations in the range of factors (ch. 1.1.2) which influence how maritime technology is created. Chapter 3.1 and 3.3 outlined the decline in the use of the Mediterranean square-sail and the increase in the use of the lateen/settee rig. The evidence available from the archaeological record concerning ancient hull construction suggests that Mediterranean shipbuilders were beginning to adopt new techniques contemporaneously. This resulted in the construction of fully frame-first ships by the end of the 5th century AD. The site formation processes impacting upon ancient shipwrecks dictate that the archaeological record contains more information relating to the hulls of ancient ships than their rigs. It is probable that the factors influencing changes to hull construction are also influencing concurrent changes to rigging practice. The relative abundance of evidence for the former may therefore provide some indication of the factors at play in the visible change occurring in the latter.

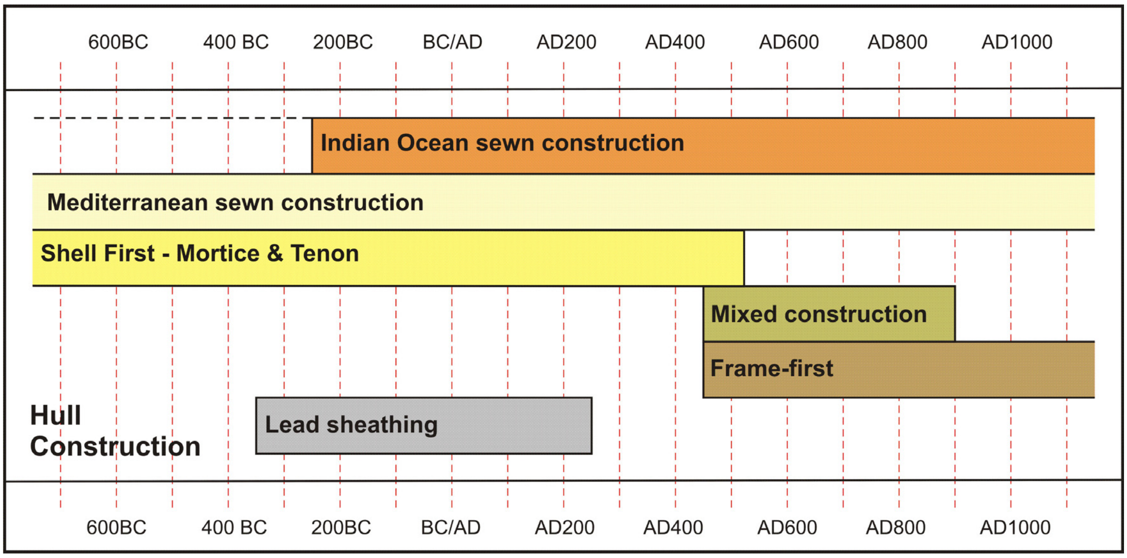

Figure 3-7. The relative time-lines of hull construction techniques and features in the Mediterranean and Indian Ocean during antiquity.

3.5 Rigging Components

The respective time-lines for the four main rig-plans involving the square-sail in antiquity are fairly clear (ch. 3.1). A 2nd century AD date for the initial invention of the lateen/settee sail can be suggested and a 5th century AD date for its more widespread adoption in the Mediterranean (ch. 3.3). A key aim of this study has been to address the individual components comprising a sailing rig and the inter-relationship between these components. This contrasts with previous approaches which have tended to privilege sail-form alone as a means to examine technological change. Chapter 2.1 and 2.2 identified the primary components from which the Mediterranean square-sail and lateen/settee rigs were comprised; deadeyes, brail-rings, blocks, running stays, mast-steps etc. The following chapter analyses the significance of these rigging components to our understanding of the Mediterranean sailing rigs during antiquity.

3.5.1 Brail-rings

Brail-rings provide a good example of a characteristic rigging component of the ancient Mediterranean square-sail (ch. 2.1). This rigging component defines the Mediterranean approach to using the square-sail as being distinct from other forms of the square-sail observed at different places during different periods which do not use it (for example the square-sails of northern Europe during the medieval period). Consequently the presence of brail-rings in the archaeological record of an ancient shipwreck indicates that the vessel was rigged with a Mediterranean square-sail (c.f. Whitewright 2007b: 287; Whitewright In Press-b). Three archaeological sites have yielded over 100 brail-rings each; Grand Congloué (S021) and Kyrenia (S024) in the Mediterranean and Myos Hormos (S034) on the Red Sea. The brail-rings from these sites bear further comment.

Reference to Appendix One describes the two forms of brail-ring found on the Kyrenia shipwreck; one group made with attachment lugs and the other group without. These two groups, of consistent diameter, may represent the product of two different manufacturing processes by two different people. The Grand Congloué site represents at least two shipwrecks, although this was not recognised until after the initial excavation, dating between 210-70 BC. 80 brail rings, all c.80mm in diameter, were excavated which had no attachment points (either lugs or hole). The consistent diameter of this group of rings mirrors the close diameter found on the two groups from the Kyrenia wreck and is likely to represent *one* of the Grand Congloué shipwrecks (c.f. Whitewright 2007b: 288-9). A second group of lead brail rings can also be identified, fitted with lugs through which attachment holes are pierced. The excavators identified three different cross-sectional forms to this second group of brail-rings; flattened on two faces, flat on one face and rounded on another and rounded on both faces. These are likely to come from the other vessel and the different cross-sectional form is likely to represent different places or people of manufacture (*ibid.*). At Myos Hormos, the wide range of diameters excavated represents the wide range of ship-type and size which visited the port (*ibid.)*. All of the rings from Myos Hormos had attachment holes pierced through the main body of the ring, no examples with lugs were found, neither were any lead brail rings found (Whitewright 2007: 285). The brail-rings again exhibit different cross-sectional form, and are circular, oval, square or rectangular in cross-section (Figure 3-8). This is again likely to be indicative of the wide range of sites and people who manufactured brail rings for the vessels which visited the port.

The general form and function exhibited by brail rings in the archaeological record remains relatively static over the period of this study. Brail-rings seem to represent a characteristic element of the Mediterranean square-sail rig, both in terms of its outward appearance, as well as in its practical usage (ch. 2.1.6 & 3.6.2). However, differences in material, attachment technique and cross-sectional form illustrate the potential for variation of form to occur within the context of a single technological continuum.

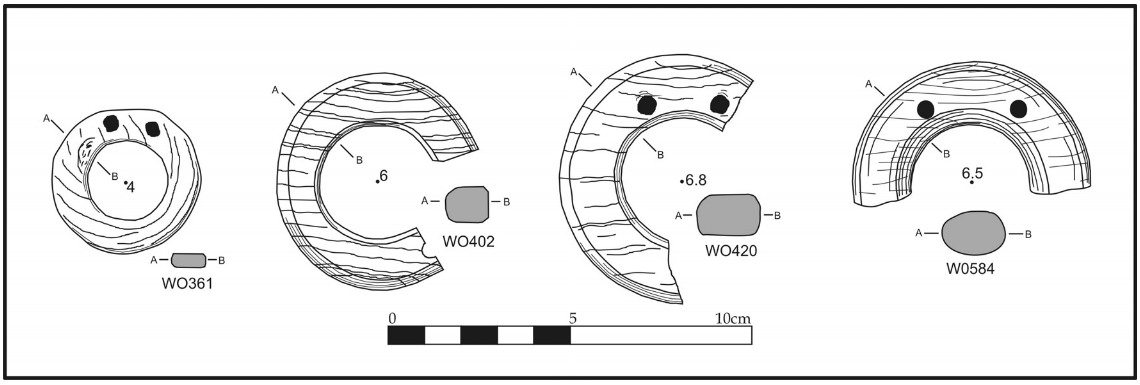

Figure 3-8. Four wooden brail-rings from the Red Sea port of Myos Hormos. Note the different cross-sectional forms created during their manufacture (J.Whitewright).

3.5.2 Sheave blocks

The sheave block from the Kyrenia shipwreck represents the earliest current example of what can be categorised as a distinctly Mediterranean form of sheave block (ch. 2.1.4). Such Mediterranean blocks had cylindrical sheaves, rather than the disc shaped sheaves commonly associated with sailing ships from many different periods and cultures. It is important to note that the two forms of sheave are not mutually exclusive, either temporally or spatially. In some cases disc and cylinder sheaves have been excavated from the same shipwreck (Grado (S020), Grand Ribaud D (S022) and Madrague de Giens (S029)) indicating contemporaneous use within a single sailing rig (Figure 3-9).

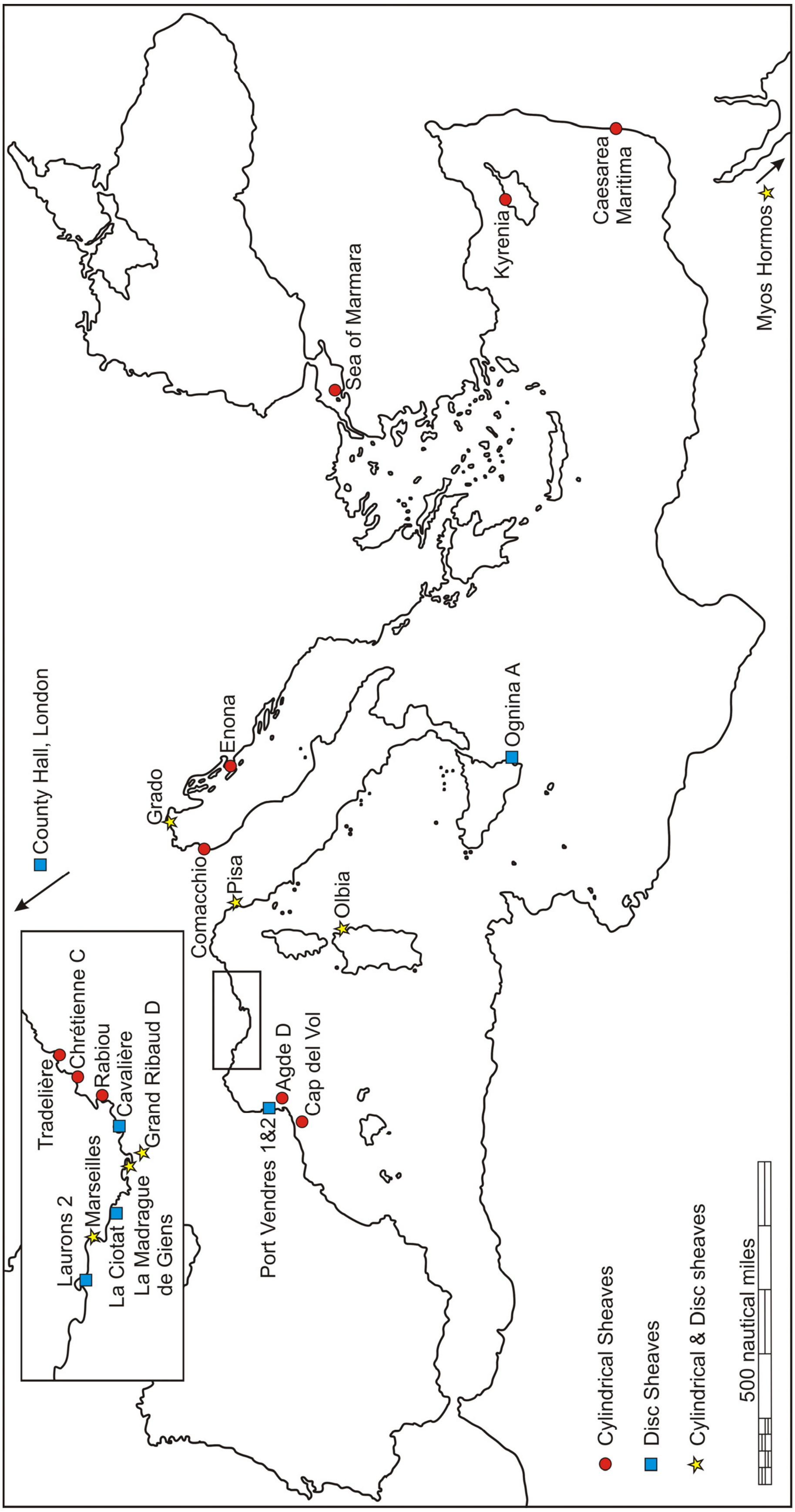

Figure 3-9. Distribution of cylindrical and disc sheaves from Classical, Roman and late-antique maritime contexts in the Mediterranean world (J.Whitewright).

In the instance of the Kyrenia wreck, the Mediterranean block is found in the context of a ship which is built using the traditional Mediterranean shell-first hull construction and sheathed in lead. The vessel's rig consisted of a single-masted square-sail set ⅓ of the ships length from the bow and trimmed using a system of brails. In most respects a typical Mediterranean open-seas sailing ship. This form of sheave block occurs on vessels designed for coastal or sea-going navigation (e.g. Chrétienne C (S012), Grand Ribaud D (S022) and Kyrenia (S024)) as well as riverine operations (e.g. Cap del Vol (S007) and Comacchio (S013)), evidence for its use has also been found at port sites across the Mediterranean world (Caesarea Maritima (S006), Marseilles (S032), Myos Hormos (S034), Olbia (S037) and Pisa (S038)) The presence of Mediterranean blocks at Nin (S035) and Comacchio (S013), both sewn vessels, indicates that their use is not confined to a particular tradition of hull construction.

Significantly for this study, the method of construction and the general form of the elements used to make the blocks (ch. 3.1.4) is the same in the 2nd century AD as in the 4th century BC. Small differences in form are visible between different vessels, for example some blocks are more elongated than others. The present corpus of evidence is not complete enough to say if these differences represent temporal or spatial distinction between riggers, or if they are simply the result of individual preference. More significant is the difference in size between Mediterranean blocks found on vessels of relatively similar sizes. For example, the Grado and Grand Ribaud D vessels are estimated to have been 16.5m (Beltrame & Gaddi 2005: 79) and 18m (Parker 1992: 477) long respectively. The Mediterranean block excavated from the Grado wreck was less than half the size of the smaller of the two blocks from the Grand Ribaud D wreck. Such a difference in size and therefore potential maximum load, suggests that the Mediterranean blocks fulfilled different functions within the overall rigging system of each wreck (c.f. Oleson 1983: 166).

Mediterranean style blocks were widespread throughout the Mediterranean from the 4th century BC and are used on a wide variety of vessel types and in varied operating environments. They are always associated with vessels constructed within a Mediterranean shipbuilding tradition. While the precise function of cylindrically sheaved blocks is still unclear, their consistent form over a long time period indicates the continued existence of a specific rigging tradition regarding the manufacture of sheave blocks. Furthermore the presence of blocks in non-Roman contexts illustrates the Mediterranean, rather than purely Roman, origin of this tradition. Such blocks appear to fall out of use along with the Mediterranean square-sail rig itself from the middle of the first millennium AD; none have been published from later contexts. While not as integral to the operation of such a rig as the system of brails, Mediterranean blocks can be closely associated with the Mediterranean square-sail rig despite the continued presence of viable alternatives. Their presence in the archaeological record may indicate the rig-form of a given vessel or shipwreck, in the absence of more characteristic components such as brail rings

3.5.3 Deadeyes

Deadeyes form part of the standing rigging of the square-sail rig (ch. 2.1.3) and their use indicates a pre-determined approach to this area of the rig. Once rigged, deadeyes are not multifunctional components and must remain static within the overall rigging system. The formal, systematic nature of this kind of standing rigging represents a further identifiable characteristic of the Mediterranean square-sail (Whitewright In Press-b). Analysis of the likely make up of early lateen/settee rigged vessels suggests that such a defined system of standing rigging is absent from these vessels. Instead a more informal system is used to support the mast relying on the use of 'running stays' which, in contrast to the standing rig of the square-sail are both moveable and multifunctional (ch. 2.2.5). The implications of the introduction of the lateen/settee rig on the standing rigging of a vessel are considered further below (ch. 3.6.3).

Like the brail-rings described above, deadeyes can further illustrate the continuity in rigging component which is evident in the Mediterranean square-sail, as well as highlighting the observable variation occurring within this rigging tradition. Deadeyes from Grado (S020) and Laurons 2 (S026) were almost certainly used in the shrouds of the standing rigging of those vessels. Both ships were of similar size, 16.5m x 5.9m and 15m x 5m respectively (Beltrame & Gaddi 2005: 79; Gassend*, et al.* 1984: 103) and dated from the mid to late 2nd century AD. Each vessel had two forms of deadeye within their rig; deadeyes with three primary holes and deadeyes with two primary holes. On both ships the three-holed deadeyes had the holes set out in a triangular arrangement with one hole set above/below the other two. All of the two-holed deadeyes were made with the holes aligned horizontally. The deadeyes from the Laurons 2 wreck are all of comparable size; c.115 x 90 x 30mm (Ximénès & Moerman 1990: 8). The Grado deadeye show a little more variation, the largest being 147 x 92 x 26mm and the smallest 116 x 78 x 20mm.

Three explanations can be suggested for the use of different types of deadeye within the rig of a single vessel. Firstly, different deadeyes were used in different areas of the ship. For example two-holed deadeyes may have been used in the forestay and backstay and three-holed deadeyes in the shrouds, or vice versa. Alternatively the difference in the form of the deadeyes may reflect a refit of the vessel at some point in its life. Analysis of the hull of the Grado ship indicates that it was repaired several times (Beltrame & Gaddi 2007: 146). It is conceivable that the replacement deadeyes were simply made in a different form to the originals. Thirdly, it is possible that deadeyes were used in pairs of three-holes and two-holes, this would contrast with their modern use where pairs of deadeye tend to have the same number of holes.

In contrast to the two sets of deadeyes from the Grado (S020) and Laurons 2 (S026) shipwrecks is a single deadeye from the Red Sea port of Myos Hormos (S034), also dating to the mid-late 2nd century AD. The deadeye was significantly larger than the deadeyes from Grado or Laurons 2, measuring 214 x 144 x 55mm and had three shroud holes set in a horizontal line. Despite the large size of the deadeye the shroud holes were roughly the same size as on the deadeyes from Grado and Laurons 2 (c. 25mm). There were no smaller secondary holes for seizing. Although intended to be used in the same type of sailing rig and having the same overall form, the Myos Hormos deadeye gives further indication of the potential variation which can occur within the rigging components of a single rig type. As well as the differing shroud-hole alignment the absence of seizing holes means that a different technique must have been used to secure the deadeye to the main shroud rope, presumably with seizing around the shroud alone rather than also through the block. Like the rigging components outlined above, deadeyes may eventually be able to illustrate specific, identifiable, regional variations operating within the overall Mediterranean square-sail rig. For now, they simply provide further evidence of the technological variation occurring within the wider context of a single rigging tradition.

3.5.4 Halyard systems

The Mediterranean square-rig can be characterised and in some cases identified in the archaeological record by its use of rigging components such as brail rings, Mediterranean blocks and deadeyes (c.f. Whitewright In Press-b). In contrast to this, the Mediterranean lateen/settee rig outlined in chapter 2.2 does not utilise such readily identifiable rigging components. The most characteristic part of this rig is the hook-shaped masthead consistently depicted in the iconographic record (Adam & Villain-Gandossi 1991: 21; Basch 1991a: 5; Mathews 2004: 179) from the 5th century AD onwards (e.g. V32-39), but so far absent in the archaeological record. Also of significance are the multi-sheaved blocks utilised (and consistently depicted) in the halyard system of late-antique lateen/settee rigged vessels (e.g. V32-34), the archaeological remains of medieval lateen/settee rigged ships (S045) and ethnographically observed vessels in the 20th century (ch. 2.2.4). The complex halyard system and associated mast-head fitting form the rigging components which best characterise the lateen/settee rig of the late-antique Mediterranean

Although characteristic of the lateen/settee sailing rig, the halyard system described above is not confined exclusively to that rig in the ancient world. A relief (V04) from Pompeii, dating to AD 50 shows a single-masted square-sail vessel in the process of furling sail. The halyard system of the vessel is clearly depicted and is directly comparable to the halyard systems used on depictions of lateen/settee rigged ships from late-antiquity (see ch. 2.1.2). As well as iconographic evidence, there is also limited archaeological evidence to suggest the use of lateen/settee style halyard systems on Mediterranean square-sail vessels. Two sheave blocks recovered during the excavation of the Grand Ribaud D (S022) and Laurons 2 (S026) shipwrecks bear direct comparison with the iconographic example cited above. As well as brail rings and Mediterranean blocks (indicating the use of a Mediterranean square-sail), another form of single-sheave block with a disc sheave was also excavated from the Grand Ribaud D shipwreck (Hesnard*, et al.* 1988: 113-126). As well as its similarity in profile to the halyard block depicted in V04, the block was also notable for its size. The sheave itself was twice the diameter and nearly twice the thickness of the sheave from the Serçe Limani (S045) halyard block and significantly larger than the sheave thought to come from the main-mast system of the same ship.

A large number of deadeyes were the main form of rigging component recovered from the Laurons 2 wreck (Ximénès & Moerman 1990: 6-9, fig. 2 & 3). The presence of deadeyes on the wreck implies the use of a permanent system of standing rigging. In the absence of any brail-ring remains, the use of such standing rigging indicates that the vessel was rigged with a Mediterranean square-sail. As well as the deadeyes a large single-sheave block was also excavated (Ximénès & Moerman 1990: 5-6) Although not as large as the block from the Grand Ribaud D wreck, the Laurons 2 block is still substantially larger than the deadeyes used to support the mast. An indication of the strain it was intended to be placed under. The authors note the similarity between the block and the single-sheave block from the Grand Ribaud D wreck (Ximénès & Moerman 1990: 6). The relatively large size of the blocks on both vessels, combined with their similarity in form to the block depicted in V04 adds further credence to the idea that they may be part of the halyard system for their respective vessels. The large size can be explained by the need for a single sheave to do the job done by multi-sheaved blocks on later vessels such as the Serçe Limani ship. Such an arrangement, utilising a single-sheave block may represent an early antecedent of the Mediterranean halyard system described by Moore (1925: 99) which utilised two single-sheaved *ramsheads* rather than one multi-sheaved *ramshead* (ch. 2.2.4).

Other, unusual forms of multi-sheaved blocks have been excavated from the Grado (S020) and Port-Vendres 1 (S039) and 2 (S040) shipwrecks. The block from Port-Vendres 2 was a triangular block which housed six disc sheaves of different sizes. The design of the block seems well suited to use in a halyard system which relied upon combining two multi-sheaved blocks to provide the purchase to raise the yard. The blocks from Port-Vendres 1 and Grado both contained multiple disc sheaves set on two rows at 90° to one another. The Grado block consisted of six sheaves in two rows of three, Beltrame and Gaddi (2005: 81) have suggested that it may have formed part of the vessel's halyard system in the manner of V04. The presence on the Grado shipwreck of deadeyes and Mediterranean style sheave blocks strongly suggest that it was rigged with a square-sail. This would provide further evidence of the use of a two-block halyard system with the Mediterranean square-sail.

The halyard system and component parts described above can be considered as one of the characteristic parts of the lateen/settee rig. They are present in all of its modern variants in the Mediterranean and Indian Ocean and early iconographic depictions of the rig consistently portray this part of the rigging. Ancient and modern examples are linked by an archaeological find from the 11th century AD Serçe Limani shipwreck. However, unlike the hook-shaped masthead (above) the halyard system is not exclusive to the lateen/settee rig in the Mediterranean. Iconographic and archaeological evidence indicates that Mediterranean square-sail vessels were utilising the same general halyard system seen on early lateen/settee rigged vessels from the late 1st century BC (c.f. Whitewright In Press-b).

3.5.5 Conclusion

The rigging components that characterise the Mediterranean square-sail rig have been presented and discussed in chapter 2.1 and Appendix One and have been analysed further in this chapter. These rigging components have exhibited continuity over an extended period of time in their form and function. It can therefore be proposed that the Mediterranean square-sail represented a distinct rigging tradition, unique to the cultures of the ancient Mediterranean. This tradition of rigging and using the square-sail should be considered alongside other, more widely acknowledged maritime technological traditions, e.g. mortice and tenon hull construction. The Mediterranean rigging tradition involves the use of brails as a means of controlling and shortening sail, a formalised standing rig using single purpose components such as deadeyes and the use of a distinctive style of cylindrically sheaved blocks in various areas of the rig. The continuity across time, cultural contexts and vessel type of rigging components such as brail rings, deadeyes and Mediterranean blocks indicates the enduring nature of the rigging components associated with the Mediterranean square-sail.

Furthermore, it can be illustrated through the archaeological record that the Mediterranean rigging tradition was not standard across the whole Mediterranean. Rigging components such as brail-rings and deadeyes exhibit technological variation while remaining within the same overall tradition. This is suggestive of a willingness amongst ancient Mediterranean mariners to alter the form of rigging components to suit their specific requirements. In time and with the excavation and publication of more evidence, distinct temporal and spatial distinctions within these rigging components may be identified. It is notable that none of the rigging components which characterise the Mediterranean square-sail seem to be associated with the use of the lateen/settee sail and some are actually incompatible with it (ch. 3.6). The adoption of the lateen/settee sailing rig therefore entailed more than the simple change in geometric sail shape acknowledged by the majority of scholars. It signalled the abandonment of a long-held tradition of rigging components whose construction and use characterises the square-sail rig of the ancient Mediterranean.

The second conclusion which can be drawn from this chapter is the concept of technological overlap between different rigging traditions. The use of halyard systems usually associated with the lateen/settee rig on Mediterranean square-sail vessels from the 1st century BC provides a clear example of continuity between different technologies usually considered as distinct from one another. This particular example also serves to highlight the benefit of an approach to studying sailing rigs based on analysis of their component parts. The traditional reliance on documenting sails in plan-form alone is inadequate as it overlooks other, equally important areas of the rig. The presence of the same complex rigging component, fulfilling the same function on two rigs which require a fundamentally different method of operation (ch. 3.6) is significant in this regard. Rigs which may appear different when analysed by sail-form alone, may in fact share certain technical traits. The lateen/settee rig, although of superficially different form, actually shares complex component parts with other contemporary rigs from the ancient world. This may help to provide an indication as to the general origin of the lateen/settee sailing rig in the ancient world.

3.6 Sail-handling and Technical Practice

Sail handling represents one of the most important, yet at the same time under-studied areas of the ancient sailing rig. In the context of this study, how the sail is handled and used (its technical practice) ultimately defines the type of rig in question (ch. 1.1.3). The technical practices involved in handling the Mediterranean square-sail and late-antique lateen/settee sail were covered in detail in chapter 2.1.6 and 2.2.6 respectively. Hence the aim here is to highlight the differences in technical practice utilised to operate either rig in late-antiquity and to explain the relevance of this difference (in the context of the present study).

3.6.1 Sail symmetry and going-about

The most important distinction between the operation of the square-sail and the lateen/settee is that the square-sail can be defined as a symmetrical sail while the lateen/settee is an asymmetrical sail, when taking the vertical centre of the sail in plan-form as the line of symmetry (Figure 3-10). With a symmetrical sail the luff/leech and tack/clew of the sail are interchangeable; the forward lower corner of the sail (tack) on a port-tack becomes the aft lower corner (clew) on a starboard-tack. Likewise the luff and the leech are also swapped on a tack by tack basis. This contrasts with an asymmetrical sail where the sail has to be set in the same longitudinal alignment on each tack. Both the luff and the leech are pre-determined, they cannot be swapped for one another and must remain at the fore or aft end of the vessel respectively.

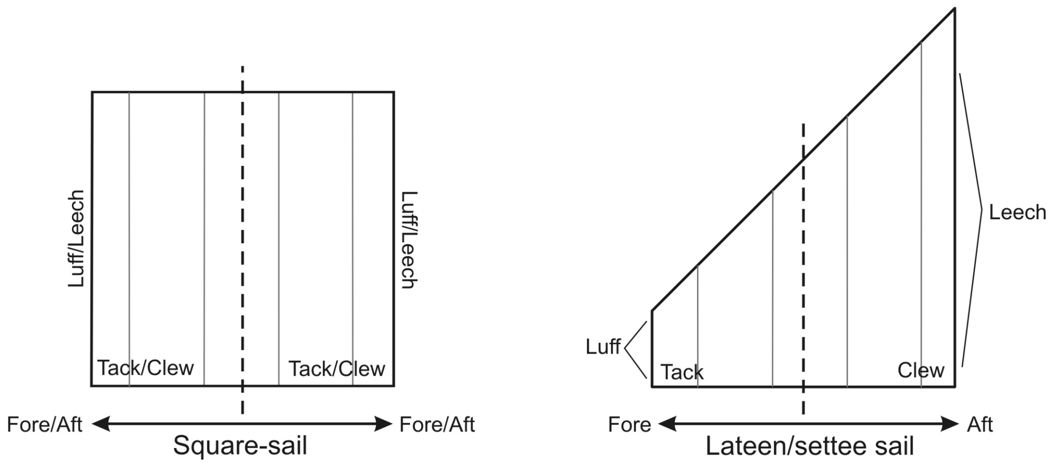

Figure 3-10. Sail symmetry across a vertical line of symmetry when viewed in plan form. The square-sail (left) is symmetrical while the lateen/settee (right) is asymmetrical.

The result of the symmetrical form of the square-sail is that to change tack, either by tacking or wearing, the crew are faced with the relatively simple task of swinging the sail and yard around the front of the mast. The tack is carried aft by the crew while the clew is carried forward and their roles are exchanged. Throughout this manoeuvre the yard remains in a horizontal plane. Pivoting the yard around the front of the mast when changing direction on all courses has dictated that braces have become a standard piece of rigging on nearly all square-rigged vessels from the earliest times.[26] Without braces, control of the yard would be very difficult to maintain. The Mediterranean square-sail, like most square-sails, is rigged underneath the forestay (e.g. V04, 09, 11, 15, 16, & 22) allowing the forestay to be permanently rigged. This greatly reduces the danger of being caught with the sail aback the mast while head-to-wind during tacking. The square-sail can be tacked through the wind in all but the strongest conditions, when it becomes preferable to wear ship (ch. 2.1.6). The loose-footed nature of the Mediterranean square-sail allows the sail to be set outside the shrouds (V09 & 15), which can be permanently rigged, with minimum interference to the sail. A permanent backstay can be rigged at all times with no interference to the use of the rig. Wearing ship is even easier on the crew as yard and sail are gradually swung around the front of the mast as the vessel alters course. Control of the yard and sail can be maintained at all times by the braces while the tack and clew are reset.

The asymmetric shape of the lateen/settee sail forces a different solution to the problem of getting the yard and sail from one side of the mast to the other. Because the luff and leech are different lengths the tack and clew of the sail are predefined and have to fulfil the same job on each tack. Consequently, the square-sail technique of swinging the yard and sail around the front of the mast and swapping tack and clew cannot work. Different techniques have been developed in the Indian Ocean and Mediterranean to swap the yard from side to side while maintaining the tack and clew positions (ch. 2.2.6). The semi-permanent nature of the halyard system on early lateen/settee vessels and its secondary function as a backstay means that the sail must pivot around the front of the mast. Unlike the square-sail this cannot be done underneath the forestay as the whole yard must come around in a vertical position. The hook-shaped masthead, characteristic of early lateen/settee rigged ships may have developed to facilitate this manoeuvre (ch. 2.2.6). A forestay can only be set up once the sail has been transferred around the front of the mast. The absence of a forestay during the transfer means that a vessel tacking through the wind faces the very real danger of being dismasted if the sail is caught aback the mast. For this reason it is more usual to wear ship. This removes the danger of being caught aback, the halyard/backstay supports the mast and the following wind serves to aid the movement of the sail around the front of the mast. The transition from square-sail to lateen/settee sail therefore involves an identifiable and significant alteration in how the ancient sailor carried out a basic manoeuvre such as changing course from one tack to another.

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[26] Braces can be clearly seen in the iconography of Egyptian square-sail vessels dating to the third millennium BC (Casson 1995: Fig. 19; Landstrom 1970: Fig. 97; Vinson 1994: Fig. 14).

3.6.2 Shortening and trimming sail

Shortening sail

The symmetrical nature of the square-sail rig and the manner in which it is brought about means that the same face of the sail is always to windward or leeward. In contrast to this the lateen/settee rig alternates the windward and leeward faces of the sail on each tack. This occurs because of the asymmetrical sail-plan of the lateen/settee rig which dictates that the tack and clew have to retain their function on different tacks. The permanent retention of the windward and leeward sides of the square-sail allows a relatively complicated system of shortening sail, such as brails, to be permanently rigged to the yard and sail. In comparison, the use of brails on the lateen/settee rig would be very complicated. Because the windward and leeward faces of the sail are inverted when going about, all of the brailing lines would also have to be passed around the front of the mast, with the yard, sheet and sail. Unsurprisingly, the Mediterranean system of brails falls out of use at the same time as the Mediterranean square-sail which carried it.

Adoption of the lateen/settee rig would have required Mediterranean sailors to develop a new technique for shortening sail as a substitute for the incompatible system of brails. The settee rig depicted in the Kelenderis mosaic (V32) shows a row of reefing points on the face of the sail and infers the presence of a second row along the foot (Pomey 2006: 329). The inclusion of such a system for shortening sail in such an early depiction of the settee rig implies that reefing was rapidly developed as a replacement technology for brails. The use of reinforcement strips on Mediterranean square-sails was highlighted in chapter 2.1.5, such existing reinforcement strips could easily double as the reefing band required to secure the reefing points to. No changes to sailmaking practices would therefore have to occur to allow the brails to be replaced by reefing points. It should also be remembered that the use of reefs, rather than brails, would require significantly less cordage and would not require the manufacture of any brail-rings.

Trimming sail

The general operation of the two types of rig, in terms of trimming the sail, depending on the course, is broadly similar. In either case tack and clew positions vary according to the course being steered. On close-hauled courses the tack is secured forward and the clew led aft, both as near to the fore-and-aft line of the vessel as possible. As the vessel bears away from the wind both tack and clew will move increasingly toward a position amidships. On running courses the square-sail is operated with two clews and both sheets may be free. It may be significant that the practice of sail-handling on lateen/settee rigged ships when sailing on running courses is quite similar to those used for the square-sail. The yard often assumes a horizontal position and a second brace can be set to allow manipulation of what would normally be the tack. This arrangement is visible in the iconography of medieval Mediterranean lateen/settee rigged vessels (e.g. V38) which seem to be used in the same manner as their late-antique counterparts (ch. 2.2.6). The similarity between the sail-handling practices on downwind courses represents a further aspect of technical continuity, in addition to the halyard systems (ch. 3.5.4), between the Mediterranean square-sail rig and the lateen/settee rig which succeeded it.

The proto-lateen

The ancient technique of sail-trimming by brailing up the aft portion of the square-sail when sailing close-hauled, to help balance the rig, was outlined above (ch. 2.1.1; 2.1.6; 2.3.3). This produced a triangular sail in which the hypotenuse runs from the tack to the peak (upper, aft corner) and with a CE further forward than normal. This technique has also been seen as a possible developmental route for the lateen sail to evolve from the square-sail (Casson 1995: 277) and so requires further discussion. Aristotle reports that the crew brail up the aft half of the sail while the forward half is left unfurled. Casson (1995: Fig. 188c) has expanded this to include the securing of the tack of the sail to the lower part of the mast with the weather sheet in order to incline the yard, something not mentioned by Aristotle. This is seen as creating a sail "*in shape not unlike a lateen*" which in turn "*sparked the invention of that all-important sail* [the lateen]" (Casson 1995: 277), this idea has recently been reiterated by Polzer (2008: 243). Casson's theory has several deficiencies. Firstly and most obviously is the fact that the shape described by Aristotle is the opposite way around to a triangular lateen sail and would retain the long luff of the Mediterranean square-sail. Casson is equating similar geometric shapes (albeit inverted), with similar sail-forms. Casson also places great emphasis on the tilting of the yard as a result of the manoeuvre. However, this ignores the fact that square-sail yards become naturally inclined when set close-hauled (brailed-up or not) because the tack is tightly secured in the bow. The tension placed on the luff in doing this naturally pulls the forward end of the yard downwards and causes the aft end to be raised upward. Personal observation of single-masted square-sail vessels which do not have brails reinforces this point. Ancient mariners would have been well aware that the yards of their square-sail rigs were inclined when sailing close-hauled. Finally, Casson's additional step of securing the tack to the lower part of the mast in order to incline the yard would cause the luff of the sail to be completely loose, something detrimental to close-hauled performance. The passage attributed to Aristotle and echoed by other sources (e.g. Achilles Tatius) clearly describes sail trimming specific to the Mediterranean square-sail.

A similar developmental process has been proposed by Basch (1997: 216-9) which has been termed the 'proto-lateen'. This is represented in the iconographic record by depictions of vessels with inclined yards. The sails of such vessels appear to be quadrilateral in shape with a luff shorter than the leech. As such they are considered to represent a stage in between the square-sail rig and the full lateen/settee rig. These depictions (e.g. V01) generally show sailing rigs with many of the characteristics of the Mediterranean square-sail rig. In particular they are shown with brails and it is the appearance of this rigging component which provides the explanation to the depictions. The discussion above highlighted the incompatability of the system of brails with an assymetrical rig because of the arrangement of tack and clew when going-about. The most likely explanation for the presence in the iconography of square-sail vessels with inclined yards lies in the fact that the yard becomes naturally inclined when sailing close-hauled. This is because of the need to secure the tack tightly in the bow of the vessel to keep the luff of the sail taught (above). In these instances, ancient artists were simply portraying vessels rigged with square-sails as they saw them being used when sailing close-hauled. Neither the sail-trimming method described by Aristotle, nor the iniclined yards visible in certain iconographic depictions should be considered as providing a logical, evolutionary route to the lateen/settee rig. They are simply contemporary records of the daily use of the Mediterranean square-sail.

3.6.3 Standing rigging

The standing rigging of the Mediterranean square-sail ship (ch. 2.1.3) consisted of permanently rigged forestays and backstays providing longitudinal support and permanently rigged shrouds providing lateral support. All of these elements of the rigging probably used some form of deadeye as a means of tensioning the stays and shrouds supporting the mast. As well as the presence of deadeyes in the archaeological record, elements of standing rigging from the Mediterranean square-sail are regularly depicted in the contemporary iconographic record. The use of a standardised arrangement of ropes and blocks to form the standing rigging of the Mediterranean square-sail represents one of the characteristic features of this type of sailing rig. The changes in technical practice between square-sail and lateen/settee sail, forced by the transition from symmetrical to asymmetrical sail-plan, also had implications for the standing rigging of lateen/settee rigged vessels (ch. 2.2.5). Maintaining the respective positions of tack and clew requires the movement of the whole yard, sail, sheets and braces around the front of the mast. This is incompatible with the use of a permanently rigged forestay which would prevent such a manoeuvre. The natural fore-and-aft arrangement of the lateen/settee rig dictates that if shrouds were permanently rigged, yard and sail would have to be hoisted *between* the mast and the shrouds with the parrel *underneath* the junction of shrouds and mast. This would also prevent the transfer of the sail and yard around the front of the mast when changing tack. Consequently, the lateral support for a lateen/settee sail is provided by running stays, which are tensioned on the windward side of the vessel only. When the vessel changes tack the running stays in use must be slackened off and their counterparts on the other side of the vessel (the new windward side) must be tensioned. This has to be done as the yard and sail is taken around the front of the mast.

The successful use of a system of running stays requires that they are easily tensioned and released in a way which is not time consuming. This prevents the use of rigging components such as deadeyes, which are designed to be permanently rigged. A far simpler means of attachment, which can also be tensioned, must be used. This may take the form of a small pulley block, or in some Indian Ocean examples a simple loop of rope is used to provide a purchase.

The difference in sail-handling techniques between the Mediterranean square-sail and the lateen/settee rig dictated by the adoption of an asymmetrical sail-plan also required a significant alteration to the standing rigging associated with either rig. The systematic, permanent standing rigging of the square-sail was replaced with a more flexible, mobile system in which running stays could be slackened off and moved around easily before being quickly tensioned again in a different location. This shift in emphasis must also have led to the abandonment of rigging components such as deadeyes from the sailing rigs of the late-antique Mediterranean.

3.6.4 Crew size

A good indication of the number of crew required to operate a vessel rigged with a Mediterranean square-sail can be discerned from the archaeological record derived from ancient shipwrecks. This has been achieved through analysis of the shipboard (not cargo) ceramics excavated from the Comacchio (S013), Grand Ribaud D (S022) and Kyrenia (S024) shipwrecks. Excavation of the Kyrenia shipwreck uncovered shipboard crockery in multiples of four; salt cellars, oil jugs, pitchers, drinking cups, casserole bowls and the fragments of four wooden spoons (Katzev & Katzev 1989: 163; Swiny & Katzev 1973: 345). Most of this crockery was made in Rhodes, which also provides a probable indication of the vessels home port (*ibid*). The Grand-Ribaud D wreck seems to have had a crew of six, based on the analysis of the cooking ware found (Hesnard*, et al.* 1988: 145-9). Similarly the Comacchio vessel seems to have had a crew of five at the time of sinking (Berti 1986: 31). The reasonably close correlation in the numbers of crew on these square-sail vessels suggests that the number and arrangement of crew may have remained similar throughout the periods in which the Mediterranean square-sail was in use. The difference in size between the 45-50 tons of the Grand-Ribaud D shipwreck and the 130 tons of the Comacchio shipwreck illustrates the increase in size which a vessel rigged with a square-sail could undergo without increasing the size of the crew.

Analysis of crew size on lateen/settee rigged ships is harder because of the lack of definite examples which have been subject to comprehensive excavation. However, good data is available from the ethnographic and historical sources. The 15m settee rigged vessel *Sheikh*

Mansur on which Alan Villiers took passage in 1938 had a crew of eight (Villiers 1961: 248). Meanwhile the larger ocean-going 26m *Bayen* had a crew of twenty-seven (Villiers 1940: 425; 1962a: 112). Lane (1934: 39) notes that a 13th century AD, 240 ton, Venetian lateen rigged ship had a crew of 50 while a 14th/15th century AD square-rigged vessel of comparable size required a crew of only 28. Commenting on the settee rigged vessels of Lamu, Prins (1965: 235) observes that "The lateen [settee] rig with its blocks and tackles has more than any other rig (in big ships) a drawback; it necessitates and astonishingly large crew." Returning to the archaeological sources, the date of the 7th century AD Yassi Ada (S048) shipwreck suggests that the ship probably carried a lateen/settee rig. Excavation of the wreck recovered place settings for four to five people surviving in the area of the galley (Bass 1982b: 188). However, the large number of cooking pots suggests that many more people, either passengers or crew, were also present on board (*ibid*). On this basis Bass interprets the identifiable place settings as being the preserve of officers or important passengers and not representative of crew size (*ibid*). Although it is therefore very difficult to accurately estimate the size of the crew of the 7th century AD Yassi Ada ship (c.f. Bass 1982a: 313-4), the large number of cooking pots found in the galley area of that wreck can be contrasted with the much smaller number found on the 4th century AD Yassi Ada ship (see Bass & van Doorninck 1971:35).

Investigation of crew size on square-sail and lateen/settee rigged sailing vessels indicates that there is a clear difference in the number of crew required to operate either rig. Although difficult to quantify, a lateen/settee rigged sailing vessel may have required twice as many crew as a similarly sized square-sail vessel. One of the reasons for the increase in crew size was alluded to in the quote from Prins (above); The replacement of the standing rigging of the square-sail with a system of running stays required a corresponding increase in the size of the crew because more sailors were needed to operate them. In contrast to this, the permanent shrouds of a Mediterranean square-sail vessel required no handling when underway. The majority of the extra crew would probably have been ordinary sailors. The increase in crew may be one explanation for the increase in cooking pots between the two similarly sized Yassi Ada wrecks. The 4th century vessel may have been square-rigged while the 7th century vessel carried a lateen/settee rig. Ethnographic data indicates that an increase in the size of crew, and a corresponding increase in wage and food costs, is not necessarily undesirable. Data gathered from Lamu suggests that skippers always prefer to take the largest crew available to sea (Prins 1965: 213). It is worth noting that such vessels are operating in the low-value, bulk cargo trade in mangrove poles between the Rufiji Delta and Lamu in East Africa where profit margins could be expected to be small. However, economic consideration is put second to the advantages gained with a larger crew (c.f. de Monfried 1935: 70).

Wages on the vessels from Lamu were based on different ranks of sailor earning a different number of 'shares' of the profits of the voyage. This system is widespread throughout the Indian Ocean and is recorded by Villiers (1940: 424-6) for the boom *Bayen*. On that vessel, half the profits went 'to the ship' or more accurately its owners, while the remaining half was used to pay the crew. A common sailor was paid one share in contrast to the boatswains, quartermasters and cook who were paid one and a half shares each (*ibid*.). The skipper (five shares) and the mate (three shares) both had their additional shares paid from the ship's half of the profit. The significance of this system of payment is that the shipowner's profits are not reduced by an increase in the number of crew. Even the cost of the crew's food is deducted from their final total. Bass (1982a: 313-4) highlights a passage from the Rhodian Sea-Law which lists the share of the profits assigned to different members of the crew. Regular seamen receive a single share while the helmsman and boatswain both receive one and a half shares (*ibid*). The recording of this system of payment in the Mediterranean implies that an increase in the number of crew would not necessarily result in a loss of profit for the shipowner who paid them.

Any increase in crew size would also have had implications for the social structures on board ship. The 4-6 men crews of small/medium square-sail merchant vessels in the Roman period must have been relatively close-knit compared to the larger crews on later lateen/settee rigged ships. The skipper on the latter vessels may have been far more remote from the majority of their crew, with an accompanying hierarchy in between. This possibility is illustrated by the crew distribution indicated by the archaeological record of the lateen/settee rigged Serçe Limani (S045) ship. On this vessel the higher ranking crew seem to have been accommodated at the stern of the vessel while the normal sailors lived on the deck amidships and forward of the mainmast (Bass & van Doorninck Jr 2004: 266-70; Cassavoy 2004: 330-7). There are also some obvious advantages to an increase in crew size; cargo can be loaded/unloaded quicker and a greater number of people are available to carry out repairs to the vessel or for defence in the event of piracy. However, if a larger crew was required, there seems no reason why extra crew could not be taken on board a square-sail vessel. The increase in crew size is a product of the lateen/settee rig, not a cause of it.

3.6.5 Implications

The differences in technical practice used to operate the two rigs are straightforward. The more difficult task lies in identifying the implications of these differences, both for ancient mariners and in assessing technological change. Transition from symmetrical (square-sail) to asymmetrical (lateen/settee) sail-plan;

- Required the development and adoption of new techniques for changing course. Including the process of tacking or wearing ship.

- Necessitated the abandonment of the system of brails and the invention of a new way of shortening sail.
- Entailed whole-scale alterations to the standing rigging of the vessel.
- Altered the number of crew required to operate the vessel and probably altered the social structure of the crew.

It is obvious that changes to the sailing rig technology of the ancient world were far more complex than the straightforward change in geometric sail-plan usually described; primarily that there cannot be a gradual shift from symmetrical to asymmetrical sail-plan. A sail must be one, or the other, there is no in-between stage. As soon as the luff becomes shorter than the leech, the sail-plan can be considered asymmetrical. Once this happens, the technical practice associated with the square-sail becomes redundant. Changes to rig and sail handling must occur rapidly if the asymmetrical sail-plan is to be successfully operated and to remain in use. Alternatively, suitable technical practice which allowed the adoption of an asymmetrical sail-plan must have been in use prior to a change. Subsequent alteration to the sail-plan of the vessel, such as an additional shortening of the luff, will not change the way the sail is handled, the components which make up the rig or the composition of the crew.

Appreciation of this fact renders unworkable the notion of a gradual change, over several defined stages (e.g. the ‘proto-lateen’), from the square-sail of the Roman period to the full lateen/settee sails of the medieval Mediterranean. The transition to an asymmetric sail-plan dictates that a change in technical practice, rigging components and crew composition must occur. Subsequent changes in sail-plan will only influence the way the sail appears to an outside observer. The possibility must also exist that it is not changes to the sail-plan of the square-sail rig which are the main driving-force of technological change. Changes to the sailing rig, associated with the adoption of an asymmetric sail-plan may actually have occurred prior to, not after, its adoption. Variation or changes to major areas the square-sail rig as a whole (e.g. standing-rigging, running-rigging), when combined, may eventually have allowed the adoption of an asymmetric sail-plan in place of the square-sail. If the inter-relationship and arrangement of rigging components from which the sailing rig is comprised is altered, then it stands to reason that the outward appearance of the rig will be different. Some of these changes may have been imperceptible to non-maritime members of ancient Mediterranean society. Other changes, for example to sail-plan, result in obvious and visible changes which are recorded in the iconographic or literary sources. Changes in sail-plan are simply the most easily visible, outward indication of deeper, more profound changes to the ancient sailing rig, the manner of its operation and the social, economic and ecological context in which it operated.

3.7 Continuity, variation and change

Part Three has covered the maritime technological change in the ancient Mediterranean and Indian Ocean from a variety of perspectives. The following chapter draws together these perspectives to present an overview of the technological change concerned. Particular emphasis has been placed on the Mediterranean square-sail rig, the lateen/settee rig and the technological continuity, variation and change related to them, these are the broad themes which tie this chapter together.

3.7.1 The unilinear progression of technology

Scholars of the ancient sailing rig have been fortunate to have an extensive iconographic record at their disposal. A general rig-type can usually be identified from an iconographic depiction. Survey of the currently available evidence conducted in chapter 3.1 and 3.2 indicates that the adoption, use and abandonment of different forms of sailing rig in the ancient Mediterranean is not a simple unilinear process (ch. 1.1). Technological change in the sailing rigs of the ancient world is multi-linear in nature (Figure 3-11) and technological development resembles an evolutionary tree with a clear antecedent to a particular technological form. Furthermore, contrary to the technological determinism which underpins the unilinear progression, the development of an alternative form of technology does not signal the immediate extinction of its antecedent. This is especially true with the Mediterranean square-sail rig where the oldest form, the single-masted rig, endures for longer than all other forms of the square-sail rig and for a significant period of time following the development of the settee sail. The failure of Mediterranean mariners to maintain square-sail rigs of apparently increasing complexity and efficiency goes against the notion of a logical progression from simple to complex and further renders the notion of technological determinism redundant.

Assigning the example of maritime technological change in antiquity a multi-linear developmental pathway allows two different explanations for the development and adoption of the lateen/settee sail. Firstly, changes to the Mediterranean square-sail rig allowed the development of the settee rig and subsequently the lateen rig. Alternatively, the lateen/settee rig represents an original and novel approach to a sailing rig which has very little in common with contemporary square-sail vessels. The possibility of such independent invention in the maritime technology of the ancient Mediterranean is illustrated by the development of the sprit-rig in the 2nd century BC (ch. 3.2). The two potential courses for the development of the lateen/settee rig are indicated by the two dashed lines on Figure 3-11 which precede the settee rig and they will be returned to below, when they will be considered in the context of wider technological processes discussed in the following sections.

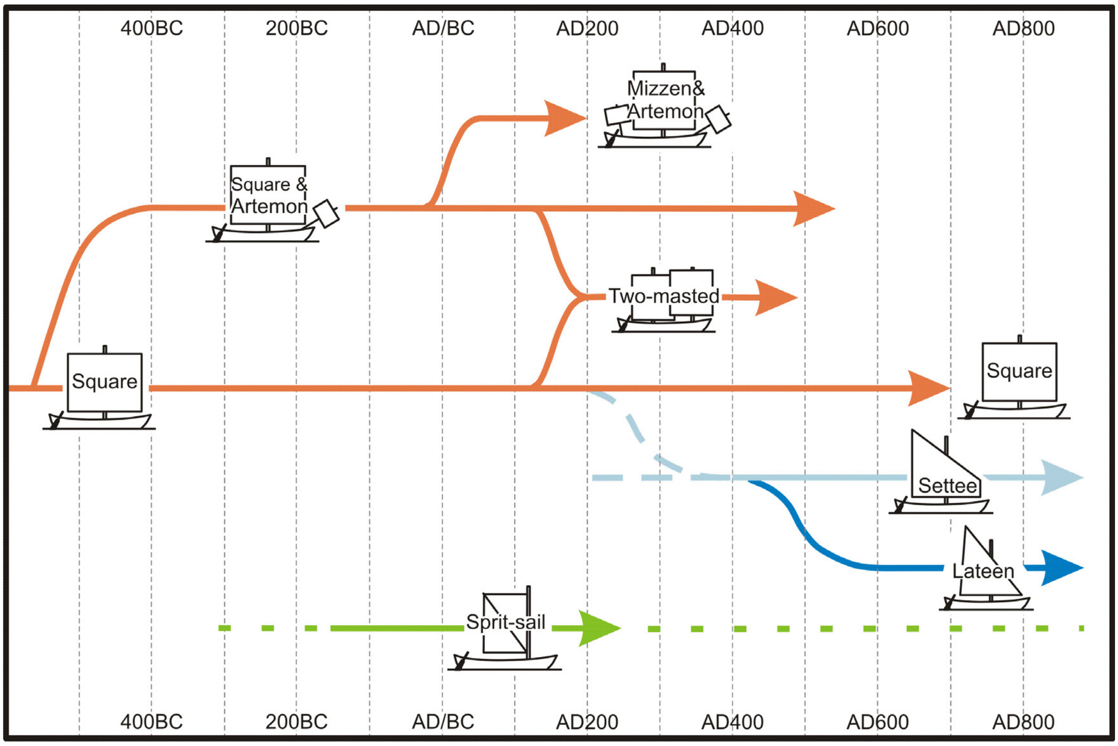

Figure 3-11. Multilinear development of ancient Mediterranean sailing rigs. Solid lines indicate definite, identifiable evidence, dashed lines indicate conjectural pathways.

Changes to Mediterranean shipbuilding traditions occurred during the Roman Imperial and late-antique period have been outlined above (ch. 3.4). Academics have begun to rethink their theoretical approach to ancient shipbuilding as a result of new archaeological evidence. This has led to the abandonment of a theory of logical, gradual, linear change in the shipbuilding techniques of the ancient world. New construction techniques began to be adopted much sooner and existing techniques continued in use for far longer than had previously been recognized. It is now widely accepted that there was considerable technological overlap and interplay between the shipbuilding traditions of the ancient Mediterranean. A satisfactory model which can explain this instance of technological change is still being developed. As more shipwrecks are discovered and systematically excavated the complexity of the situation will increase and the model will develop further depth.

Because hull and rig must ultimately be combined in the production of a sailing vessel, it is useful to be able to consider the technological change observable in Mediterranean rigging and shipbuilding traditions during antiquity alongside one another. An alternative expression of change is therefore proposed which simply sets out observed change/stasis in shipbuilding and rigging technology over an extended period of time (Figure 3-12). In this case it is helpful to maintain groupings of technology which can be identified as sharing certain characteristics; fore-and-aft rigs, square-sail rigs, hull construction techniques. Reference to Figure 3-12 illustrates that technological fluctuation, either through the adoption of new technology or the abandonment of existing technology, is a continuous feature of the shipping of the ancient Mediterranean. In contrast to this, the limited evidence currently available from the Indian Ocean suggests far more continuity in the maritime technology of that region. However, it should be noted that the relative scarcity of the evidence dictates that it very difficult to observe variations within specific types of technology. For example, it is probable that the Indian Ocean square-sail has included both single-masted and two-masted vessels (ch. 3.1.) but it is impossible to say with any accuracy when either was adopted, altered or abandoned.

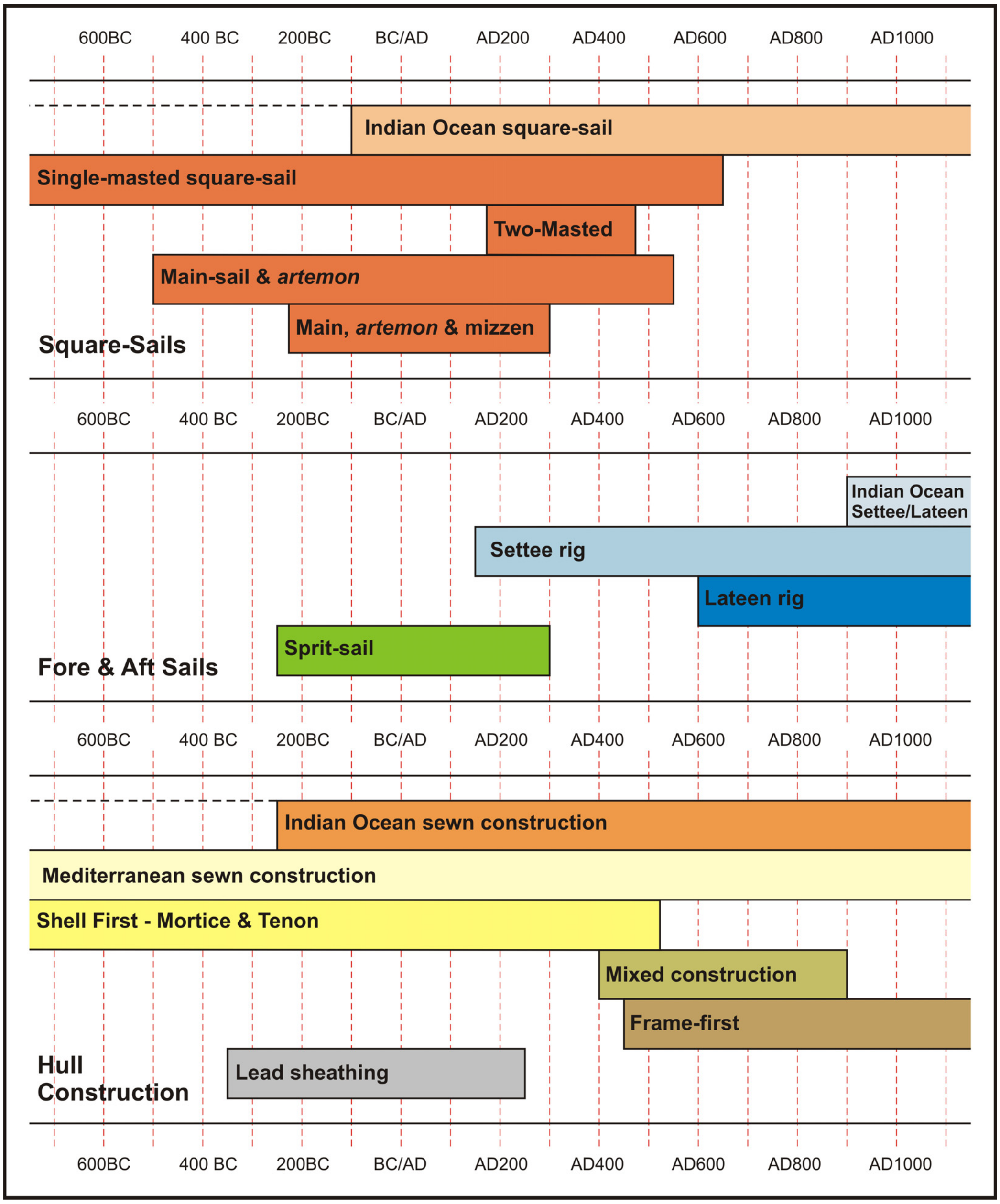

Figure 3-12. Maritime technology in the Mediterranean and the Indian Ocean, 650 BC-AD 1050, utilising archaeological, iconographic and textual source material. All technology is Mediterranean in origin unless labelled otherwise, e.g. 'Indian Ocean square-sail'. Technological details can be found in the following chapters: Square-sail (ch. 2.1 & 3.1); Fore-and-aft rigs (ch. 2.2, 3.2 & 3.3); Hull construction (ch. 3.4).

3.7.2 Technological continuity

To recognise technological change, existing technological *continuity* must first be documented. In order to understand technological *change* it is therefore necessary to understand the pre-change technology. In the context of this study, the Mediterranean square-sail represents technological continuity over time and also the principle Mediterranean sailing rig prior to the adoption of the lateen/settee rig. The continuity of the square-sail is expressed through the archaeological record from the 4th century BC and in the iconographic and literary sources a further 1000 years earlier.[27] In order to be adopted, new technology has to overcome existing notions regarding the creation, use and social position of technology. In the ancient Mediterranean, the pre-existing notions concerning the square-sail seem to have been deeply embedded. Certainly they were deep-rooted enough to span a variety of maritime cultures and encompass a range of shipbuilding traditions within the Mediterranean. The Mediterranean square-sail tradition also remained in use, seemingly unaltered through a range of significant social, political and economic change ranging from the conquests of Alexander the Great, the Punic Wars and the conquest of the whole Mediterranean by the Roman Empire. This situation can be contrasted with the western Indian Ocean where ships constructed and rigged within Mediterranean traditions operated for several hundred years (ch. 3.1.1). Despite this, the brailed square-sail or mortice and tenon hull construction does not seem to have become widely adopted and maintained by the maritime cultures of the Indian Ocean.

Identification and acknowledgement of existing technology and the associated traditions and technical practices is therefore crucial. Without an awareness of these it remains impossible to fully understand or explain subsequent technological change (c.f. Mokr 1996: 83). While it may be possible to suggest or theorise why a replacement technology was invented, it is likely to remain impossible to explain why its technological forebears were abandoned if they are neither identified nor fully understood. Addressing the reasons why a long period of technological continuity comes to an end represents a significant part of explaining why a new technology remains in use after its invention.

3.7.3 Technological variation

The Mediterranean square-sail witnesses little distinct or profound technological change during the Roman period. This statement initially seems at odds with what seem like obvious changes to the outward appearance of the square-sail rig in the form of extra masts or auxiliary sails. The

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[27] The Kyrenia shipwreck (S024) represents the earliest archaeological example where several components characteristic of the Mediterranean square-sail have been found together. Brail rings have been found on the Etruscan shipwreck at Giglio dating to c. 600 BC (Bound 1985: 60) and appear in the iconographic record in the late 2nd millennium BC (Vinson 1993).

technological continuum represented by the Mediterranean square-sail from at least the time of the 4^{th} century BC Kyrenia shipwreck (S024) was noted above. The components which comprise this technological system vary in their form, arrangement and quantity from vessel to vessel throughout this period. There is further documented difference in the rig-plan of square-sail vessels, particularly in the first half of the first millennium AD. Throughout this period, the apparently ‘simplest’ form of the square-sail rig endures longer than all of the variations in the square-sail outlined above (ch. 3.1, Figure 3-11 & Figure 3-12). It can be argued that if the component parts which comprise two technological systems (for example the single-masted square-sail and the two-masted square-sail rig) and the technical practices required to operate them are demonstrably the same then it seems impossible to term such a process as technological change. Especially when set against the more explicit examples of technological change and difference such as the lateen/settee rig and the sprit-rig. The single-masted square-sail rig is simply the basic building block for the other forms of square-sail rig which are used in the ancient Mediterranean. The differences which are observable in the Mediterranean square-sail rig are therefore perhaps better termed *technological variation* rather that the more explicit *technological change*.

This technological variation can be observed occurring on two levels, both alluded to above. Firstly in the form of the individual rigging components which comprised the square-sail rig (ch. 3.5). Analysis of individual rigging components such as brail-rings, deadeyes and sheave blocks illustrates that there is variation in the form and material of these components in different periods and regions of the Mediterranean. Secondly, when these components are combined in the overall sailing rig, viewed as an aggregation of technology then it becomes clear that variation is also occurring with the development of two-masted vessels, auxiliary sails, etc. (ch. 3.1). The introduction of features such as auxiliary sails and extra masts are the outward manifestation of technological experimentation and variation within the square-sail tradition. Mediterranean sailors were obviously happy to adjust and alter the square-sail rig until it suited their specific requirements, but to do so within an overall rigging tradition which spanned the whole of the Mediterranean world.

3.7.4 Technological change

In contrast to the continuity and variation exhibited by the Mediterranean square-sail, the invention and adoption of the lateen/settee rig represents an explicit case of technological change. As well as the obvious change in sail-form which has held the attention of most commentators, the invention and adoption of the lateen/settee rig entailed the development of new rigging components and the associated practice required to use them. Adopting this new form of technology also required the Mediterranean mariner to forego the rigging and sailing tradition which had operated in the region for hundreds of years.

The origin of the lateen sail

One of the traditional assumptions regarding the development of the lateen sail has been its Indian Ocean origin (e.g. Hourani 1951: 104; Le Baron-Bowen 1949: 93-96). Iconographic and textual evidence has rendered its traditional transmission from the Indian Ocean to the Mediterranean at the hands of 7th century AD Arab invaders impossible, due to the existence of images of lateen/settee rigged ships in the Mediterranean which predate this event (Basch 2001: 68; Frost 1995: 154; Kreutz 1976: 80-81). The lateen/settee rig was in use in the Mediterranean from at least the 5th century AD and probably the 2nd century AD (ch. 3.3). The origin of the lateen/settee sail has also been attributed to Mediterranean Byzantine sailors (e.g. Adam 1976: 561), while others have maintained its Indian Ocean origin, simply at an earlier date (Kingsley 2004a: 78-79; Ward & Ballard 2004: 12). The collective evidence for the type of sail used in the Indian Ocean points to a strong tradition of square-sailed vessels in the Indian Ocean during the first millennium AD (ch. 3.1). In contrast to this, evidence for the lateen/settee sail in the region is limited to a conjectured textual presence from the 9th or 10th centuries AD and limited archaeological evidence from the 13th or 14th centuries AD (ch. 3.3.3). Only from the 15th century AD is there definite iconographic, textual and ethnographic evidence which indicates the use of a lateen/settee sailing rig in the Indian Ocean region. Consequently there seems no reason, based on the currently available evidence to assign the lateen/settee rig an origin in Indian Ocean waters.

In contrast to the Indian Ocean, the lateen/settee rig seems to have been fairly widespread in the eastern Mediterranean from the 5th century AD. Distinct depictions of vessels carrying lateen/settee rigs have been found in Southern Turkey (V32), Corinth (V33) and Egypt (V34). These depictions inform us that during late-antiquity, vessels rigged with lateen/settee sails had entered the consciousness of Mediterranean cultures to the extent that they were depicted in formal mosaics and informal graffitos in the place of square-sail vessels. A Mediterranean origin for the lateen/settee rig is further hinted at by the continuity with the Mediterranean square-sail of halyard systems (ch. 3.5.4) and downwind sailing handling techniques (ch. 3.6.3). In the same vein, Basch (2001: 57) observes that the criss-cross pattern depicted on the sail of V34 is consistent with the patterning often seen on depictions of Mediterranean square-sail vessels (e.g. V10, 11, 17, 19, 21) and may represent a common origin. The lack of comparative archaeological evidence to confirm this, means that it may simply be a continuation of an artistic convention for showing sailcloth, rather than technological continuity itself. The lack of evidence from the Indian Ocean, combined with the available Mediterranean evidence points to a Mediterranean origin and subsequent adoption between the 2nd and 5th centuries AD (c.f. Pomey 2006: 329). It may be speculated that this occurred in the eastern Mediterranean due to the lack of evidence for lateen/settee rigged vessels in the western Mediterranean during this period.

The way to the lateen/settee rig

It is an assumption in the literature relating to the development of the lateen/settee rig that it must have evolved from the square-sail via a series of logical developmental stages (Basch 2001: 64; Hourani 1951: 101-2; Pomey 2006: 329). Such an assumption is in keeping with an approach to technological change by maritime archaeologists and historians which is underpinned by a determinist, unilinear progression of technology (Chapter 1.1). The nature of the present study requires that such theories, based on the visual examination of geometric sail-plan undergo re-assessment.

Chapter 1.1 set out a methodology for investigating, characterising and defining sailing rigs via a detailed analysis of the form, function, use and inter-relationship of the rigging components of which the sailing rig is comprised. Analysis in this way provides a far more detailed assessment of the nature and use of ancient sailing rigs than simply assessing sail-plan alone and can indicate if the lateen/settee rig developed from the Mediterranean square-sail or was an independent invention in its own right. Chapter 3.5 identified rigging components surviving in the archaeological record that are representative of a rigging tradition specifically related to the Mediterranean square-sail. Investigation and comparison of the technical practice used to operate Mediterranean square-sail and lateen/settee rigged vessels during late-antiquity indicates that different techniques were used to tack and wear ship (ch. 3.6.1). Such difference developed because of the symmetrical nature of the square-sail in comparison to the asymmetrical nature of the lateen/settee rig. Furthermore it dictates that certain rigging components utilised within the square-sail tradition, such as brails, brail-rings and deadeyes are not used with Mediterranean lateen/settee rigged vessels. In contrast to these areas of difference, are identifiable areas of continuity. Multi-block halyard systems are utilised on both square-sail and lateen/settee rigged vessels and represent continuity over time in that part of the rig. Similarly the practice of taking the yard and sail around the front of the mast is reminiscent of the technique used to transfer yard and sail on square-sail vessels. This is especially obvious when it is contrasted with the practice of sailing with the yard and sail inside the shrouds and aback the mast on one tack which is utilised from the late-medieval period onwards (ch. 2.2.6). Finally, the practice of setting the yard in a horizontal position when sailing downwind and controlling it with a pair of braces is very closely related to the sail-handling practice used on similar courses on square-sail vessels.

It can be concluded that there are definable areas of both similarity and difference between the Mediterranean square-sail and lateen/settee rigs of the ancient Mediterranean. Continuity in certain areas of the both rigs and in some of the technical practice used to operate them indicates that at least some characteristics of the Mediterranean lateen/settee rig developed, or were adopted from contemporary square-sail rigs. However, the arrangement of other rigging components and the technical practice to tack/wear ship is representative of independent development, unrelated to the square-sail rig. The lateen/settee rig can be classified as at least a partial development from the Mediterranean square-sail. However, it must be strongly emphasised that this development included significant areas of unrelated innovation in the arrangement and use of rigging components, for example running stays and reef bands. It is this fact that sets the lateen/settee rig apart from other developments such as the two-masted square-sail rig or the *artemon*, mainsail and mizzen rig. These latter rigs represent the same set of rigging components as the single-masted square-sail, used in the same way, yet arranged in a manner which creates a different outward appearance. In contrast to this, the lateen/settee rig has a different outward appearance resulting from the development of an original set of rigging components and technical practice. In summary, identifiable areas of continuity suggest that the lateen/settee sail developed in part from the Mediterranean square-sail. However, the final outward form of this development resulted in a distinct and different sailing rig, both in its constituent parts and technical practice, as a result of the invention of unique and original rigging components. By the 5th century AD, this new form of sailing rig had come to be accepted and adopted by Mediterranean sailors and ship-owners and had begun to replace the square-sail which had dominated for so long.

3.7.5 Conclusion

The overall picture of Mediterranean maritime technology during the first half of the first millennium AD is one of contrasts. On the one hand is an identifiable tradition of rigging and sailing practice occurring on a Mediterranean wide basis for hundreds of years represented by the Mediterranean square-sail. Set against this technological continuity is the invention of new forms of sailing rig which, in the case of the lateen/settee rig, eventually replaces the established square-sail tradition. This process includes the abandonment of the many variations of the square-sail rig which are indicative of a willingness by Mediterranean mariners to alter and adapt their existing maritime technology. Survey of the available evidence indicates that the lateen/settee rig was developed in the eastern Mediterranean during the 2nd century AD, before being more widely adopted from the 5th century AD. This occurred by combining rigging components and technical practice from the existing square-sail tradition with new components and practice which became characteristic of the lateen/settee rig.

In conjunction with the processes of technological change affecting the rigs of Mediterranean sailing vessels, wholesale changes are occurring, on a roughly contemporaneous timescale, to the long-held shipbuilding traditions of the region. Given the fundamental relationship between the systems of hull and rig which comprise what may be described as a sailing vessel, it is perhaps unsurprising that these two examples of technological change are concurrent with one another. The external factors, outlined in chapter 1.1 which impact upon technology are unlikely to have affected either hull or rig in isolation. Recognising the link between changes to hull and rig technology opens up new avenues of investigation. Causal factors, grounded in the range of constraints and stimuli which influence the construction of watercraft (see Adams 2001; 2003) and set out in chapter 1.1 are likely to influence both hull and rig, but may be more easily observed in the former due to the larger quantity of archaeological remains. The rejection of the explanation offered by theories of technological change grounded in a determinist, unilinear progression dictate that an alternative explanation for the invention and adoption of the lateen/settee rig in the Mediterranean must be offered. In doing this, the challenge of the concluding section of the present study will be to relate the observed continuity and discontinuity of maritime technology to the wider social, economic and environmental context of seafaring in the ancient Mediterranean and late-antiquity in particular.

Part Four: Conclusion

It is clear from the survey of the evidence presented in Part Three that there was significant change in the maritime technology of the ancient world during the early/mid-1st millennium AD. By the 5th century AD the lateen/settee sail had begun to replace the square-sail as the principle sail-plan of Mediterranean sailing vessels. This process continued during the early-medieval period and ultimately witnessed the disappearance of the Mediterranean square-sail from the archaeological record. This study set out to investigate why such a process of technological change took place when it did.

4.1 Maritime technological change

4.1.1 The status quo

The investigation and introduction of the lateen/settee sail into the Mediterranean is not a new topic. Maritime scholars have debated the mechanisms and origins of the lateen sail with varying intensity at different times during the last 100 years (ch. 1.1.2). Their analysis has relied, almost exclusively on the typological arrangement of sailing rigs based on the geometric shape of a vessel's sail (e.g. Figure 1-2). Modern yacht races, contested by vessels carrying bermudan rigs, are won and lost by incremental improvements to the windward performance of the vessel. In the minds of most racing sailors and the wider yachting industry, the single most important factor when assessing a vessel is how well it will perform to windward. This is often at the expense of seemingly more useful characteristics such as stability of seaworthiness (Marchaj 1996: 19-22).

This desire for windward performance has been absorbed into the scholarly analysis of sail-development. It provides the obvious 'need' which fuels the development of maritime technology in past societies when viewed from an overtly functionalist outlook. As such, each inevitable development will improve performance along a logical trajectory in a predictable fashion. The end of this progression lies with the sailing rig created to suit the sailing needs of western society. This has occurred in an age when the absence of commercial sailing vessels dictates that racing and recreation provide society's impetus for the construction of sailing rigs. Recent maritime scholars have failed to challenge this flawed theory of technological change. The unconscious imposition of the needs of our society, on an ancient society, in order to understand technological change has led to the current study. This has attempted to redress the balance and to develop an approach which is more holistic in its investigation of sailing rigs and non-deterministic in outlook.

4.1.2 An alternative approach

Recourse to the available evidence relating to the sailing rigs of the ancient world indicates that the notion of a unilinear progression of technology is totally unsuitable for understanding maritime technological change (c.f. Whitewright In Press-a). Technological change, variation and continuity is readily observable in the iconographic record of the ancient world. Although the iconographic record can only provide us with a general view of shipping in antiquity, it is detailed enough to inform us that the square-sail continued to be used after the initial invention of the lateen/settee rig, before ultimately being abandoned. Iconographic evidence also illustrates the point that the square-sail itself was used in a variety of different forms within the context of the ancient Mediterranean. Furthermore, the iconographic record allows us to identify the invention and use of unrelated pieces of maritime technology, such as the sprit-rig, which does not comply with the suggested development from simple to complex, ancient to modern (ch. 3.7.1). The available, published iconographic record of the ancient Mediterranean paints a view of the use and availability of maritime technology far more complex than that currently acknowledged within the maritime literature. With detailed investigation of the technology in question, a range of further possibilities relating to the introduction of the lateen/settee rig and the abandonment of the square-sail become clear.

The current investigation has set out to build upon the available iconographic and literary evidence and to further understand the same areas of technology by also drawing upon the detailed evidence available via the archaeological record. By utilizing as widely as possible, the archaeological record of rigging components preserved from antiquity, a detailed characterisation of both the Mediterranean square-sail rig and lateen/settee rig has been produced. This has allowed a movement to be made away from the categorisation of rig-plan according to sail-form alone, to one where all of the components which comprise the sailing rig are considered equally. Implicit within this approach is the identification of the technical practice used to operate a sailing rig as a means of defining it. This reunites the ancient sailor and mariner with the sailing rig which they created, used, experimented upon, altered, refined and changed on a daily and yearly basis. This approach has allowed ancient sailing rigs to be visualised as aggregations of technology rather than simple geometric shapes (Figures 2-1 and 2-15) (c.f. Whitewright In Press-b). The technological continuity, variation and change of ancient Mediterranean sailing rigs, generalised by the iconographic record, is visible at the level of individual rigging components when observed through the archaeological record. This refinement in our view of ancient maritime technology opens up potential new ways of observing and understanding the invention and adoption of the lateen sail, returned to below.

4.1.3 Windward performance

Study into the development of the lateen/settee sail must address the central concern of every other study into the subject, namely the question of windward performance. Previous studies and commentary have simply tended to state that the lateen/settee sail represents an improvement in windward ability, when compared to the square-sail (ch. 2.3). Scholars who have put forward this argument have failed to produce any form of verifiable evidence to support their claim that the lateen/settee sail offers improved windward performance relative to the square sail. They have simply reiterated the words of their predecessors and the windward improvement offered by the lateen sail has become unquestioned and unreferenced. This study confronted this issue by drawing together data from a variety of sources to produce an assessment of the potential performance of late-antique Mediterranean square-sail and lateen/settee rigged vessels (ch. 2.3). Based on the available evidence gathered from the sailing trials of replica vessels, modern traditional vessels and historical sources there seems little cause to attribute the lateen/settee rig with superior performance characteristics in comparison to the square-sail. The 'need' which has resided at the centre of a determinist interpretation, is not satisfied by the adoption of the lateen/settee rig.

4.1.4 A Mediterranean Tradition

Use of the archaeological record has enabled the identification of a definably 'Mediterranean tradition' in the rigging and use of ancient sailing vessels. The use of the square-sail in the Mediterranean during antiquity entailed the adoption of a set of rigging components which were unique to that sail-plan at that time. The fully brailed sail and the presence of cylindrically sheaved blocks are the most visible representation of this tradition. Other elements, such as the formalised arrangement of standing rigging can also be identified which distinguishes the Mediterranean square-sail from later lateen/settee developments. This Mediterranean tradition of rigging and using square-sail vessels is not confined to a single culture or period within antiquity. Although the principal focus of this study is the Roman Imperial and late-antique period, the phrase *Mediterranean tradition* is retained rather than more specific descriptions, for example; *Roman rigging tradition*. The commonality of rigging components and technical practice identified by this study transcends any of the spatial, temporal and cultural boundaries inferred by labels such as Greek, Hellenistic, Ptolemaic, Roman, Gallo-Roman or Byzantine. Commentators (e.g. Braudel 1972: 14; Horden & Purcell 2000: 10-12; McCormick 2001: 83) have drawn upon the notion of the sea as the fundamental link between the various cultures ranged around the shores of the Mediterranean. These cultures were linked as much by the tradition of rigging and using sailing vessels, as by the sailing vessels themselves.

In comparison to the wealth of evidence relating to ancient shipbuilding, the archaeological evidence for a Mediterranean rigging tradition is still relatively sparse (ch 1.2.2). This evidence will inevitably increase in quantity as further shipwrecks and port sites are discovered, excavated and published. It can be speculated that as the quantity of available evidence increases, regional or cultural variations operating within the overall tradition (see Horden & Purcell 2000: 12; Whitewright 2007b: 291) will be identified. The archaeological record is detailed enough, even in its current state, to illustrate the potential variety in the form of characteristic rigging components used within the Mediterranean tradition. The archaeologically visible evidence of a willingness to adapt the square-sail rig can now be considered alongside wider variation and adaptation visible through more general sources.

4.1.5 Why?

It is against this background of trans-Mediterranean technical practice and technological continuity and variation that the invention and adoption of the lateen/settee sail must be viewed. This process did not witness the replacement of a primitive, inefficient sailing rig with a superior rig capable of offering long sought for improvements in windward performance. Neither was it representative of the first step along the road to the perceived perfection of the modern bermudan rig. Instead, the widespread adoption of the lateen/settee sailing rig, probably during the 5th century AD, represents the abandonment of an established, widespread and adaptable maritime tradition. By adopting the lateen/settee sail, the ancient mariner made a conscious decision to change the fundamental rigging components propelling their ship. This entailed inventing a new and original set of technical practices in order to change direction, deal with bad weather or to stow the sail (ch. 3.6). Finally the shipowner or skipper had to recruit, accommodate, feed and pay at least twice as many sailors as had previously been required. The changes entailed in adopting the lateen/settee rig were as much alterations to the social structures on board the sailing ship as they were alterations to the arrangement of rigging components and their subsequent operation. The underlying issues and themes are therefore vastly more complex than have previously been acknowledged by existing studies. Despite the alteration to the nature of maritime technological change rendered by this study, the basic question still remains; why?

4.2 The Way to the Lateen Sail

4.2.1 Technological stabilisation

The available evidence suggests that the lateen/settee sail was invented in the Mediterranean as early as the 2nd century AD (ch. 3.3). However, it does not seem to have become more widely adopted until the 5th century AD when representations of such sailing vessels become more visible in the Mediterranean. At the same time there is a reduction in the appearance of rigging components in the archaeological record which are specifically related to the Mediterranean square-sail rig. Chapter 1.1.1 highlighted the concept of *stabilisation* and *closure* following the invention of a new piece of technology. This concept traces the debate and alterations made by society to newly invented technology. It is likely to continue until the technology in question has assumed a form which requires no further alteration in order to be accepted and utilised by society. At this point, closure can be said to have been reached (Law 1989: 111-2; Pinch & Bijker 1989: 44-46; Pinch 1996: 24-5).

The fundamental differences between the symmetrical square-sail and the asymmetrical lateen/settee sail were outlined in chapter 3.6. It was observed that as soon as a symmetrical sail was replaced with an asymmetrical sail, radical changes must rapidly occur to the rigging components and technical practice required to operate the rig. The period between the initial invention of the lateen/settee rig in the 2nd century AD and its more widespread adoption from the 5th century AD may represent such a period of technological stabilisation. The same interpretation may be assigned if the rigging components and technical practice are undergoing adaptation first, which subsequently allow or dictate the use of a different sail-plan. From the 5th century AD onwards, lateen/settee rigged vessels are depicted with a characteristic set of rigging components (ch. 3.3.1). This suggests that stabilisation has ceased, the point of closure has been reached and the lateen/settee rig is associated with a consistently definable set of rigging components in the consciousness of Mediterranean societies.

4.2.2 Tradition, Ideology and Economics

Chapter 1.1.2 acknowledged the seven factors identified and defined by Adams (2001; 2003) which dictate the form, structural characteristics, appearance and use of watercraft (c.f. Figure 1-3); environment, materials, ideology, technology, tradition, economics and purpose. The maritime technological change observed during the course of this study has highlighted the areas of tradition, ideology and economics as exhibiting significant alteration during the period concerned and these factors are considered further in this section. This is not intended to unduly privilege these factors, it simply reflects the fact that in the course of this study, factors (as defined by Adams) concerning the environment (ch. 1.3.1), purpose (ch. 1.3.4), materials (ch.

3.4.4) and technology[28] (ch. 3.4.4) have not exhibited any change which can be related to the present study or maritime technological change in general. In contrast to this, obvious changes are visible in the tradition, ideology and economic contexts in which ancient maritime technology operated.

Tradition

In the context of watercraft, a tradition (be it rigging or shipbuilding) can be identified as a conglomeration of different traits which when taken together, represent and characterise a coherent entity; hull, rig etc. (for a full definition and discussion see Adams 2001: 301-2; 2003: 27-8). The biggest archaeologically visible change to the maritime technology of the ancient Mediterranean can be seen in the alterations to shipbuilding traditions between the 1st - 5th centuries AD (ch. 3.4). The established Mediterranean tradition of shell-first built vessels, edge-joined using mortice and tenon joints gave way to a building tradition based on a frame-first conception of the hull to which planking was quickly fastened with iron nails. Archaeologists have also identified vessels built using ‘mixed construction’ which utilised some elements from both traditions. The former, shell-first, technique seems to have been relatively time-consuming, wasteful of timber and required a reasonably skilled workforce (Steffy 1994: 85; 2000: 265). In contrast to this the frame-first technique was more rapid to build, required less timber and could utilise less skilled workers (Steffy 1994: 85; 2000: 265). This transition was initially also seen in linear, evolutionary terms (e.g. Steffy 1994: 84 & Fig. 4-8). However, recent archaeological discoveries have revealed that the transition was far more rapid than previously realised, was demonstrably non-linear in its chronology and was probably complete in some areas by the late 5th century AD (ch. 3.4.1). The occurrence of significant change in one area of maritime technology should alert us to the possibility of changes in related areas. Reference to chapter 3.7 indicates that this is the case in the late-antique Mediterranean. Changes to the way Mediterranean mariners rig and use their sailing rigs are occurring concurrently with changes to the shipbuilding practices.

Chapter 3.5 identified the existence of a distinctive rigging tradition associated with the Mediterranean square-sail (c.f. Whitewright 2007b: 291). This tradition is not compatible with the use of the Mediterranean lateen/settee sail, either in the composition or operation of rigging components (ch. 3.6). Characteristic components such as brails do not reappear in the archaeological record of the square-sail when it is re-adopted in the Mediterranean during the late-medieval period. This suggests that the square-sail tradition of rigging is abandoned in the

[28] Adams (2001: 301) defines technology in this context as “the technological means for constructing the vessel”. This is concerned more with shipwrightry tools and fastening materials, areas which have not exhibited demonstrable change in the context of this study.

Mediterranean following the widespread adoption of the lateen/settee rig. The limited iconographic record illustrates that the Mediterranean lateen/settee rig also employed certain characteristic rigging components (ch. 3.3.1) from the late-antique period until the 13th century AD. Future archaeological research may be able to identify these rigging components (such as hook-shaped mastheads) as belonging to a rigging tradition comparable to the Mediterranean square-sail.

It is clear that the rigging practices of the ancient Mediterranean underwent significant change by the 5th century AD. These changes required the creation of new ways of operating a sailing rig as well as simply creating new forms of rigging components (including sails). It should also be clear that this change corresponded with the equally significant technological change which was altering the way in which Mediterranean shipbuilders conceived and constructed ships during late-antiquity. In summary, the set of values which governed the creation and use of Mediterranean sailing vessels through established building and rigging traditions underwent a significant alteration by the 5th century AD. The changes to these values are clearly reflected in the outwardly visible changes to the shipbuilding and rigging traditions of the period.

Ideology

Adams (2003: 29) notes than in relation to watercraft, *Ideology* refers to the sum of ideational and ideological concepts that govern what ships are understood to be and how they are used. The ideologies of all the different groups within a society who utilise watercraft are likely to contrast with one another, based upon their different relationships to watercraft. A ship captain or common sailor might have perceived their vessel to simply represent their livelihood and means of subsistence. Meanwhile a merchant, politician, aristocrat or common citizen might perceive watercraft to represent a means to deliver or obtain commerce, materials and food staples or to project the power and prestige of themselves or their society. Ideology, in the context of this study, must therefore be considered at two levels. Firstly, the more ‘top-down’ approach, considering the ideology of wider Mediterranean society in general towards watercraft. Secondly, from a more ‘bottom-up’ perspective, the ideology of sailors and mariners with regard to the everyday use of their sailing vessels must also be considered.

The apparent prejudices against trading and ship-owning held by upper class members of Roman society are often cited by modern commentators on the ancient economy (e.g. Duncan-Jones 1990: 46; Garnsey & Saller 1987: 45; Tchernia 1997a: 272) (ch. 1.3.2). However, to judge by the variety and extent of the iconographic record, watercraft of all shapes and sizes played an important part in the lives of Mediterranean people during the Roman period. Despite the apparent lower status of traders and shippers, merchantships were considered prestigious enough to appear on various issues of Imperial coinage (e.g. V20 & Torr 1895: Pl. 6, figs 27, 28 & 34). As well as this Imperial imagery, watercraft are also frequently depicted throughout the Roman period on tombstones, sarcophagi, decorative mosaics and casual graffiti. Individual members of Mediterranean society obviously had an explicit desire to be associated with watercraft, either during their lifetime or in their afterlife. Even the spread of Christianity across the Mediterranean led to the representation of watercraft in biblical scenes, the story of Jonah being the most obvious (Reece 2007: 50).

The difference between the Mediterranean art and representation of late-antiquity, when compared to the early Imperial period is well documented (e.g. Reece 2007). However, the range of styles and medium used to depict watercraft remains similar to the Imperial period. The creation of maritime iconography continues into late-antiquity with all the available mediums being used to express a link between Mediterranean society and its ships and boats. Throughout this time maritime technological developments, including the lateen/settee rig, are integrated into the iconography of society (Appendix Three). For lateen/settee rigged ships to have been included in such pieces of work, the lateen/settee rig must have been suitably embedded in the consciousness of Mediterranean maritime societies. The same comment can hold true for the appearance of the two-masted ship in the iconography of the 2nd century AD. Likewise when a feature which has previously been consistently depicted, disappears, it must have slipped from consciousness. If the iconography is any guide, the manner in which Mediterranean society related to ships and boats does not seem to have dramatically altered over the course of the period covered by this study.

In contrast to this, the shift from symmetrical to asymmetrical sail-plan must have dictated a change in the ideology of sailing on a daily basis; change in the way mariners related to their vessels and constructed their approach to the action and process of sailing (ch. 3.6). Mariners would have been required to conceive and arrange the rigging components comprising a sailing rig in a different way. Firstly, certain elements of the rigging (e.g. brails and deadeyes) become redundant, while the importance of other components (e.g. the halyard system) increases. Secondly, the required increase in crew to operate the lateen/settee rig probably altered the social structures on board a ship. Thirdly, enforced changes to technical practice, as a result of alterations to rigging components had a knock-on effect in areas of sail-handling and manoeuvring. Despite these changes to the day to day aspects of seafaring, vessel capability, and windward performance in particular, remained unchanged (ch. 2.3). It follows that wider considerations partially dependent on such functional features (navigational practice, trade routes, commodities and suitable sailing seasons) remain uninfluenced by such changes. Therefore, although the sailing rig may be comprised of a different set of rigging components which necessitate certain alterations to the use of a sailing ship, the maritime considerations (e.g. Frake 1985; Gell 1985; Taylor 1956: 35-64) which a mariner may have drawn upon in order to successfully conduct a voyage, of any scale, would have remained unchanged.

The greatest difference between the Mediterranean square-sail rig and lateen/settee rig is in the number and function of rigging components. The systematic standing rigging of the square-sail is replaced with a multi-functional, flexible system of running stays which can be moved around the vessel as required. The Mediterranean system of brails, allowing rapid furling and adjustment of the sail, but requiring a significant number of specific component parts (brail rings, yard-fairleads and long lengths of brailing line), is replaced. In its place a system reliant on reef-bands is developed, these are integral to the sail, rather than being additional to it and utilise a limited quantity of cordage attached to the existing reinforcement strips present on the face of the sail (ch. 2.1.5). In summary, the lateen/settee rig of the 5th century AD represents a sailing rig with less component parts, which are more multi-functional in their use, than the Mediterranean square-sail. In order to utilise these components, the lateen/settee rig requires an increase in the number of crew and significant changes to the way a sailing rig was used on a day to day basis. The principle differences between the square-sail and the lateen/settee sail are summarised in Figure 4-1. Adoption of the lateen/settee rig seems to have had little effect on the perception of watercraft by Mediterranean society as a whole. In contrast, the ideology of the Mediterranean mariner, relating to the everyday use of a sailing vessel must have undergone a comprehensive change in order to accommodate the lateen/settee rig.

	Area of Analysis	Square-Sail	Lateen
Rigging	Components are unique to the rigging system in form and function.	✓	✗
	Components are simple to acquire manufacture and assemble.	✗	✓
	Components are multi-functional within the overall rigging system.	✗	✓
Crew	Rig requires a relatively small crew.	✓	✗
	Crew can utilise existing technical practice to operate the rig.	✓	✗
Performance	Sail can be easily shortened in response to weather conditions.	✓	✓
	Sailing performance is 1-2 knots average Vmg to windward.	✓	✓

Figure 4-1. Comparison of the Mediterranean square-sail and lateen/settee sail rigs.

Economy

The Roman Imperial period is often separated between 'early' and 'later' periods on the basis of the political and economic crisis that engulfed the Empire during the 3rd century AD. Prior to this point the Mediterranean economy (ch. 1.3.2), under Roman control was heavily influenced by the State-organised redistribution of staple goods. Products such as grain and oil dictated the path of the principle shipping routes across the Mediterranean. Archaeological remains attest to the practice of 'piggy-backing' private cargoes onto State requisitioned cargoes along these routes (ch. 1.3.2). Commercial trade also existed in the Early Empire and is witnessed in the heterogeneous cargoes which are common on shipwrecks from the period (Parker 1990: 342). In some cases such cargoes tell a tale of skippers engaged in *cabotage* along the coast and from port to port (ch. 1.3.2).

Following the re-establishment of Imperial authority from the reign of Diocletian, the late-antique economy exhibits different characteristics from the early period. State financed trade no longer influences shipping routes in the manner of the earlier Imperial period. Instead shipping routes, at least to judge from the archaeological record, reach areas of the Mediterranean outside the ability of the late-antique State institutions to influence. In conjunction with this, the late-antique period witnesses the rise of the church as a Mediterranean wide institution and the development of large aristocratic estates comprised of geographically separated lands. Evidence suggests that both of these conducted their own shipping operations for the purpose of internal redistribution. The reduction in the influence of State-directed trade and the apparent commercialisation of trade in general must have altered the economic conditions of the later period in comparison to those of the early period. It is this alteration in the over-riding conditions which may have precipitated changes to shipbuilding practice as a response to a desire to reduce costs of production. This link is explored further in chapter 4.3 when seeking to identify the reasons for the adoption of the lateen/settee sailing rig.

4.2.3 Summary

In the context of the shipping of the ancient Mediterranean, McCormick (2001: 64) has observed that "*Profound shifts in the economy, culture and political structures of late antiquity precipitated deep changes in how – and how much – people and things moved long distances.*" The previous section has highlighted more specific factors related to watercraft, within those broad areas commented on by McCormick which exhibit noticeable change. Alterations to three factors which act as a restraint/stimuli on the creation of watercraft can be identified; *ideology*, *tradition* and *economics*. The concept of *Ideology* witnesses both change and stasis. The way in which society perceives and reflects shipping as viewed through the creation and incorporation of iconographic images of ships and boats into areas of everyday life seems to exhibit continuity. In contrast to this, the conception of a sailing rig by a mariner and the ideas which underpin its creation and use, undergo marked change. This change in ideology is also visible in the concept of *Tradition*. The shipbuilding and rigging traditions which seem to have been embedded in maritime activity for centuries are superseded by alternative traditions and techniques. The abandonment of these long-held traditions of shipbuilding and rigging are both observable in the archaeological record of the Mediterranean. Finally, there are significant differences between the over-riding *Economic* conditions during late-antiquity when compared to those of the early Imperial period. This may be summed up by an increase in the commercialisation of the late-antique Mediterranean economy and a reduction in the influence and importance of State-directed trade.

The relationship between the identified areas of change (Tradition, Ideology and Economics) may be considered further. The replacement of square-sail ships with lateen/settee rigged ships in the iconographic record, by Mediterranean society in general, suggests that ideological change with regard to watercraft took place mainly in the context in which watercraft were used on a day to day basis. There does not seem to have been a change in the context of portrayal of sailing vessels by society. Any such change might be indicative of an alteration in the way wider society perceived sailing vessels, resulting in a reactionary change to building and rigging traditions. The link between Ideology and Tradition was noted above. It is therefore suggested that ideological change in the day to day use of sailing vessels took place as a result of the shift, discernable in the archaeological record, in the building and rigging traditions of these vessels. With regard to the relationship between Tradition and Economics. It can be hypothesized that altered economic conditions following the re-establishment of Imperial authority in the late 3rd century AD impacted heavily upon Mediterranean shipbuilding traditions in the subsequent centuries. Keeping this in mind, the direct processes and changes which led to the invention and adoption of the lateen/settee rig in the ancient Mediterranean should now be considered further.

4.3 Conclusion: The Invention and Adoption of the Lateen Sail

4.3.1 The invention of the lateen sail

The principle differences between the rigging and use of the Mediterranean square-sail and the lateen/settee rig which displaced it have been described above and should now be clear. However, the reason for the change in sail plan from symmetrical to asymmetrical has not been fully explained. Such a transition requires explanation because of the immediate implications that it has for the continued use of the vessel and rig which has undergone the transition (ch. 3.6). It is important to note that all of the alterations to the rigging components which characterise the switch from square-sail to lateen/settee sail could be conducted without altering the sail-plan of the vessel; brails can be replaced with reef-bands and standing-rigging with running stays, extra crew can be signed-up at any point. None of these require the abandonment of the square-sail because they are incompatible with it. Conversely, as soon as the square-sail and its symmetrical sail-plan is dispensed with for the asymmetrical lateen/settee rig, all of those changes must happen immediately. It is this difference which hints at the processes which lead to the invention of the lateen/settee sail. Changes to rigging components probably preceded and facilitated subsequent changes to sail-plan, because it seems improbable that such radical change could happen instantaneously.

The totality of the evidence available to this study will probably always lack the required resolution to identify the 'eureka' moment when the lateen/settee rig was invented. All that can be achieved is to observe the relationship between the trends, changes, variations and continuums visible in the various sources of evidence. Based upon this observation it is possible to construct a conjectural, theoretical pathway of technological change which results in the development of the lateen/settee rig. What follows will therefore always remain a theory, never a fact.

Simplification and variation

At some stage during the 2nd century AD, a small group of mariners (perhaps fisherman or short-haul traders) begin to simplify the Mediterranean square-sail rig. Such processes of rig simplification had occurred previously in the context of earlier sailing rigs and would occur again in the context of later sailing rigs.[29] This may have been an attempt to reduce the costs

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[29] A similar process of simplification took place in the square-sail rig of the eastern Mediterranean over the course of the Late Bronze Age. This saw the abandonment of long-held elements such as the boom and topping lifts as well as the appearance of the system of brails for shortening sail. It is likely that these developments did improve the performance of the square-sail rig on offwind courses as well as simplifying its use. Similar processes have also taken place on full-rigged ships in the post-medieval period and in the sail-plan of racing yachts during the 20th century

and overheads associated with the creation and maintenance of the sailing rig. Standing rigging is overhauled; shrouds and stays are replaced with running stays and the halyard is moved aft to replace the backstay when the yard is raised. The complex, but highly efficient system of brails is replaced with a series of reef-bands. These maintain the idea of the sail being rolled upwards but require the crew to do it by hand rather than through the brail-lines. Finally the bowlines and lifts may have been simplified or reduced. The process of simplification may be represented by the disappearance of square-sail rigging components from the archaeological record of late-antiquity but the continued depiction of square-sails in the iconographic record until the 7th century AD. This study has demonstrated that variation and alteration was a key feature of the Mediterranean square-sail rig, at the level of individual rigging components and the overall system. The simplification of the square-sail may have initially occurred as a result of the same willingness to embrace technological variation which gave rise to the different sail-plans operating within the Mediterranean square-sail tradition.

The maintenance of performance

By the 2nd century AD the Mediterranean square-sail was a refined, flexible sailing rig capable of being used on a variety of courses, including upwind ones (ch. 2.3). Rigging components such as brails and bowlines could be utilised to flatten the sail and maintain tension in the luff. This, in conjunction with the development of a strong system of standing rigging to support the mast allowed ancient sailors to maintain courses above 90° to the wind. This contrasts with square-sail rigs from earlier periods, such as the Bronze Age, which probably could not sail upwind. The removal of these components in order to simplify the rigging would have undoubtedly reduced the ability of the Mediterranean square-sail to sail to windward. It seems likely that an attempt may have been made to maintain the previously achieved levels of windward performance while at the same time retaining the simplified rig. The most obvious way to do this would have been to keep the luff of the sail taught by dramatically shortening it and reducing the amount of sail-cloth susceptible to sagging. Such an alteration would produce an asymmetrical sail.

Changes to sail-handling would have to be developed concurrently with the alteration. The likely origin of these new practices in those used to handle the Mediterranean square-sail is evident in the fact that yard and sail were still pivoted around the front of the mast, in the manner of the square-sail rig (ch. 2.2.6). On courses directly downwind, the yard is still set horizontally and athwartships and controlled with braces in the manner of the square-sail rig (ch. 2.2.6). Finally the new system of shortening sail, using reefbands, mimics the use of brails by furling the sail in staged, predetermined positions. The invention of the lateen/settee rig therefore represents the maintenance of sailing performance whilst simplifying and reducing the rigging components used to handle the rig. Following its invention, the lateen/settee rig underwent an inevitable period of refinement and adjustment which may be termed technological stabilisation. It is at this stage that the rigging components which came to characterise the lateen/settee rig probably developed. The new rig may then have only continued in use within the region, community or social group which oversaw its initial development until it began to be more widely adopted from the 5th century AD.

4.3.2 The adoption of the lateen sail

At the time of its initial invention, probably in the 2nd century AD, the lateen/settee rig did not immediately become widely adopted in the Mediterranean. This is based upon the general absence of depictions or references to the lateen/settee rig in the textual or iconographic evidence. The failure of the lateen/settee rig to be adopted outside of the region or social group which invented it suggests that overall factors and conditions (social, economic and environmental) were not suited to the lateen/settee sail being accepted by Mediterranean society. The existing square-sail rig was clearly still more acceptable/suitable to the majority of people. Only from the 5th century AD does the lateen/settee sail come to equal and then replace the square-sail in the Mediterranean consciousness of what constitutes a sailing ship. For the lateen/settee sail to be adopted at this juncture indicates that there must have been alterations to the over-riding conditions which prevented its adoption following its initial invention.

Survey of these assorted constraints/stimuli over the course of this study suggests that in the context of Mediterranean watercraft, three areas underwent significant alteration between the 2nd and 5th centuries AD; ideology, tradition and economics. Chapter 4.2.3 summarised the relationship between these factors and concluded that alterations to ideology of sailors and mariners regarding their sailing vessels took place because of changes to the rigging and shipbuilding traditions within which Mediterranean watercraft were constructed and rigged. Economic factors related to such watercraft also underwent significant alteration between the 2nd and 5th century AD. The later period exhibits a far greater level of fully commercial trade in comparison to the early period where State-directed redistribution has a major influence on shipping activity. It is this change in the economic conditions of the Mediterranean between the early Imperial period and late-antiquity which impacts in a visible way upon the shipbuilding and rigging traditions in the Mediterranean and causes archaeological visible changes to occur in both areas.

The most visible change is in shipbuilding practice. Shell-first shipbuilding traditions are increasingly adapted to be more economic of time and materials and are ultimately replaced by frame-first ships which can be built faster, with less material costs and with less skilled (therefore cheaper) labour. Archaeological evidence indicates that in some areas of the Mediterranean, the transition to frame-first shipbuilding was complete by the late 5th/early 6th century AD. This study has been able, for the first time, to equate the changes to Mediterranean rigging practices during late-antiquity with the contemporary changes in Mediterranean shipbuilding practice. The square-sail rig undergoes a process of simplification which reduces the cost of that area of a sailing vessel. Such changes mirror the more visible changes to shipbuilding practice occurring in the hull of a sailing vessel. Unlike the hull of a vessel however, the sailing rig requires manual operation during use and changes to rigging components result in changes to technical practice. Ultimately, the re-arrangement of the rigging components which comprise the square-sail rig and the associated alteration in how they are used results in the development of a different sail-form. If the component parts are re-arranged, the outward appearance will inevitably be different. This maintains the performance achieved with the square-sail rig, but utilises a reduced, simplified and more economic aggregation of rigging components. The lateen/settee sail eventually became more widely adopted in the Mediterranean when different economic conditions in late-antiquity increasingly caused shipbuilders, owners and skippers to place more consideration on commercial, economic factors. The lateen/settee rig represented an existing alternative to the Mediterranean square-sail which allowed merchants and ship-owners to maintain existing trade routes while reducing the costs incurred in the capital outlay on their vessels.

One final, obvious question remains to be answered. If changes to maritime technology are explained via processes of simplification and economisation, why was a sailing rig adopted which required a much greater number of crew? The answer to this question has two main strands. Firstly, at the time when the lateen/settee rig seems to become more widely adopted the population of the Eastern Empire seems to have been increasing (ch 1.3.2). This suggests that there was not a manpower shortage, at least in the eastern Mediterranean, which might have prohibited the adoption of the lateen/settee rig. After the dramatic reduction in population due to plague in the second half of the 6th century AD (see Laiou 2002: 49-50; Laiou & Morrisson 2007: 25 & 38; Morrisson & Sodini 2002: 172-6) the square-sail is not re-adopted. This indicates that the lateen/settee rig was well-established as the main form of sailing rig by this stage. Secondly, the influence of crew size on the economic costs of sailing vessels may have been over-simplified with regard to pre-industrial economies. The use of a system of profit-shares as a means of payment, rather than a set daily wage may have mitigated the effect of an increase in crew on the profits of a ship owner (ch. 3.6.4). Although outside the scope of the present study, a fruitful area of future research would undoubtedly be the investigation of how the maritime elements of Mediterranean society dealt with the decreasing human resources and increasing costs during the early medieval period.

4.3.3 Conclusion

In the course of the investigation into the lateen/settee rig, this study has addressed ancient maritime technology in the wider context of recent studies of technological change. It has been observed that the use of a deterministic unilinear progression of technology to explain maritime technological change is inadequate. Such an approach must be replaced by one which acknowledges the variety of inter-related factors which dictate the form and use of watercraft. With specific regard to the investigation of ancient sailing rigs, this study has developed an original methodology which relies upon the arrangement and use of individual rigging components to define a sailing rig rather than simply on the geometric shape of the sail. This approach allows the identification of rig-type to be made on the basis of archaeological remains, as well as through more traditional sources, such as iconography. As such, it is suggested that the adoption of the lateen/settee sail during the 5th century AD, led to the displacement of the Mediterranean square-sail from those waters during the late-antique period and subsequent abandonment during the early-medieval period. These processes are visible in the reduction of characteristic square-sail rigging components in the archaeological record of late-antiquity and the absence of such components when square-sails are re-adopted in the Mediterranean during the late-medieval period.

Analysis of the available sources indicate that the invention of the lateen/settee rig probably took place in the eastern Mediterranean during or immediately prior to the 2nd century AD. Future archaeological finds may allow a refinement of both the date and geographical location of this. It is hypothesized that this invention occurred in order to meet the technological requirements of a small regional or social group within Mediterranean society. In reality, it will probably remain impossible to identify the exact point, or moment of invention. Technological variation and adaptation is a strong feature of the use of sailing rigs by Mediterranean mariners throughout antiquity. The explanation offered here is that the lateen/settee rig was conceived as a way of simplifying and economising the existing Mediterranean square-sail rig, without sacrificing sailing performance. It is worth reiterating that the invention of the lateen/settee rig did not lead to an increase in the speed, manoeuvrability or upwind performance of Mediterranean watercraft. As noted above, the lateen/settee rig eventually became more widely adopted from the 5th century AD. Current understanding of the economic conditions of the late-antique period conclude that trade and exchange in this period was generally conducted on a more commercial basis than previously. This probably provides the impetus for the adoption of a sailing rig which offers a reduction in the quantity of rigging components required to build and operate it. The economisation of the Mediterranean sailing rig mirrors concurrent change, transition and abandonment of long-held traditions visible in late-antique Mediterranean shipbuilding practice.

Changes to the maritime technology of the ancient Mediterranean and specifically to sailing rigs, did not occur to fulfil a pre-determined technological development. Neither did they lead to a long sought after improvement in performance. The maritime technological change visible in the archaeological record of the ancient Mediterranean was the product of alterations and changes to Mediterranean society. Such changes may initially have occurred within an as yet unidentifiable area, region or social group. Whatever the case, these changes are subsequently reflected through the watercraft of the Mediterranean via the invention of the lateen/settee rig. Further changes, manifested in alterations to the economic structures of the ancient Mediterranean led to the lateen/settee rig becoming more widely adopted and displacing the Mediterranean square-sail. Previously the lateen/settee rig had only met the requirements of a limited portion of Mediterranean society, perhaps remaining confined to the area or group that invented it. During late-antiquity, the lateen/settee rig came to fulfil the needs and requirements (with regard to maritime technology) of wider Mediterranean society, just as the square-sail had done in previous eras.

The Mediterranean square-sail was not replaced because the lateen/settee rig represented a better, more efficient sail, but because it represented a rig more suited to the changing circumstance of late-antiquity than the square-sail. Even following substantial alterations to the traditions associated with Mediterranean shipbuilding and rigging, the pattern and pace of communication, trade and exchange across the Mediterranean during late-antiquity was maintained. Changes to maritime technology did not alter the underlying social structures of the Mediterranean world. In reality, Mediterranean society was responsible for shaping, maintaining and changing the internal arrangement and outward appearance of its maritime technology.