INFLUENCE AND EVOLUTION:

THE DEVELOPMENT OF THE BATTEN LUG SAIL

A Thesis

by

TIMOTHY JOSEPH KANE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

August 2006

Major Subject: Anthropology

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Approved by:

Chair of Committee,	Luis Filipe Vieira de Castro
Committee Members,	Deborah N. Carlson
	Donny L. Hamilton
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ABSTRACT

Influence and Evolution: The Development of the Batten Lug Sail.

(August 2006)

Timothy Joseph Kane, B.S., University of California, Davis

Chair of Advisory Committee: Dr. Luis Filipe Vieira de Castro

With its ease of reefing, subtle control, and unmatched ability to generate thrust effectively in both severe and minimal weather, the Chinese batten lug is perhaps one of the most sophisticated sails in history. However, its development remains unclear, as its relatively sudden appearance in the iconographic record as a mature technology, and its seeming lack of affinity to other Chinese sails, gives no indication of a regional evolution.

An analysis of the batten lug suggests that it likely descended from some simpler sail. As it is separated from the most rudimentary square rig by several key features, the batten lug's development probably occurred in an incremental, or stepwise, fashion. But, no intermediate form representing such progression of the batten lug has yet been discovered in China, or even in the greater Pacific basin. An examination of iconographic evidence from India and the western reaches of the Roman Empire, however, suggests that sails bearing battens or possessing lug morphology existed in these regions prior to the emergence of the batten lug in China. The question therefore arises whether it is possible that these sails were ancestral to, or in some way influenced the development of, the more sophisticated Chinese sail.

In an attempt to answer this question, this thesis considers the significance of diffusion as a mechanism for the dispersal of ideas, both today and in antiquity. It also presents a review of the numerous artifacts and textual accounts that suggest commercial and cultural exchange occurred between the Roman Empire, India and China during the Imperial and early Medieval periods. As a result of these evaluations, it seems possible, and even probable, that the technologies of these regions influenced each other. Considering this possibility, the likely evolution of the batten lug, and the distribution of potentially ancestral forms, this thesis concludes that the development of the batten lug in China may indeed have been influenced or inspired by the sails of India and the western Roman Empire.

DEDICATION

To the radiant apparitions of love that are my inspiration and constant support – my wife Debra, and our two daughters Sophia and Anya.

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1. INTRODUCTION

Since the forefathers of the ancient Chinese populated the highlands of central Asia some 700,000 years ago, this eastern culture has often eclipsed the western world with its technological advances. Perhaps the single most poignant example of China's historical primacy is its long history of naval innovation. Developments in ancient China frequently predate similar technology in Europe by centuries, and many of the West's medieval maritime advances are thought to have been the result of eastern knowledge imported on the heels of intrepid travelers such as Marco Polo and Ibn Battuta. Among China's staggering collection of naval achievements are paddle-wheeled warships, 150 m-long super-ships, articulated vessels, multi-layer hulls, watertight bulkheads, dampening compartments designed to flood, stern sweeps and yulohs, lee-boards, centre-boards, the stern rudder, and the compass.[1] In addition to this litany of innovations, it has long been believed that the Chinese shipwright's remarkable independence of thought gave rise to yet another development, and perhaps one of its greatest, the batten lug sail (fig. 1.1).

In recent years, the performance and efficiency of this sail have been hailed as unmatched, and even in antiquity its stability and usefulness have been noted.[2] In *Kao Li*

This thesis follows the format of the *American Journal of Archaeology*.

[1] Keith and Buys 1981, 119-23; Green and Burningham 1998, 279-83; 1983, 253-54; Needham 1971, 379-486.

[2] Phillips-Birt 1962, 62-67.

Thu Ching, a Chinese text dating to approximately A.D. 1124, the author Hsu remarked in regard to the batten lug sail:

Figure 1.1. The Chinese batten lug sail, from modern Fuchow (from Needham 1971, plate CCCXCII.)

> But when the wind blows from the side they use the advantageous mat sails (*li pheng*), set to the left or the right like wings according to the direction of the wind…To get a favorable wind is not easy, so that the great cloth sails are not as useful as the mat sails, which, when skillfully employed, will carry men wheresoever they may wish to go.[3]

Today, the batten lug is found almost exclusively in East Asia, and found there in great numbers. Its prevalence in China, and its virtual absence elsewhere in the world, has given rise to the natural assumption that the batten lug sail must have been an innovation of strictly Chinese origin.[4] Representing a highly complex development that is in form unlike the majority of other sails, and in function completely unique, the batten lug sail, like most advanced technologies, is also believed to have evolved from a simpler regional ancestor. As it is separated from the most rudimentary square rig by several key features, the batten lug's development probably occurred in an incremental, or stepwise, fashion. Unfortunately, the poor archaeological record of Asia and the Pacific has done little to shed light on the identity of any intermediate form or likely predecessor. With the omnipresent batten lug eclipsing all other contemporary sails in China for nearly a millennium, the discovery of a less complex sibling or antecedent remains a challenge. Consequently, scholars have sought to invoke the less sophisticated sails of the greater

[3] Needham 1971, 602-03.

[4] Needham 1971, 597.

Pacific, specifically the canted square sail of Indonesia and the Melanesian double-mast sprit-sail, as possible progenitors of the batten lug.[5]

However, iconographic evidence from India and from Gaul, in the western reaches of the Roman Empire, suggests that sails bearing battens or possessing lug morphology existed in these regions prior to the development of the batten lug in China.[6] With numerous artifacts from Egypt and India, and textual evidence from South and East Asia implying certain, if not extensive, contact between Rome, India and China during the Imperial and early Medieval periods, the question arises whether it is possible that these earlier sails were ancestral to, or in some way influenced the development of, the later and more advanced Chinese batten lug sail.[7]

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5 Needham 1971, 591, 606, 612-13, 616.

6 Casson 1994, 135.

7 Begley (1991), Comfort (1991), De Puma (1991), Deo (1991), Raman (1991), Sidebotham and Wendrich (1995, 1997, 2000), and Tchernia (1997) all provide abundant and compelling data that suggest significant contact existed between East and West during the Imperial and early Medieval Periods.

2. THE BATTEN LUG SAIL

2.1. Character

For the past 1,000 years, the batten lug sail has animated the immense waters that bound and cross China. In these waters, where squalls and typhoons are frequent, it is this remarkable sail that has allowed the people of China's coastline, lakes, and rivers to harness the formidable winds of the region and to ply their way in some of the world's worst conditions. One of the most efficient fore-and-aft-sails ever designed, and the quickest reefing sail in the world, the batten lug occupies a unique place in the evolution of sail technology.[8]

The earliest and perhaps simplest type of rig for which there is evidence is the boom-footed square sail of ancient Egypt. Set rigidly and more or less perpendicular to the bearing vessel's axis, it receives wind on only one surface, the after face, and can only utilize winds abaft the beam. These sails, like the Melanesian double-mast sprit-sail and other primitive square rigs, are not far conceptually from what can be easily imagined as man's first attempts at using the breath of nature to travel over water – attempts that almost certainly took the form of sheets of woven leaves or skins stretched across the breeze and secured at their periphery to some supporting structure. They are the result of the simple observation that wind can propel an object forward when that object obstructs its flow. Physically, this propulsion, or lift, is the consequence of a pressure gradient across the sail.[9] On the windward side of the sail, airflow is obstructed,

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[8] Phillips-Birt 1962, 62-67.

[9] Needham 1971, 591-94.

and air is accumulated and compressed, increasing its pressure. On the lee side of the sail, no such accumulation occurs, as there is no downstream body restricting its flow, and the air pressure remains less than on the windward side. The result is a pressure gradient and an unbalanced force perpendicular to the sail (L – lift), a fraction of which is translated into forward motion (T – thrust) (fig.2.1).[10]

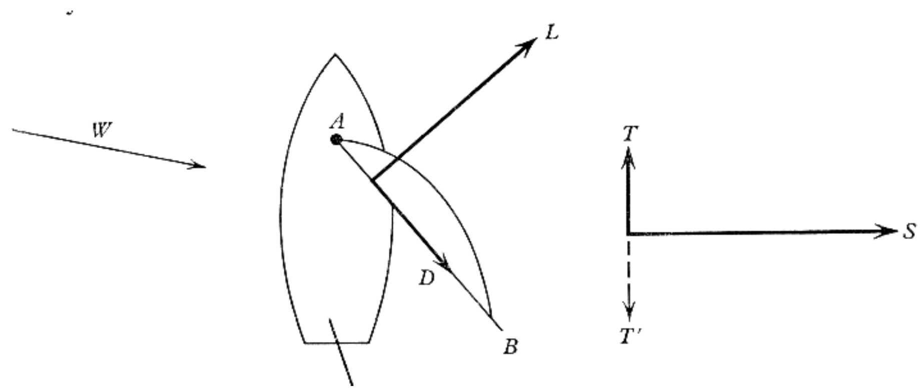

Figure 2.1. Basic aerodynamics of the sail (from Needham 1971, 593.)

While the square sail and other simple sails with a similar orientation are ideal for capturing the energy derived from this force when the wind is directly astern, they rapidly become inefficient and ultimately futile as the wind moves forward through the ship's points.[11] This inefficiency is primarily the result of changing pressure gradients across the sail. As the wind approaches the beam, its angle of incidence to the sail decreases and an inversely proportionate fraction of its mass is deflected. The amount of air accumulated on the windward face, and the overall pressure gradient across the sail, are thus reduced, with the end result being a reduction in the total motive force or thrust generated by the sail. The easiest solution to this problem is to loosen the sail and its

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10 Needham 1971, 593.

11 Casson 1950, 45.

timbers, if possible, and rotate them as a unit about the mast so that they are constantly perpendicular to the wind. With such manipulation, the square sail can be positioned along the length of the vessel both fore and aft of the mast, and can consequently receive wind on either surface depending on the direction of the wind. When set in this manner, the square sail closely approximates a fore-and-aft rig, specifically the lug, which is classically defined as a quadrilateral fore-and-aft sail hung with an oblique yard.[12] With its ability to remain perpendicular to the wind through more than 180 degrees of exposure from beam to beam, and its subsequently increased compass of utility and value to sailors, it is the fore-and-aft rig that represents one of the most significant developmental advances over the rigidly-set transverse sail (fig. 2.2).[13]

The efficiency of many sails is further affected by yet another factor - the integrity of the sail's leading margin. As the wind's angle of incidence decreases, the integrity of the sail's leading edge, or luff, can be compromised. If this edge is lengthy or loose, winds parallel to the sail, or nearly so, can cause the luff to flutter back and forth, channeling the wind to each side of the sail alternately, and thereby disrupting and reducing the pressure gradient and unbalanced force that could otherwise be generated. One solution to this problem is to minimize the amount of luff that is vertical to the wind. This can be accomplished by either reducing the angle of the luff, as seen in the canted square sail of Indonesia, or by reducing the actual length of the luff, as seen in traditional lugs or lateen sails where the yard is tilted towards the wind yielding a luff that is shorter

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[12] Needham 1971, 590.

[13] Casson 1950, 45; Needham 1971, 593-95.

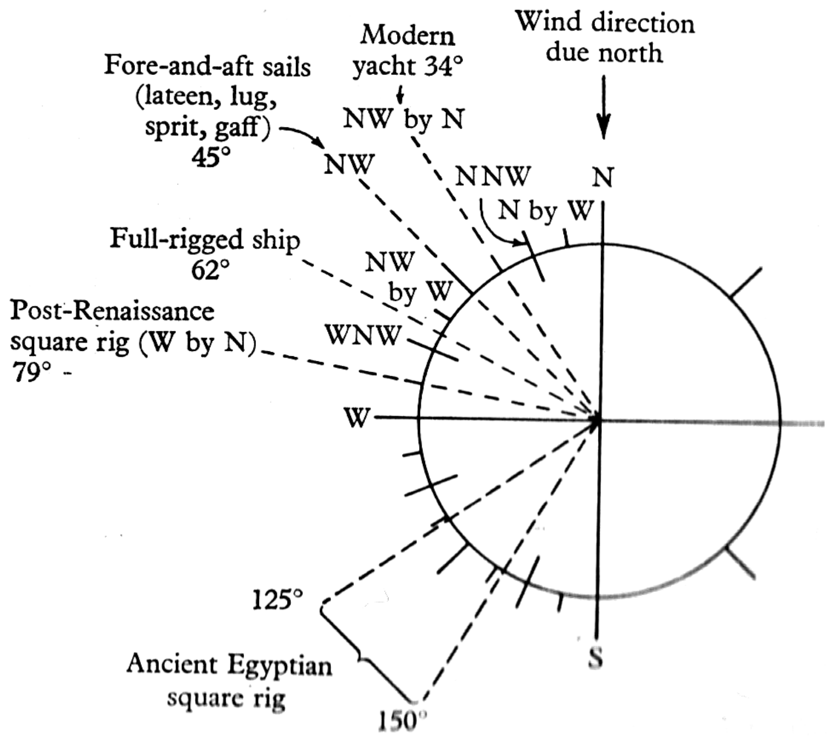

Figure 2.2. Sailing capabilities of various rigs (from Needham 1971, 594.)

than the following edge of the sail, or leech.[14] Another solution to this problem is to control the tautness of the luff. This can be effected by positioning the sail so that more of its yard and area are on one side of the mast than on the other.[15] The lengthier lee yard arm then exerts a torque that is greater than that exerted by the weather yard arm. The difference in these forces across the mast, which acts as a fulcrum, is balanced by the tension, or torque, exerted by the luff, such that the greater the lee yard arm, the tighter the luff. Both of these adaptations effectively manage the sail's leading edge as it cuts closer to the wind, and thereby aid in yielding a more constant pressure gradient and consequently a greater amount of propulsive energy. Although the majority of fore-and-

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[14] Bowen 1953, 186.

[15] Bowen 1953, 185.

aft sails, including lugs, adopt one or both of these adaptations, the batten lug sail represents the optimization of sail efficiency and the greatest technological advance over the square sail.

The Chinese lug enjoys the benefits of being set fore-and-aft and its performance is typically augmented by a shortened luff and/or an unbalanced yard, but it is the presence of stiffening battens that separates and distances this sail from all others. These elements impart an overall rigidity to the sail, including the luff. The sail's leading edge is therefore highly constrained in its ability to move, oscillate, or otherwise flutter, regardless of the position of the wind, and an essentially uninterrupted pressure gradient is maintained across the sail. This feature therefore yields a sail that is unmatched in ability to utilize close winds, especially when it is coupled with the other luff-controlling mechanisms discussed above. Consequently, the batten lug sail is capable of readily harnessing winds that are only a few points off the bow. Furthermore, the aerodynamic rigidity provided by the battens is known empirically to better and more conservatively translate the pressure gradient across the sail into lift, or propulsive energy, than the comparatively relaxed surface of other sails.[16] This effect is further amplified by the characteristically tall aspect ratio of the Chinese lug, which serves to reduce the sail's drag relative to its lift, again maximizing the efficiency of this design, particularly in light winds.[17] Additionally, the battens, acting as multiple booms, allow for the rapid and

[16] Needham 1971, 592-93, 597.

[17] Needham 1971, 592-93.

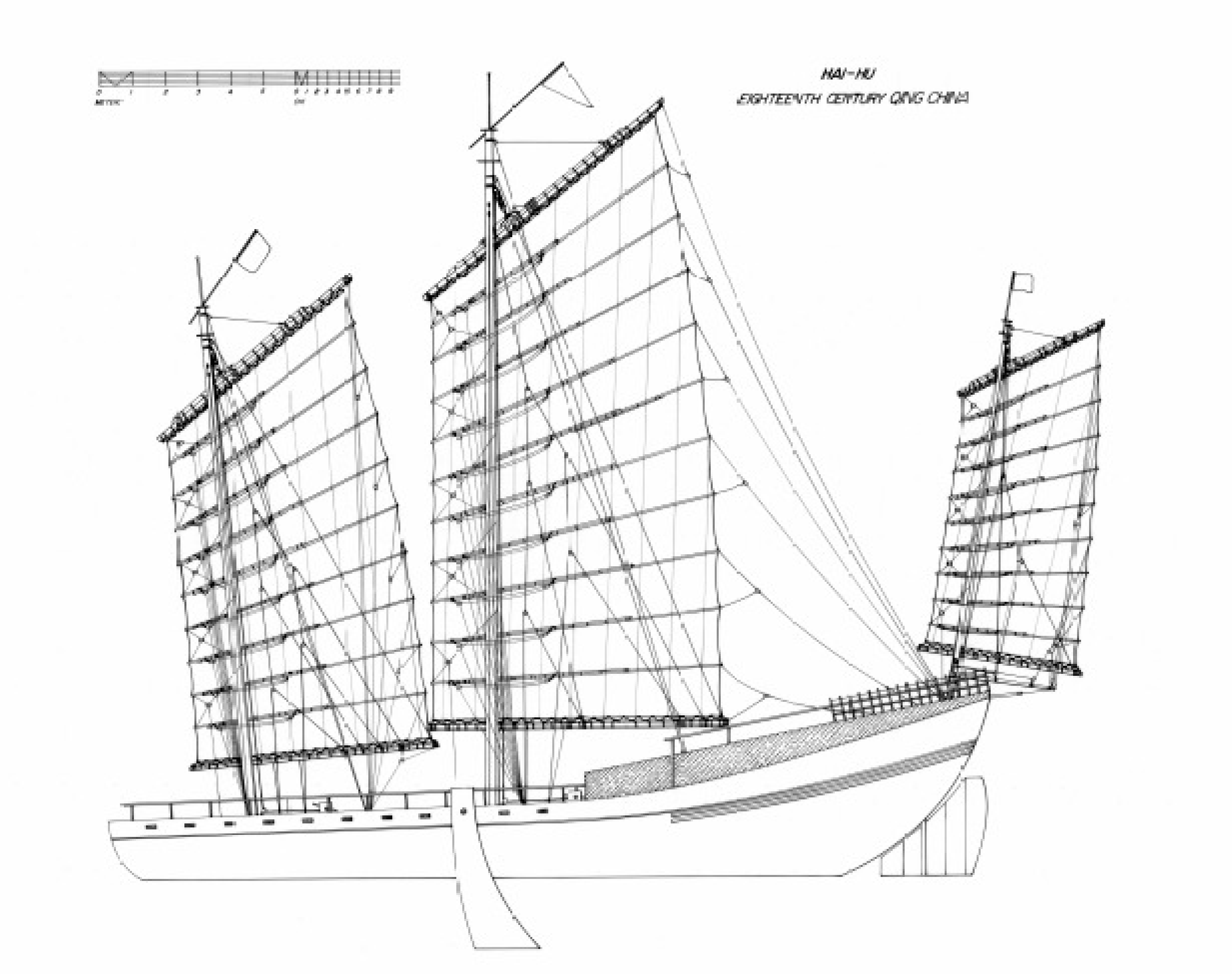

Figure 2.3. The batten lug sail, ca. 18th century A.D. (Kane 2003)

stepwise reefing of the sail through successively smaller sail areas in tempestuous seas.[18] And as the sail itself is bent to each batten, these timbers also prevent the sail from being carried away in entirety during severe weather, and effectively compartmentalize any damage to the rig that may ensue during such episodes.[19] In similar manner, they also enable the sail to be hoisted and used even if much of its surface area is missing.[20]

[18] Needham 1971, 597.

[19] Ibid.

[20] Ibid.

Hence, regardless of whether standing, dipping, balanced, or unbalanced, it is the presence of these battens that has been, and continues to be, the central and performance-defining feature of this sail. As it is not simply the modification, or morphological alteration, of some pre-existing form, but the creation, introduction and inclusion of a novel element into the sail itself, the presence of battens also embodies the conceptual abstraction manifest in the design of this particular lug, and it is the feature that situates this rig at the farthest tip of the sail's evolutionary tree.

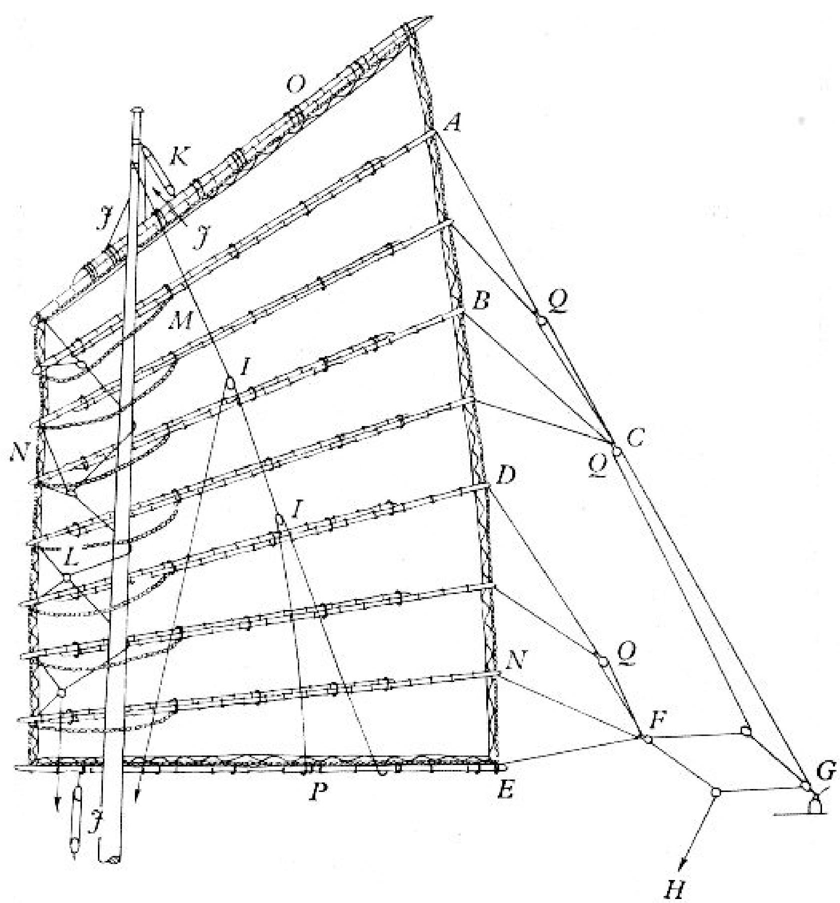

Figure 2.4. Diagram of the batten lug (from Needham 1971, 595.)

Although the Chinese lug can be easily distinguished by these split cane stiffeners, its fore-and aft lug morphology, and its tall aspect ratio, it can also be more specifically defined by two frequently complex components – the supporting body and the manipulating body. The supporting body is comprised of the yard, the boom, and the interspersed battens (fig. 2.3). Textual accounts and numerous 18th-century watercolors indicate that, although these timbers have been extremely variable over the entire historical range of naval and merchant vessels, certain trends and features are common.[21] The yard (*O*) of the Chinese lug, to which the top of the sail is bent, is typically a heavy, composite piece, composed of multiple spars lashed together (fig. 2.4). While not as massive as those of European sails, the yard, in overall diameter, is usually two to three times the size of the boom or bottom timber (fig. 2.4). Imitating the yard, the boom is also frequently constructed from a number of smaller components, but neither the yard nor the boom are very long, as the typical shape of the Chinese lug sail is rectangular and generally much taller than wide. Though not considered to be true spars, the omnipresent split cane stiffeners of Chinese lug sails function essentially as multiple booms that support and strengthen the sail over both its height and width (fig. 2.5). But unlike the other skeletal members, these battens are often composed of only one element (fig. 2.6).[22] It is these timbers, the yard, the boom, and particularly the battens, which are acted upon by the numerous lines of the manipulating body, and it is these timbers, therefore, that ultimately define the functional characteristics of the Chinese lug sail.

[21] Donnelley 1924, 25-137; Sokoloff 1982, 15,19,23-43,47-53; Worcester 1971,65.

[22] Sokoloff 1982, 35; Worcester 1971, 65.

Figure 2.5. Battens of the Chinese lug (from Needham 1971, plate CDXXIIIa.)

Figure 2.6. Single-element construction of battens (from Needham 1971, plate CDXXII.)

Undoubtedly more diverse and intricate than the supporting structure, the manipulating body is comprised of the numerous lines, ropes, sheets and blocks that are used to raise and lower the yard and to reef and trim the sail. While many of the components of Chinese rigging are similar to those found in the western world, such as the single split and double split block, others have evolved in response to the particular needs of the batten lug sail, such as the euphroe - a long block without sheaves designed to distribute or transmit the tension placed on a main sheet to several other lines attaching to the sail (figs. 2.3-2.4, 2.7-2.8).[23] Furthermore, although many of the lines themselves can be referred to by terms that are familiar, the configuration of these same lines is at once both strangely ingenious and bewildering, betraying the subtle complexity of the sail and its conceptual abstraction.

The 18th-century watercolors of Qing China and the 19th-century illustrations of western observer and ethnographer Admiral Paris provide a great deal of information on the composition and function of the various elements that control this sail (fig. 2.7).[24] Running through the sheaves of sister blocks and single split blocks around the mast to each batten, the hauling parrel and the parrels (*L*) work in tandem not only to position the sail horizontally with respect to the mast, thereby defining the asymmetry of the sail, but also to control the degree to which the sail can billow away from the mast (figs. 2.3-2.4). While common parrels cannot normally be adjusted from the deck, "running parrels" can in fact be independently manipulated, allowing a great degree of fine control (fig. 2.3).

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[23] Worcester 1971, 76.

[24] Solokoff 1982, 35.

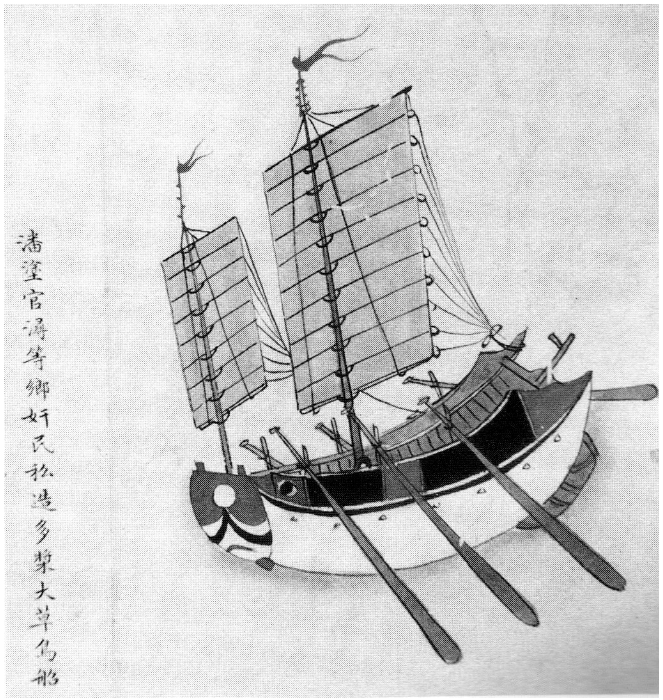

Figure 2.7. 18th-century watercolor of the Chinese lug
(from Deng 1997, 167.)

Suspending and supporting the boom are the topping lifts (*I* – fig. 2.4). On the majority of vessels, especially those depicted in the 18th-century watercolors, these elements are composed of two segments. The lower of these comprises a series of lines, frequently simple loops, that cradle the boom and that, at their distal ends are somewhat static. The upper segment, however, is typically composed of two arrays – one on each side of the mast, that are attached to the lower loops by single split blocks. The terminal lines of each array are passed to the deck through either single split blocks attached to the top of the mast or through blocks that are incorporated into the mast itself. By hauling in on these free ends, the boom can be raised and the sail consequently reefed. As an alternative arrangement, the lower sections can be tied to the boom on each face of the sail and connected to two sets of upper lines operated through a series of single split blocks. If one of these lines is held fast while the other is drawn in, the boom can be raised unevenly, and as such is another mechanism for asymmetrically altering the shape of the sail as conditions require. Additionally, there are the standard free lines at the top of the arrangement that can, upon being pulled in, lift the boom evenly. All of these lines, when hitched, serve to support the boom and the bottom of the sail.

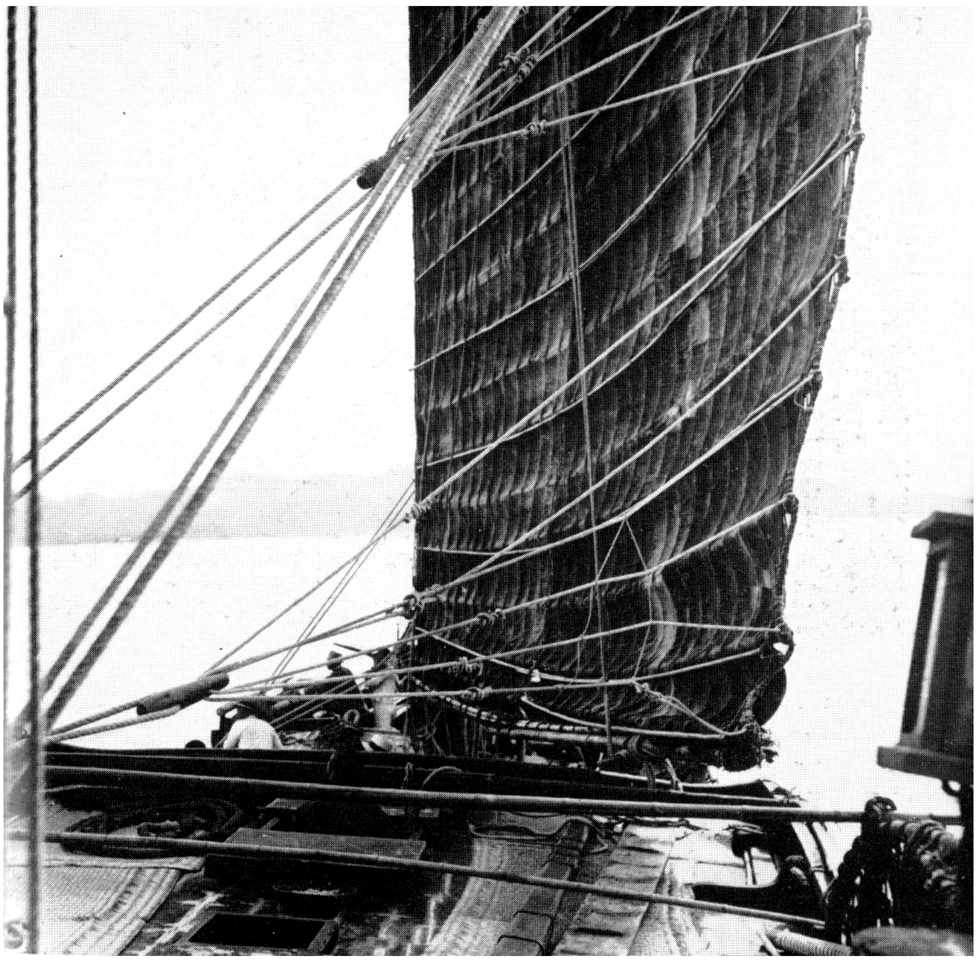

Figure 2.8. The sheets of the batten lug
(from Needham 1971, CDXXI.)

Controlling the leech of the batten lug are the sheets (fig. 2.8). These elements can often be very complex, consisting of differing lines, sections of lines and numerous blocks, but their arrangement has always been designed to satisfy the needs of the bearing vessel. For naval craft this has been tantamount to performance and consequently fine control, but for merchant vessels, maximum handling efficiency by a minimal crew has typically been the most significant consideration.[25] Paris' illustration of a military vessel depicts an arrangement of single sheets that, while much simpler in design, results in greater control than the complicated arrangements of its merchant counterparts. The line connecting each pair of battens is passed through a simple, single split block that is also attached to the sheet. Therefore, by hauling on, or releasing, a given sheet only two battens and a relatively small portion of the leech is affected. While requiring more manpower, this arrangement ultimately allows for the fine-tuning of the sail and maximum performance.

The merchant vessel, on the other hand, has traditionally employed only one or two main sheets, leading through a number of single split blocks to a euphroe, which then distributes the movement of the main sheet to as many as six pairs of battens.[26] Each pair of battens is connected to each other by a line that passes from one, through the euphroe, to the other.[27] This arrangement requires the hauling of only one, or possibly two, main sheets to effectively control, often times, as much as three quarters of the leech.

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25 Sokoloff 1982, 15, 19, 23-43, 47-53; Worcester 1971, 77-82.

26 Ibid.

27 Worcester 1971, 77.

Obviously, a degree of fine control at the level of single, or single pairs of battens is lost, but in trade, an incredible degree of handling efficiency is gained.

The halyards, in contrast to the other elements of the manipulating body, are relatively straightforward. Attached to the yard itself, or to a specialized spar that is lashed to the yard, these heavy ropes raise, lower, and support the upper structural timbers and consequently the entire sail with the exception of the boom. Passing through blocks that are either integrated into or secured to the mast, the halyards, are the primary means by which the sail is reefed (*K* - fig. 2.4).[28] In addition to these ropes, another line, depicted in the 18th-century watercolors and many later representations, is also frequently associated with the yard (figs. 2.3, 2.7). Attaching closer to the leech and shoulder than the halyard, this line is used to cant the yard, allowing the sail to acquire the characteristic dipping shape of the sea-going Chinese lug, again altering the symmetry of the sail enabling it to approach closer to the wind.

With its ability to be reefed from both top and bottom, and with its unparalleled degree of control, including its multiple mechanisms for altering symmetry, the Chinese batten lug is one of the most sophisticated sails in history. Even the most fundamental features that define this sail, the presence of stiffening timbers, a fore-and-aft lug morphology, and a tall aspect ratio, reveal a technology that is conceptually distant from the observation of any naturally-occurring phenomena that could have given rise to its development. As such, it is unlikely that the batten lug sail could have emerged as a mature technology without having first progressed through a series of increasingly

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[28] Donnelley 1924, 25-137; Sokoloff 1982, 15, 19, 23-43, 47-53; Worcester 1971, 65.

complex developmental stages, each possessing a greater number of characteristic elements than the previous. On a general level, this development might be described by three stages, depending on the presence of its three essential features. The final stage of development, occupied by the mature technology, would possess all three features. The proximal, or intermediate, stage would possess only two of the features, and would include the possible sail variants: tall-aspect lug; tall-aspect batten-bearing; and batten-bearing lug. The initial stage would possess just one of the features. Of these, the proximal stage is perhaps the most useful in evolutionary analyses as the first and last are too exclusive and inclusive respectively. And given the distribution of the intermediary forms and possible remnants of parentage in the iconographic record, it seems that the evolution of the Chinese batten lug sail may not have been entirely regional, regardless of the sail's ultimate and overwhelming presence in China, and the innovative history of the Chinese shipwright. This suggestion seems particularly justifiable as neither the canted square sail of Indonesia nor the double-mast sprit-sail of Melanesia, both of which have previously been proposed as ancestral to the batten lug, are characteristic of any developmental stage.

2.2. History

Although the batten lug sail has been perhaps the most ubiquitous feature of maritime innovation in China from the Medieval period to the present era, it is remarkably absent from the earlier iconographic and textual records. While evidence for the propulsion of inland craft by rowing or paddling dates back more than 6,000 years, the initial development of basic sail technology in China occurred no later than 3000 B.C., based on the appearance of the ancient character for sail, *fan*, on oracle bones (fig. 2.9).[29]

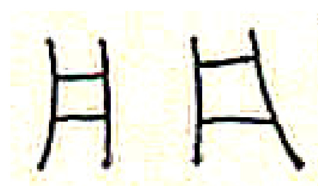

Figure 2.9. *Fan*, the ancient Chinese ideogram for sail
(from Needham 1971, 599.)

Likewise, the implicit use of sails on coastal craft can be traced back to possibly as early as the 3rd century B.C., based on an historical journey of great length. During the Qin Dynasty (221-207 B.C.), the Taoist priest, Xu, led an expedition to Japan to retrieve exotic medicines.[30] Consisting of some 2,900 km along the Sino-Korean-Japanese coasts, the journey was of such great length that the complement of food required to feed the rowers alone would have necessitated a vessel too large to have been rowed effectively.[31] A similar voyage of 1,300 km to Ryukyu several centuries later, during the

[29] Deng 1997, 32; Needham 1971, 439, 599.

[30] Deng 1997, 32.

[31] Ibid.

Sui Dynasty (A.D. 581-618), would also have necessitated the use of sails, if only for a portion of the journey.[32] However, as the characters borne by the oracle bones are essentially ideograms, even a passing examination of the script is sufficient to surmise that the earliest sails in China were not of the batten lug design that would come to dominate the Chinese waters thousands of years later, but were more likely sails supported by pairs of masts, or sprits, similar to that carried by modern Melanesian vessels.[33] Textual references from the Warring States Period (481-221 B.C.) also indicate how unlike the first sails were to the later batten lug sails in noting that they hung like an open fan and were constructed of woven leaves.[34]

By the 5th or 6th century A.D., the Chinese sail had changed significantly. The carving on a Buddhist stone stele from the Wan-Fu Ssu temple (fig. 2.10) unequivocally depicts a vessel carrying a loose-footed square sail, probably of cloth construction. And one hundred years later, a fresco from the Tunhuang cave-temple (fig. 2.11) again depicts a square sail, albeit boom-footed and of greater aspect ratio. Although these two sails likely represent both ocean- and river-going variants, neither of them, regardless of their developmental progress over the earlier designs mentioned in ancient texts, are of the batten lug type, nor do they seem ancestral to it.[35]

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32 Deng 1997, 33.

33 Needham 1971, 589, 591.

34 Deng 1997, 34; Worcester 1971, 64-69.

35 Deng 1997, 34.

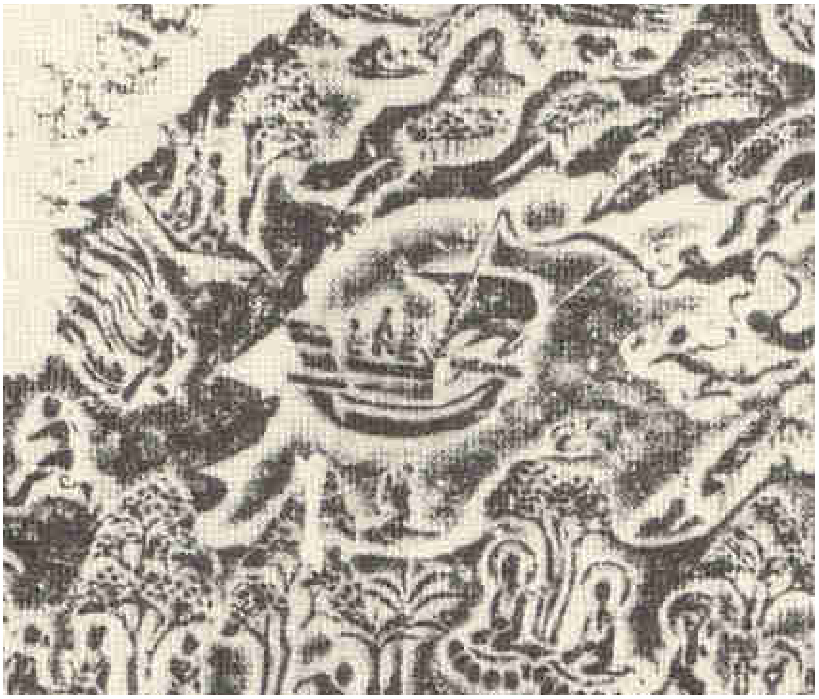

Figure 2.10. Loose-footed sail from the Wan-Fu Ssu temple
(from Needham 1971, plate CDIV.)

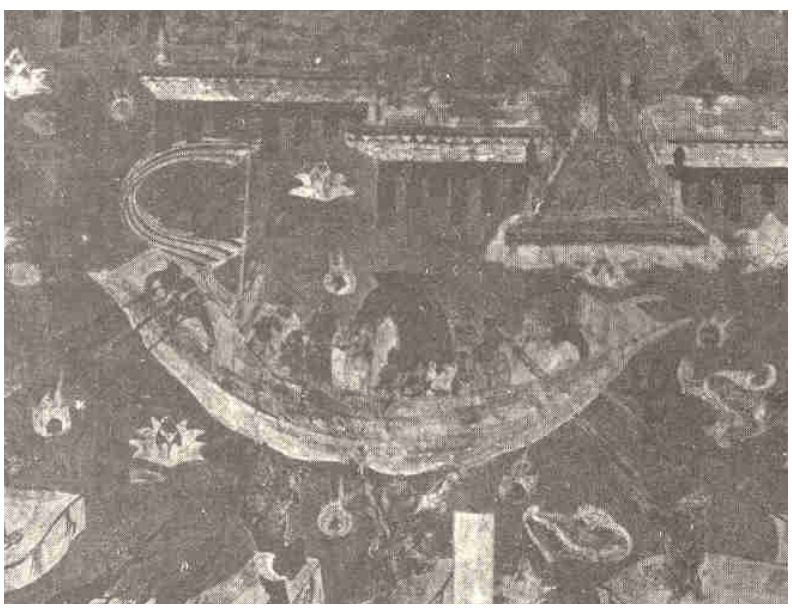

Figure 2.11. Boom-footed square sail from the Tunhuang cave-temple
(from Needham 1971, plate CDIII.)

The batten lug sail first appears carried by a Chinese vessel in a temple relief from Borobodur (fig. 2.12), Java, dated to between A.D.760 and A.D.830.[36]

Figure 2.12. The Chinese batten lug sail from Borobodur
(from Needham 1971, plate CDVII.)

With only the lowermost portion of the sail depicted, it resembles a brailed square sail due to its numerous semi-lunate features and the prior existence of the loose-footed square sail in the iconographic record. However, the sail is also divided horizontally into two sections, implying the presence of either two stiffening battens or a yard and boom hauled together, each of which precludes the use of brails. With its vertical segmentation of cloth or mat, characteristic of later batten lugs, this sail is unique in the reliefs of Borobudur, and it is distinct from the boom-footed square sails depicted elsewhere in the temple that typically exhibit a smooth or otherwise uniform surface (fig. 2.13).[37]

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[36] Frederic 1994, 18; Miksic and Tranchini 1990, 25. Needham (1971, 602) identifies these vessels as Chinese seagoing merchantmen on the basis of their bluff ends, stern gallery and thwart timbers, features typically accepted as Chinese.

[37] Frederic (1994, 215-329) presents a photographic catalogue of the temple reliefs,

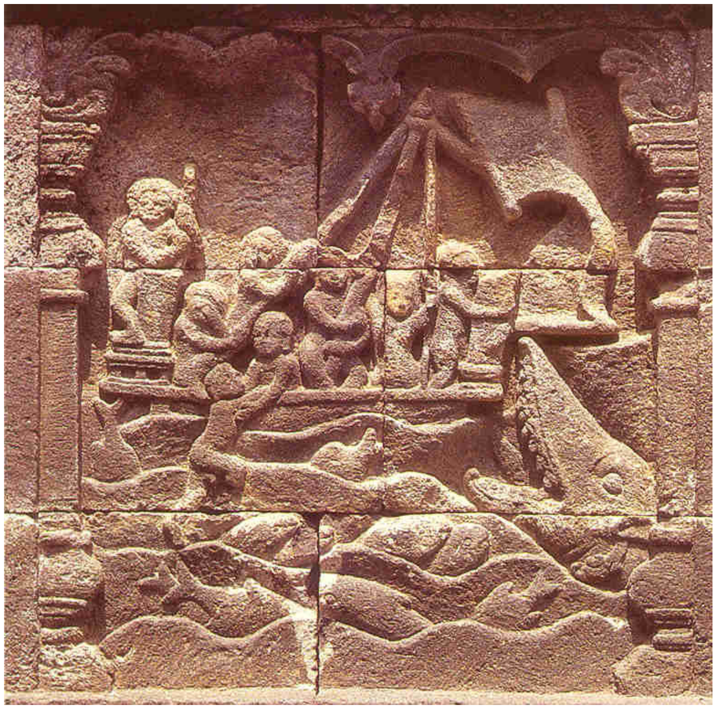

Figure 2.13. Boom-footed square sail of Borobodur
(from Frederic 1994, 62.)

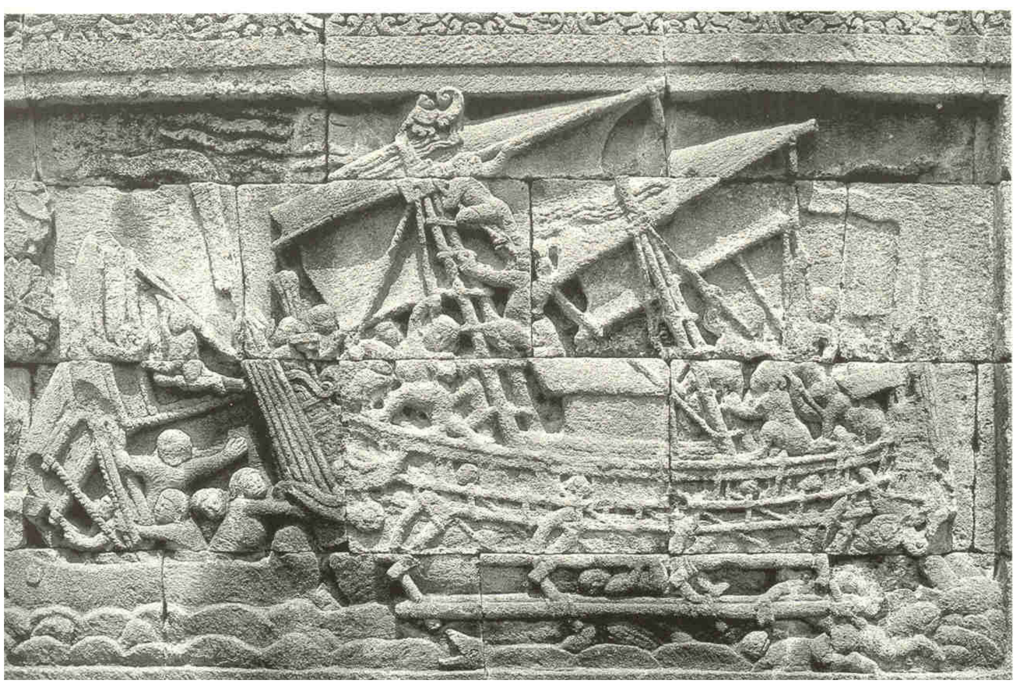

Figure 2.14. Billowing square sail (from Miksic 1990, 88.)

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in which several vessels are depicted.

The absence of a billowing body of slackened sail, observable in the depictions of other vessels (fig. 2.14), further suggests that this sail is not shown with its yard and boom hauled together, a result of the men amidships working the halyards. Consequently, the division of the sail must be the result of stiffening timbers, and we must therefore conclude that this relief may in fact depict a Chinese batten lug sail, the first in the archaeological record.

While the information provided by this first portrayal is relatively modest, another depiction from A.D.1185 renders a much more detailed image.[38] Carved on the Bayon at

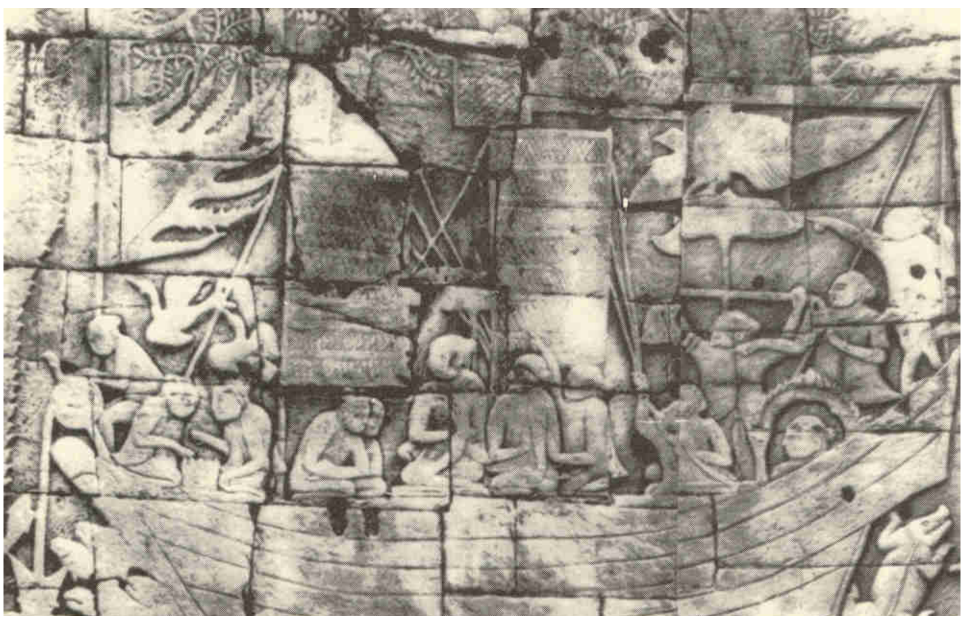

Figure 2.15. Chinese merchant ship from Angkor Thom
(from Needham 1971, plate CDVIII.)

Angkor Thom, Cambodia (fig. 2.15), this later relief clearly illustrates the mat construction of these sails, their use of stiffening battens, and the multiple sheets of their

[38] Needham 1971, 602.

rigging – elements that are frequently retained with minimal change until even the 20th century (fig. 2.16). Although the lower two sails do not extend forward of the mast, as is characteristic of lug sails, a third upper sail atop the central pole adopts the more typical lug morphology with portions of the sail both forward and aft of the mast. This particular sail technology seems then to have firmly taken root in China by the 12th century A.D., and by the Qing Dynasty, this square-headed sail of purely rectangular shape, found still today on many inland vessels, gave rise to the modern dipping lug, which due to its tilted rig and greater asymmetry, allowed vessels to sail ever closer to the wind. By the 18th

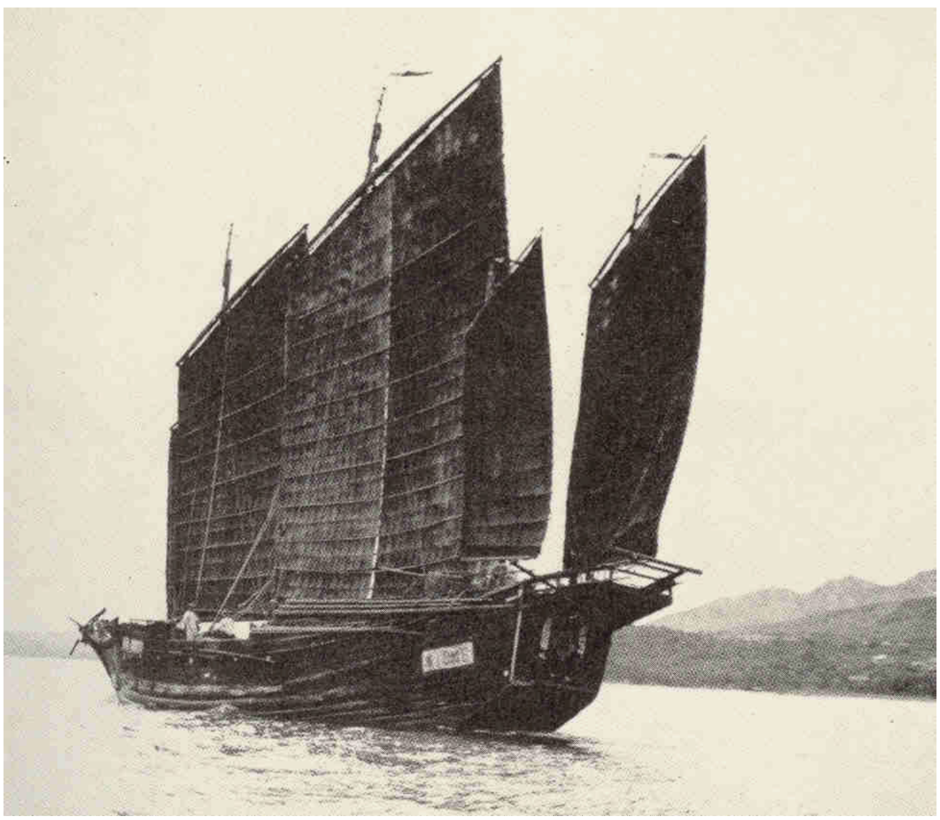

Figure 2.16. 20th-century freighter bearing modern batten lugs
(from Needham 1971, plate CDXIII.)

and 19th centuries, batten lug sails, possessing both straight and shouldered leeches, became widespread in China and standard among sea-going vessels of the time, eclipsing all other sails in the iconography.[39]

Although the number of battens used in stiffening the sail, the number and type of blocks and lines used for manipulating it, and the detailed shape of the sail itself are all features that vary subtly by province, by community and indeed by individual shipwright, the sail's general appearance has undergone little change with the passage of time, retaining three essential characteristics – the battens, a relatively tall aspect ratio, and a fore-and aft design. Its earliest representations consequently give no real indication of a formative or early stage of development. The relatively sudden emergence of this unique but largely matured technology therefore suggests that its early evolution may have occurred extra-regionally. An indication of this ancestry may be derived from an ancient 3rd-century A.D. text, *Nan Chou I Wu Chih*, or *Strange Things of the South*:

> The people of foreign parts (*wai yu jen*) call *chhuan* (ships) *po*. The large ones are more than 20 *chang* in length (up to 50 m), and stand out of the water 2 or 3 *chang* (about 5 m - 8 m). At a distance they look like 'flying galleries' (*ko tao*) and they carry from 600 to 700 persons, with 10,000 bushels (*hu*) of cargo.
>
> The people beyond the barriers (*wai chiao jen*), according to the sizes of their ships, sometimes rig (as many as) four sails, which they carry in a row from bow

[39] Donnelley 1924, 25-137; Sokoloff 1982, 15, 19, 23-43, 47-53; Worcester 1971, 65.

> to stern. From the leaves of the *lu-thou* tree, which have the shape of '*yung,*' and are more than 1 *chang* (about 2-1/2 m) long, they weave the sails.
>
> The four sails do not face directly forwards, but are set obliquely, and so arranged that they can all be fixed in the same direction, to receive the wind and to spill it (*Chhi ssu fan pu cheng chhien hsiang*, *chieh shih hsieh i hsiang chu, i chhu feng chhui feng)*. Those (sails which are) behind (the most windward one) receiving the pressure (of the wind), throw it from one to the other, so that they all profit from its force (*Hou che chi erh hsiang she*, *I ping te feng li*). If it is violent, they (the sailors) diminish or augment (the surface of the sails) according to the conditions. This oblique (rig), which permits (the sails) to receive from one another the breath of wind, obviates the anxiety attendant upon having high masts. Thus (these ships) sail without avoiding strong winds and dashing waves, by the aid of which they can make great speed.[40]

Although it is not clear which regions to the south are referred to in the text's title, nor to whom "the people of foreign parts" and "the people beyond the barriers," refer, it is doubtful they are Chinese or vassals of the early Dynastic states – Han (206 B.C. – A.D.220), Three Kingdoms (A.D.221 – A.D.265), Jin (A.D.266 – A.D.420).[41] It may be that the vessels mentioned are Indonesian, carrying the multiple canted square sails seen in the reliefs of Borobodur (figs. 2.13-2.14). However, the passage unequivocally states

40 Needham 1971, 600-01.

41 Deng 1997, xxiii.

that "if it is violent, they (the sailors) diminish or augment (the surface of the sails) according to the conditions," an impossibility for boom-footed square sails, unless entire sails are set or struck. Furthermore, there are no depictions of these vessels carrying four sails. In fact, there is no depiction of them carrying more than two, probably a result of the unwieldy size of such sails.[42] Indeed it is difficult to imagine, at this time in history, four square sails, brailed or otherwise, being carried "in a row from bow to stern" by any vessel. It is more likely, therefore, that some type of tall, balanced lug sail may have been implied.[43]

A fresco from the Ajanta temple complex of India (figs. 2.17-2.18), dated to circa A.D. 630, depicts just such an arrangement of four sails in a row, three of which are of lug design.[44] Set into the rocky sides of a crescent-shaped gorge some 100 km north of

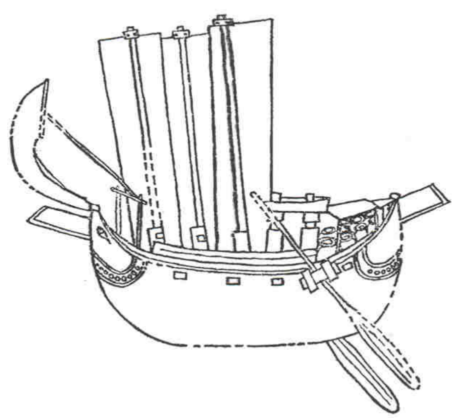

Figure 2.17. Multiple tall-aspect sails from the frescoes of Ajanta (from Bowen 1953, 194.)

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[42] Needham 1971, 601.

[43] Needham 1971, 601.

[44] Bowen 1953, 194; Needham 1971, 454, 602;

Aurangabad in western India, the complex is the result of two distinct phases of construction by Buddhist monks.[45] The first phase, undertaken in the 2nd and 1st centuries B.C. by followers of the Hinayana sect gave rise to six relatively unadorned temples, while the second phase, undertaken in the 5th and 6th centuries A.D. by Mahayanist monks, resulted in 24 highly decorated temples and halls.[46] It is in this later phase that the ship representations are found in association with an impressive array of votive figures and depictions of scenes from the life of the Buddha and narrative episodes from the *Jataka*.[47] However, as the *Jataka* is a voluminous body of folklore and mythic tales, the accuracy of the ship representations may be called into question. Do they indeed

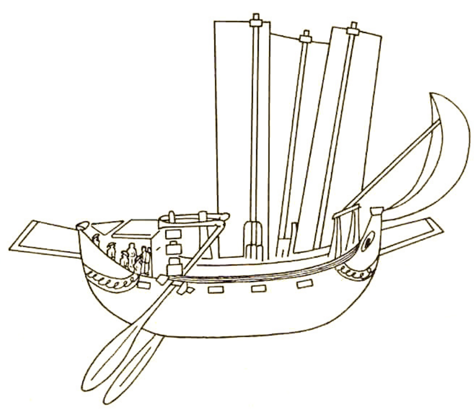

Figure 2.18. Indian lugs from Ajanta (from Needham 1971, 454.)

reflect reality or merely fantasy? Furthermore, due to the fact that the temple complex was located well inland among pristine surroundings in order to enable the monks to

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45 Gupte and Mahajan 1962, 32; Pant 1998, 23.

46 Gupte and Mahajan 1962, 34-43; Mitra 1983, 9-10; Pant 1998, 23

47 Gupte and Mahajan 1962, 36; Mitra 1983, 11; Pant 1998, 30-36

meditate undisturbed, it is likely that the portrayals were constructed from memory rather than the concurrent observation of watercraft. As such, their nature and accuracy may again be questioned. Several noted scholars also query the origin of the vessel's sails, and even the vessel itself, suggesting they are of Chinese derivation. However, a contemporary Sanskrit text relates, in a short treatise on ancient Indian ships, that vessels of the time were one-, two-, three-, and even four-masted, clearly corresponding with and corroborating the substance and character of the temple paintings.[48] Moreover, the hull of the Ajanta ship in no way resembles that of a Chinese junk but, rather, is more like the

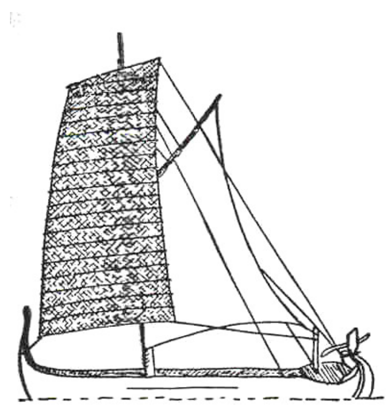

Figure 2.19. Modern batten lug from the Maldive Islands
(from Bowen 1953, 195.)

double-ended hulls of the recently extant Sinhalese coaster and, more historically, those of the ships portrayed on 2nd-century A.D. coins from Coromandel.[49] It seems therefore that the Ajanta vessel is likely of Indian origin.[50] And as it predates the earliest depiction of a Chinese batten lug by more than 100 years, it also seems likely that the sails of this

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48 Bowen 1953, 194; Donnelly 1925, 344-54; Hornell 1920, 203; Mookerji 1912, 25.

49 Bowen 1953, 194.

50 Mookerji 1912, 26-30.

craft may have influenced the development of the batten lug sail in China rather than vice versa. This suggestion is particularly tenable, considering that the tall-aspect lugs borne by the Ajanta vessel represent one of the possible developmental stages in the evolution of the mature batten lug sail. That no such stage has yet been found for the latter in East Asia, and that sails of identical shape, but with battens, are found today borne by fishing boats in the remote Maldive Islands, (fig. 2.19), is further suggestive of the ancestral role the tall lugs of Ajanta may have played in the development of the Chinese sail.[51]

Figure 2.20. River craft of the Sarre/Moselle River region
(from Casson 1994, 135.)

Surprisingly, the depiction of another sail perhaps equally influential in the development of the batten lug comes neither from India nor China, but from the western

[51] Bowen 1953, 195; Needham 1971, 455.

reaches of the Roman Empire. Depicted on a relief dated to the 2nd or 3rd century A.D., this sail, with its stiffening timbers and relatively tall aspect ratio, clearly represents another of the possible developmental stages in the evolution of the batten lug (fig. 2.20).[52] Furthermore, although it is essentially a square sail, it appears to be set fore-and-aft as a half-lug, or square-headed standing lug. Consequently, this sail may possibly be even more immediately ancestral to the mature batten lug than the tall Ajanta sails, as it appears to have incorporated, if only partially, the last essential feature of the complete technology.

Although this early batten-bearing sail was discovered near the present day border of France and Germany, its development may not be attributable to the Romans. Indeed, the relatively small vessel depicted likely represents some type of vernacular river-craft from the Sarre or Moselle, as the boat, or barge, portrayed and its sail, are unique in Roman iconography [53] Roman river-craft were typically associated with the secondary conveyance of goods from major ports, such as Ostia or Portus, Marseilles, and Antioch, to settlements or populations further inland (fig. 2.21).[54] This transport was, for the most part, hampered by the frequently contrary currents of the rivers upon which it was borne. The Roman square sail, carried by sea-going vessels (fig. 2.22), would have been impractical under riverine conditions and likely contributed little to such traffic.

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52 Casson 1994, 135.

53 Ibid.

54 Casson 1965, 31-34, 39; 1994, 131.

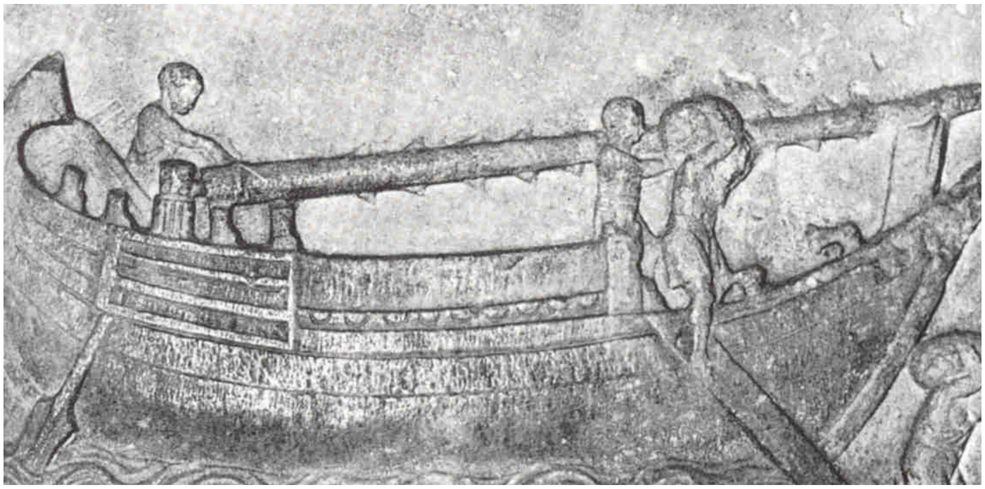

Figure 2.21. Typical Roman river craft. Carved in relief at the Cathedral of Salerno, ca. 3rd century A.D. (from Casson 1994, 127.)

Figure 2.22. Roman sea-going vessel with loose-footed square sail. Depicted on an Ostian sarcophagus, ca. 3rd century A.D. (from Casson 1994, 134.)

Frequent changes in river direction coupled with the inconstant topography of surrounding lands no doubt resulted in highly changeable winds from all quarters. Such conditions would have not only necessitated excessive manpower for the continual brailing of the large square sails but also reduced the effectiveness of the rig and hence the upstream progress of the vessel. Consequently, these watercraft, specifically the *caudicaria* of the Tiber, relied either upon towing, by teams of men or oxen, or on the use of a spritsail for headway and were correspondingly designed with a shallow draft, a towing mast stepped forward of mid-ships, and occasionally a capstan in the stern for winching the vessel forward in extreme currents (fig. 2.23).[55]

Figure 2.23. Roman river boat hauled by towlines
(from Casson 1994, 132.)

With the Roman preference for towing in river transport, as indicated by the iconography, it is necessary to consider the significance of the batten-bearing sail in regional technology. Both the Sarre and the Moselle rivers can be considered tributaries of the Rhine, in so much as they, at some point, join the larger river. And it is from the Rhine River valley that we have another depiction of this unique sail (fig. 2.24). While its construction seems ambiguous or inconclusive at first, an evaluation of its design, in light of the more detailed representation from the Sarre/Moselle, indicates that this sail also seems to possess battens. That this particular sail design is of Gallic rather than

[55] Casson 1965, 31-34, 36-38; 1994, 131, 133.

Roman inspiration seems likely considering that the vessel depicted in the Rhine mosaic belongs to a larger class of open-bow cargo vessels known to have existed in Gaul since at least the 5th century B.C., the *Bugpforte*.[56] With a relatively flat bottom and steep

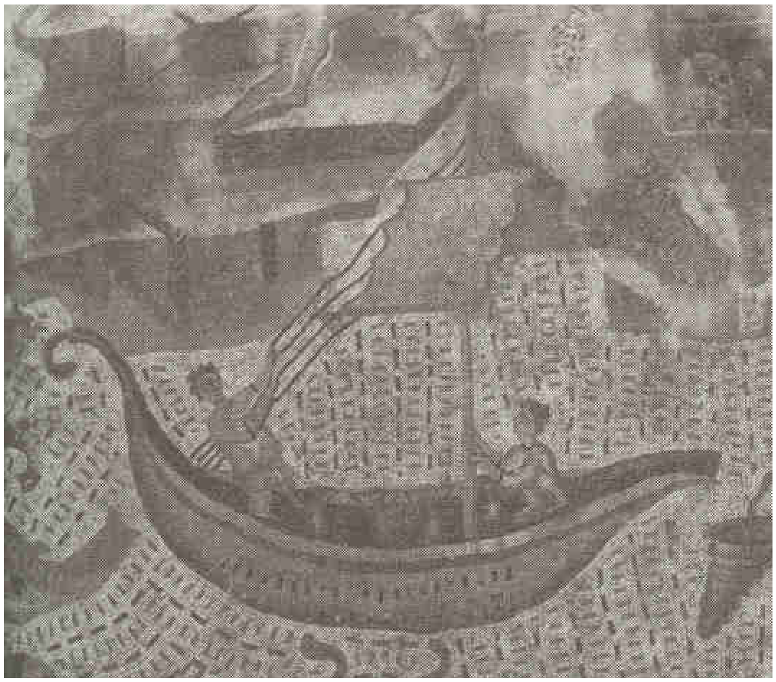

Figure 2.24. Batten-bearing sail from the Rhine River valley (from Ellmers 1978.)

sides, these vessels were ideally designed for beaching on flat river banks and for the easy loading, unloading and storage of goods.[57] And although these vessels and others of the region were well adapted to their environment and purpose, they were quite unlike contemporary Roman watercraft, as noted by Caesar in 59 B.C., during his campaign against the Gauls:

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[56] Ellmers 1978, 1.

[57] Ibid. Ellmers suggests that the unique shape of these vessels was the developmental result of using the two halves of a longitudinally split dugout to form the opposing transitional timbers between floor and sides. Originally, these craft also possessed relatively low bow entrances to facilitate the loading of barrels. Several archaeological examples of the type have been found in Belgium and Germany.

> The Gauls' own ships were built and rigged in a different way from ours. Their keels were somewhat flatter, so they could cope more easily with the shoals and shallow water when the tide was ebbing; their prows were unusually high, and so were their sterns, designed to stand up to great waves and violent storms. The hulls were made entirely of oak to endure any violent shock or impact; the cross-beams, of timbers a foot thick, were fastened with iron bolts as thick as a man's thumb; and the anchors were held firm with iron chains instead of ropes. They used sails of hides or soft leather, either because flax was scarce and they did not know how to use it, or, more probably, because they thought that with cloth sails they would not be able to withstand the force of the violent Atlantic gales, or steer such heavy ship.[58]

Thus given the similarity between the *Bugpforte* and the vessels described by Caesar in this passage, it would seem that the vessel depicted in the Rhine valley mosaic may well be Gallic rather than Roman. Consequently, an origin for the batten-bearing sail it carries may also best be described as Gallic. This suggestion seems particularly plausible given that this type of sail is not found depicted in any other region of the Roman Empire, and that prior to and throughout Rome's rule of the region, its inhabitants were predominantly Gallic. Furthermore, considering Caesar's comments on the construction of Gallic sails, it seems reasonable to propose that the use of battens may have emerged in Gaul as a response to the unwoven nature of regional sails, such that the

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[58] Caesar, *Bellum Gallicum* 3.13.1-6.

joining or attachment of the adjacent leather segments comprising the sail may have been facilitated or strengthened by the use of regularly spaced timbers.

Although the batten lug sail has dominated the waters of East Asia for more than 1,000 years, its evolutionary development there is uncertain. As a highly sophisticated technology, it is likely to have emerged in its mature form only after having progressed through a series of increasingly complex developmental stages. Intuitively, the stages most proximal to the final form would have possessed all but one of the sail's fundamental features, thereby emerging as a climax technology with the inclusion of the last essential attribute. It seems likely, therefore, that the immediate ancestor of this unique rig may have been either a tall-aspect lug or perhaps some type of tall-aspect batten-bearing square sail. However, while the batten lug is well documented in Chinese iconography, there is no evidence for the presence of either of its likely ancestral forms in China or the greater Pacific.

Consequently, the batten lug's relatively sudden emergence as a climax technology suggests the possibility that some portion of its evolution occurred extra-regionally. The appearance of both a tall-aspect lug and a batten-bearing square sail in the iconographic records of India and the Roman Empire seems to substantiate this notion. Each of these sails represents one of the possible developmental stages of the batten lug, both possessing two of the three essential features characteristic of the final technology. And as each of them also predates the appearance of the batten lug in China, it is possible that either or both of them may have influenced the development of the Chinese batten lug sail. Considering the absence of evolutionary equivalents elsewhere, this proposition seems to bear significant merit.

But given the great distance, both physical and cultural, between the Roman Empire, India, and China, the question still looms whether it is possible that these earlier sails could actually have had an impact on the development of the later and more advanced Chinese batten lug sail. The answer to this query can only be affirmative if it is indeed possible for the ideas and technology of one culture to be adopted or assimilated by another.

3. DIFFUSION AND INFLUENCE

One of man's greatest attributes is his ability to learn. The perpetual communication of knowledge from one generation to the next and from one individual to another is the hallmark of our success as a species. It is the capacity to imitate, reproduce, and modify even the most primitive technologies that has been the most enduring constant of society, and it is what has fostered the emergence of civilizations and enabled the extension of empires. Whether direct or indirect, whether through the intellectual exchange between master and apprentice or through the influence of cultural contact, the diffusion of ideas and knowledge was as certain in the ancient world as it is today.

As an explanation for the historical distribution of technology, diffusion has been central to numerous theories advanced in modern times. German scholars Alexander von Humbolt (1769-1859) and Carl Ritter (1779-1859) were among the first to advocate the importance of man's ability to learn and the consequent transmissibility of knowledge.[59] In their geographic works, though they proposed environmentalist theories for the causation of human behaviors, it was diffusion that was of paramount importance for the distribution of variations in spatially associated phenomena.[60] A century later, diffusion again gained prominence in German thought with the appearance of the *Kulterkreis*, or "culture circle," school of anthropogeography. As a reaction to the cultural evolution that had eclipsed all other schools of thought in the study of man and culture since the mid-

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[59] Hugill and Dickson 1988, xvi.

[60] Ibid.

1800s, the *Kulterkreis* school stressed historicism and particularism in the study of culture history.[61] This approach led Friedrich Ratzel (1844-1904), Leo Frobenius (1873-1938), and other members of the school to view the worldwide distribution of technology and material culture as the result of the diffusion of traits from one population to another, often as a function, or in association with migratory events, rather than as the result of cultures traversing a single, universal set of developmental stages as had long been held by the evolutionists.[62] Consequently, according to the tenets that came to define the school, there were, historically, only a few "original cultures," the *Urkulturen*, and the variations observed in global culture were the result of either the diffusion of traits from the *Urkulturen* or the migration of peoples bearing trait complexes from the *Urkulturen*.[63] Furthermore, through the description and comparison of culture traits, these diffusions and migrations could be traced back in concentric circles, or *kreise*, to the centers from which they had initially radiated.[64]

Although the efforts of the *Kulturkreis* School and the *Urkulturen* reconstructed by its members were perhaps marred by an excessive reliance on the formal similarity between traits to describe historical connections, they nonetheless represented what was seen as a tremendous gain over cultural evolution, and others soon championed similar theories.[65] In Britain, G. Elliot Smith (1871-1937), W.J. Perry (1887-1949), and W.H.R.

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[61] Hugill and Dickson 1988, xii.

[62] Ibid.

[63] Ibid.

[64] Ibid

[65] Ibid

Rivers (1864-1922) carried the notion of *Urkulturen* further with the premise that mankind was essentially uninventive and that the bulk of human culture had arisen in Egypt, reducing the number of "original cultures" to one, and thereby emphasizing the role and importance of diffusion.[66] In the United States, Native American ethnologists Clark Wissler (1870-1967) and Alfred L. Kroeber (1876-1960) proposed that within a "culture area," separate peoples, even those of distinct breeding populations, exhibited similarities as the result of the diffusion of traits from a cultural center. And Roland B. Dixon (1875-1934) espoused diffusion so totally that he virtually rejected independent invention as an important factor in the formation of human cultures. Diffusion thus became the foundation of a paradigm that quickly found widespread support not only in continental Europe but also in Great Britain and the United States.[67]

During the 1950s and 1960s, however, the social sciences were increasingly impacted by popular movements characterized by cultural sensitivity and equality, movements that were inherently contradictory to the premises of cultural primacy forwarded by many diffusionists. The Nilotic origin of all civilization, as proposed by Smith, Perry, and Rivers, the singular origin of agriculture as suggested by George F. Carter (1912-), and similar theories that discounted the possibility of independent invention were contentious to a new generation of scholars, particularly anthropologists, who emphasized the innate and universal creativity of man.[68] Consequently, by the middle of the 20th century, diffusionism had become equated with the negation of such

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[66] Hugill and Dickson 1988, xiii

[67] Hugill and Dickson 1988, xii-xiii

[68] Hugill and Dickson 1988, xiii, xix

creativity and began to experience a decrease in popularity within the wider academic community. Today, diffusion theory is seldom invoked and often avoided in scholarship as a result of its earlier overzealous assertion and the emergence of alternative schools of thought, but, as a process responsible for the distribution of technology, it remains not only highly visible but indisputable.

In 1948, the invention of the first transistor was announced in the United States by Bell Laboratories. The commercial production of these solid state semiconductors began three years later under the lead of Western Electric, and within five to seven years, the new technology had spread from the U.S. to Britain, Germany, France, Japan and ultimately to less advanced production states such as Taiwan and Hong Kong.[69] Germanium and silicon crystal based circuitry soon replaced the inefficient and limited reliability electron tubes that had dominated electronics manufacture since the 1920s, and quickly permeated not only the governmental and industrial sectors but also the consumer markets, being utilized in everything from radios and televisions to computers, SONAR and missile guidance systems.[70] In the decades that followed its initial development, the transistor served as the foundation for countless other innovations, which diffused rapidly, appearing in the production manifestos of competing states and companies within four years and frequently in less than two.[71] So pervasive was its presence and so meteoric was its rise to prominence in the world of electronics that, at the time, the

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[69] Tilton 1971, 10, 16-17

[70] Tilton 1971, 8-12, 14

[71] Tilton 1971, 16-17, 34-35

transistor was quite possibly the fastest spreading and most ubiquitous technology in man's history.

Without a doubt, the rapid diffusion of the technology associated with the transistor was predicated upon the need for competing states and companies to be viable within the economic sphere. This economic utility continues to influence the parameters that define modern markets and international trade and to promote notions of ownership, both actual and conceptual. Proprietary constraints such as copyrights, trademarks, patents, licenses, and leases control access to technology packages which can include not only processes and hardware but also training and technical assistance.[72] As a result, these same constraints support and enhance the diffusion of knowledge from one group to another through the application of trade laws, particularly if ownership, or some fragment thereof, is transferable upon purchase.

While most modern innovations are proprietary, there are a small number of exceptions. Yet frequently, those few that are neither protected nor controlled by ownership, nor legally restricted, also diffuse rapidly as a result of advances in global communication.[73] Satellite-based media facilitate the dispersal of non-proprietary technology by allowing ideas and the news of invention to reach the most remote places of the earth within years, days and even minutes of their evolution elsewhere, rather than the decades, centuries and, in cases, millennia that passed before such contact was possible. Additionally, knowledge of these same technologies is often disseminated

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[72] Robinson 1988, 4

[73] Robinson 1988, 5

through professional publications, symposia and expositions.[74] Thus with the modern world's ease of access to information, the dispersal of unrestricted innovations is greatly facilitated.

For both proprietary and non-proprietary technologies then, current conditions favor the diffusion of knowledge from one group to another. And while these conditions distinguish the current era from the majority of past periods, the fact that technology diffuses and that man is capable of such transfer of ideas remains. The distribution of the transistor and an ever increasing number of other innovations, such as the medical vaccine, global positioning (GPS), and the internet, stands as a testament to man's ability to learn and imitate and as a reminder that technology does indeed diffuse. Evidence for diffusion, however, is found not only in distribution of modern technology, but it is also found in the dispersal of knowledge and the many innovations of man's more distant past.

The diffusion of technology, or more broadly the transmission of knowledge in general, from one group to another in antiquity is perhaps most visible in those cases where independent evolution or re-invention was not possible. The trans-oceanic distribution of certain domesticated plants, specifically those with known geographic origins, implies contact between distinct human populations and the transfer of knowledge between them. As non-human agency cannot account for the dispersal of many of these plants, diffusion must be invoked. The sweet potato, for example, according to geneticists and taxonomists is undoubtedly American in origin, yet this tuber has been found distributed over vast expanses of ocean and has been shown to have

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[74] Robinson 1988, 6.

existed throughout Polynesia prior to European contact, even though it is a poor candidate for dispersion by bird, insect, wind or even ocean current.[75] While such agency may be argued by some, one further observation must be considered. The sweet potato bears the same name throughout the Pacific and in certain regions of the Americas, and has done so since before the earliest writings of the Pacific's first botanists.[76] It would seem then that this plant was borne by human populations from the American continent to one or more islands of the Pacific, from where, the sweet potato and the knowledge complex associated with it, including its name, was transferred to the remaining islands. The sweet potato forms a large portion of the diet for many inhabitants of these islands and has, since its introduction, been essential to survival in a frequently harsh environment. Consequently, its cultivation and use represents a corpus of information that has been completely assimilated and integrated by a population other than that responsible for its initial exploitation or utilization and it stands as an example of diffusion.

Hibiscus rosasinensis presents a similar example. Long believed to have originated in Southeast Asia, the red-flowered hibiscus, diagnostic of traditional Polynesian dress and worn by women as an adornment in their hair, is now known to have come from the Americas.[77] And yet, it is also known that this plant first appeared in Asia before the dawn of the common era, and that China was importing it from what is

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[75] Carter 1988, 6; Robinson 1988, 6.

[76] Carter 1988, 6.

[77] Carter 1988, 7-8.

now North Vietnam and exporting it to Persia by the 2nd century B.C.[78] Significantly, this plant, unlike its cousin *H. tiliaceous* can not be dispersed by water, and it is only naturally pollinated by hovering birds, the most common of which is the hummingbird - also strictly American.[79] The appearance and persistence of *Hibiscus rosasinensis* in Asia therefore was unquestionably the result of diffusion, the diffusion of not only the plant itself, but also the specific knowledge that a bird such as the hummingbird was in fact necessary for the plant's pollination and reproductive viability.

One further example of early diffusion is cotton. In 1947, the first cytogenetic investigation of this plant was undertaken, a study that indicated all Old World cottons were of one genotype while all New World wild cottons were of another. Of particular interest, however, was the fact that all New World domestic cottons possessed the genetic signature of both types.[80] The significance of this last observation was that Old World cotton must have been purposefully brought to the New World and there bred with native species to give rise to the new hybrid. Although one may be initially inclined to consider environmental or non-human agency as an explanation for the presence of Old World genes in the American domesticates, their absence in the wild populations of the New World suggests that neither chance nor chaotic events were responsible for the dispersal. Consequently, New World domestic cotton must have emerged as the result of the controlled cultivation of Old World cotton in proximity to wild strains of New World cotton, and the subsequent intentional hybridization of the two. Moreover, the

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[78] Ibid.

[79] Ibid.

[80] Carter 1988, 5.

emergence of domestic New World cotton implies the diffusion of both the Old World plant and the knowledge associated with its cultivation and domestication. And given the time necessary for both genotypes to reach 100% frequency in New World domestic cotton, this diffusion must have occurred very early in antiquity.[81]

While these examples and others including the peanut and maize provide strong evidence for the transfer of ideas and knowledge in antiquity, the influential role of the loose-footed sail in the development of maritime technology throughout the Mediterranean is perhaps more relevant to the question at hand. According to the iconographic record, the earliest direct evidence for the emergence of a purpose-built sail, the boom-footed square sail, comes from Egypt during the Predynastic, or late Gerzean, period approximately 3500-2900 B.C. (fig. 3.1).[82] Unlike Mesopotamia's great rivers, the Tigris and Euphrates, which are plagued by frequent rocky shores and shallows, and by local winds that blow in the same direction as the current, the Nile comprises an 800 km long unobstructed reach against the current from the Delta to Upper Egypt.[83] It was here that the square sail, a sail that performs best running with the wind directly astern, would have been the ideal mechanism to harness the energy necessary to easily drive a

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[81] Carter 1988, 5-6.

[82] Bass 1972, 12-13; Casson 1994, 14, 19; Wachsmann 1998, 248. Whether this sail is actually of Egyptian origin remains a matter of some debate. For although the vase upon which this vessel is depicted is undoubtedly of Egyptian origin, the hull structure of the vessel, with its high prow and stern, is reminiscent of Mesopotamian watercraft represented elsewhere in Egyptian art. Carvings from the rock walls of Wadi Hammamat and upon the ivory handle of a knife found at Gebel el-Arak in Upper Egypt, as also the paintings from a Gerzean tomb at Heirakonpolis again in Upper Egypt distinguish these vessels from those of the Nile. Furthermore, seal stones and pictograms from the Uruk period (3500-3000 B.C.) of Mesopotamia depict native watercraft with high bow and stern.

[83] Casson 1994, 13.

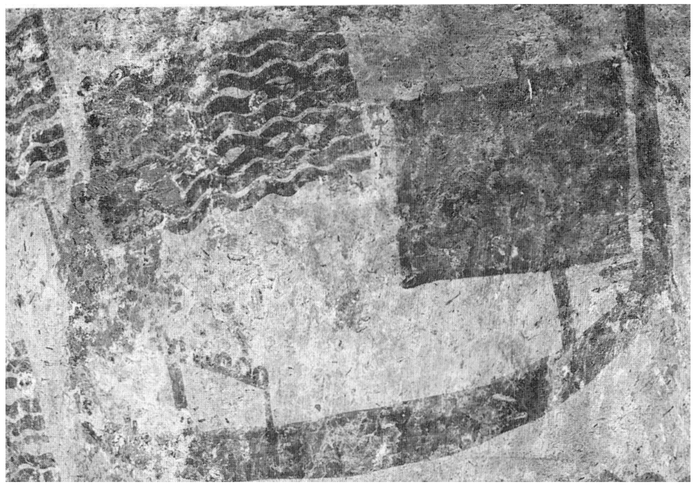

Figure 3.1. The earliest depiction of a sail (from Casson 1994,14.)

vessel upstream contrary to the current.[84] Consequently, the use of the square sail, coupled with the rapid and unaided downstream travel made possible by the river's flow, transformed the Nile into a unifying thoroughfare of unparalleled commercial and political significance. The square sail itself thus came to dominate Egyptian shipping. Initially hung from a pole mast well forward on the vessel's centerline, the square sail was attached top and bottom to large spars, the yard and boom respectively.[85] Early variants frequently possessed a tall aspect ratio, which was effective for catching the wind above the Nile's often bluff banks, but with time this design was replaced by a more stable horizontally rectangular shape (figs. 3.2-3.4).[86] Likewise, the pole mast itself gave rise to a bipod style supporting structure that was secured to the hull on either side of the

[84] Le Baron Bowen 1960, 129; Wachsman 1998, 253. It has been suggested by Bowen that the square sail is in fact incapable of function at headings greater than seven points to the wind.

[85] Casson 1994, 14, 19; Wachsmann 1998, 248.

[86] Casson 1994, 20-21.

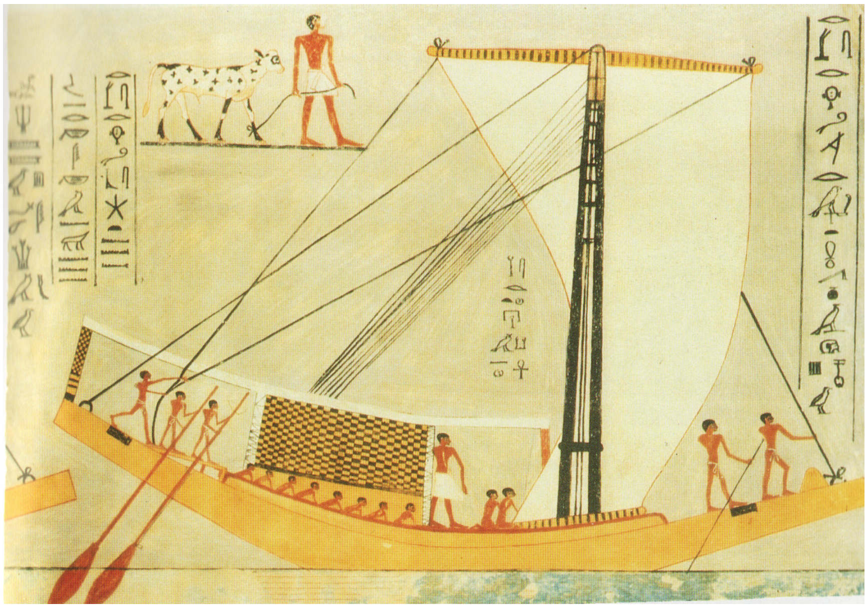

Figure 3.2. Egyptian sail with tall aspect ratio. The sail, hung from a bipod mast, is depicted on a tomb at Giza, ca. 2400 B.C. (from Casson 1994, 33.)

Figure 3.3. Tall-aspect square sail of Egypt, ca. 1900 B.C. (from Casson, 1994, 20.)

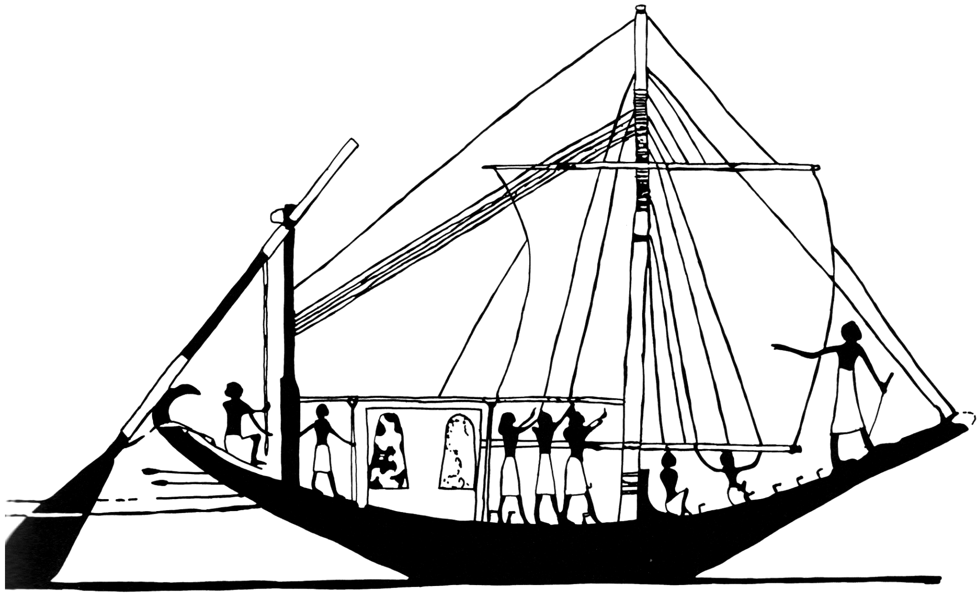

Figure 3.4. Low-aspect rectangular square sail. Rig is from a tomb at Beni Hassan – 12th Dynasty (from Wachsmann 1998, 249.)

craft's midline or possibly atop the gunwhales (figs. 3.5).[87] The distribution of weight facilitated by this development was likely necessary due to the increasing size of the sail/mast apparatus as dictated by larger vessel design, particularly since these same vessels were keelless and therefore could not support a large and concentrated burden weight amidships. However, as seen in the representations of Queen Hatshepsut's expedition to the land of Punt at Deir el Bahri, the later introduction of a thick, robust keel plank, or proto-keel, again allowed the mast to be located near the center of the ship (fig. 3.6).[88]

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87 Casson 1994, 19-21; Wachsmann 1998, 13, 25-27.

88 Wachsmann 1998, 24-27, 241-43.

The square sail, stretched between an upper yard and a lower boom, however, could not be reefed easily when subjected to wind of variable direction and strength. The yard had to be lowered to the boom, and the original sail had to be replaced with a

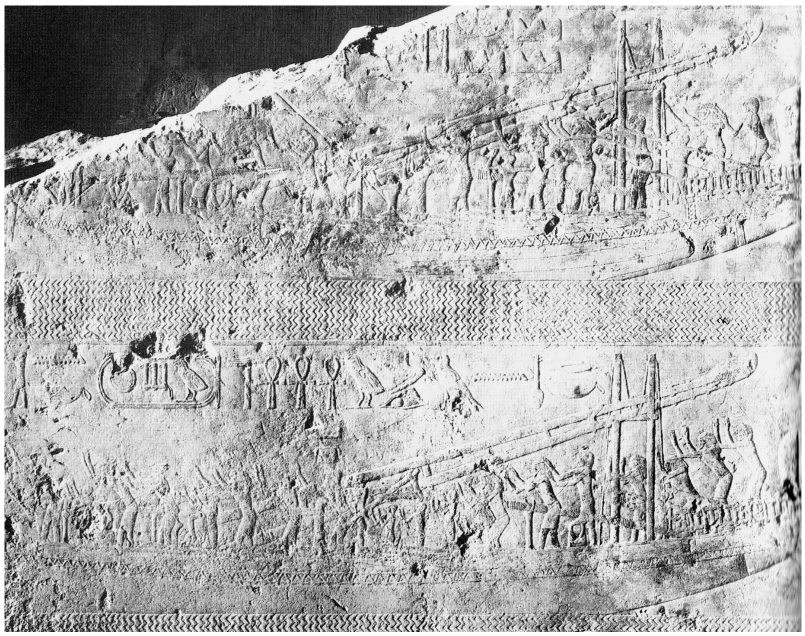

Figure 3.5. Egyptian bipod masts. The seagoing ships depicted are from a relief on the pyramid of Sahure, ca. 2450 B.C. (from Casson 1994, 22.)

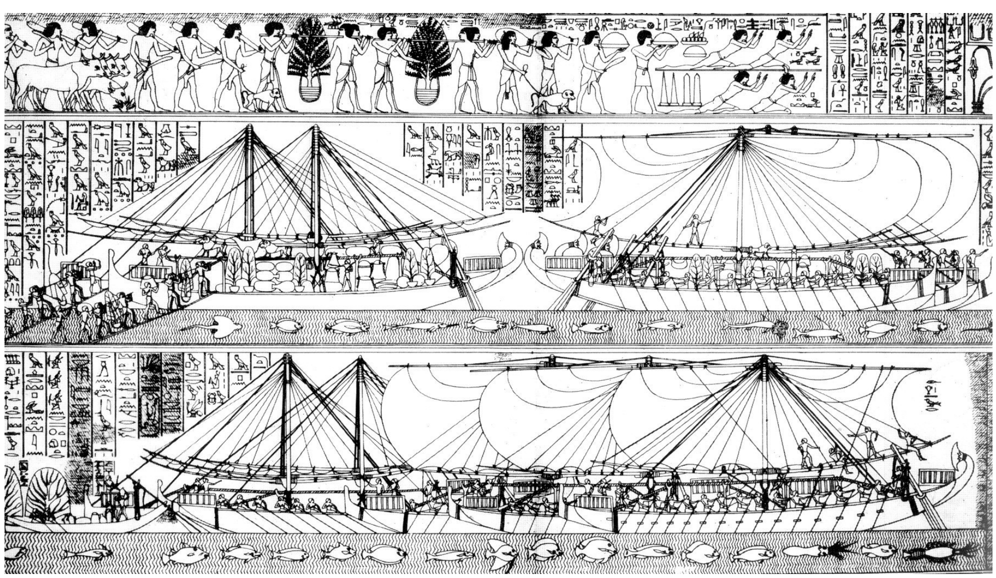

Figure 3.6. Hatshepsuts's keel plank or proto-keel. These structures are evident at bow and stern of the ships on the expedition to Punt, ca. 1500 B.C. (from Wachsmann 1998, 17.)

smaller or a larger one, depending on the conditions, and then reset – a difficult and laborious enterprise, especially at sea, such as the Punt voyage, where strong and changeable winds could have necessitated frequent changes.[89] It was not until the end of the Bronze Age, during the reign of Ramses III, that evidence of another type of sail appears, a sail capable of not only coping with diverse conditions but also of sailing closer to the wind.[90] From carvings depicting the great naval battle between the Egyptians and the enigmatic Sea Peoples at Medinet Habu, the loose-footed square sail becomes visible in the archaeological record for the first time (figs. 3.7-3.8).[91] With brailing lines to alter its symmetry, this sail represented a significant advance over the yard-and-boom set square sail and allowed greater flexibility, efficiency and safety in coastal and open-water sailing. While it is likely that the loose-footed square sail was

Figure 3.7. Brailed sail of Medinet Habu. The rig is borne by both Egyptian and Sea Peoples' vessels and is depicted at the temple of Ramses III (from Wachsmann 1998, 31.)

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[89] Casson 1994, 25; Wachsmann 1998, 248-49.

[90] Casson 1994, 24; Wachsmann 1998, 166, 251.

[91] Wachsmann 1998, 29-31, 166, 251.

developed neither by the Egyptians nor by the Sea Peoples but by the Syro-Canaanites, what is clear is that at the time of the battle at Medinet Habu (ca. 1176 B.C.), at least two, and probably three, distinct populations were in possession of the very same technology.[92] That these peoples lived in reasonable proximity to each other and that contact between them existed is certain. It is therefore unlikely that this sail design was independently developed by each group, especially considering that such development would have had to have been simultaneous given the exactness of similarity, including the mirrored presence of brailing lines, of the sails at the time of Medinet Habu.

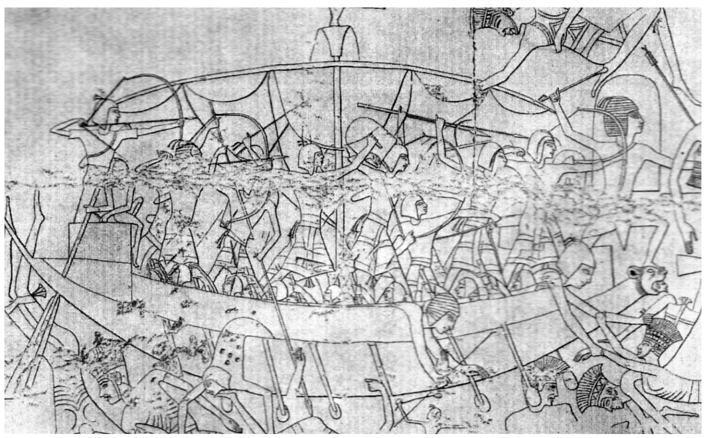


Figure 3.8. Earliest evidence for a loose-footed sail
(from Wachsmann 1998, 30.)

Moreover, with the passage of time, the loose-footed square sail came to be adopted, not re-invented, by the Greeks and the Phoenicians, the Romans and the Persians, the Etruscans and the Carthaginians, the Venetians, the French and the British and every other people of the region from antiquity through the end of the medieval period right up to the modern era (fig. 3.9-3.14). Consequently, the dominance of the loose-footed square sail in the Mediterranean from the time of Ramses III until the introduction of the

[92] Casson 1994, 39; Wachsmann 1998, 166, 252.

steam engine provides perhaps the greatest and most irrefutable evidence for the diffusion of knowledge and ideas in antiquity, and hence for the ability of one culture's technology to influence the development of another's.

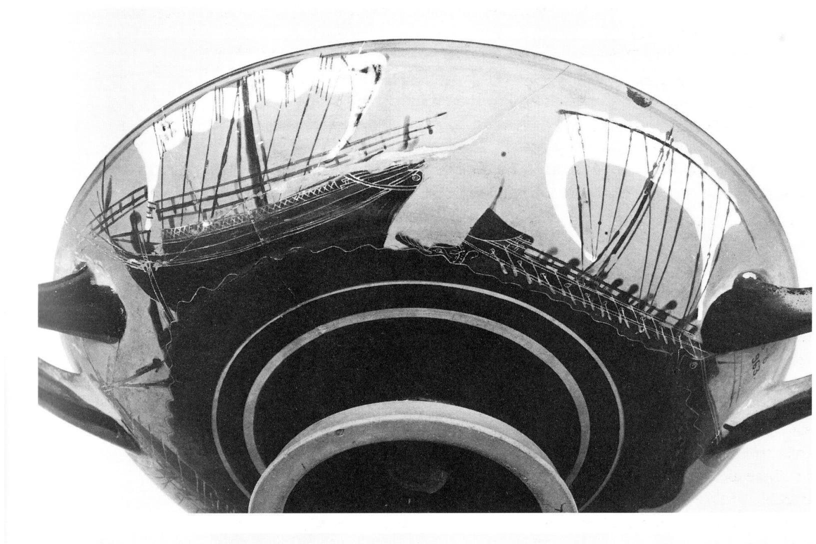


Figure 3.9. Greek merchantman and pirate ship with loose-footed sails. Late 6th century B.C. (from Casson 1994, 45.)

Figure 3.10. Brailed sail on Odysseus' ship. Late 6th to early 5th century B.C. (from Casson, 1994, 49.)

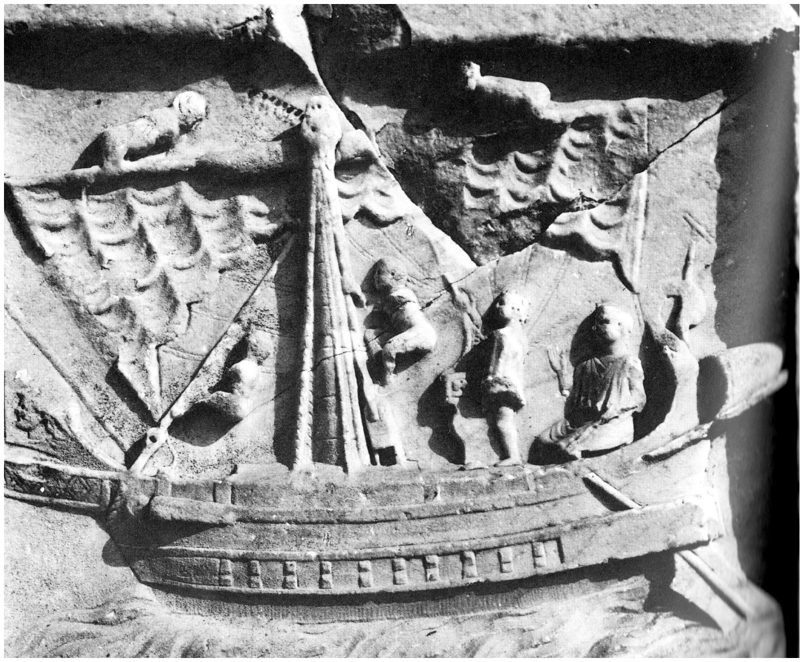
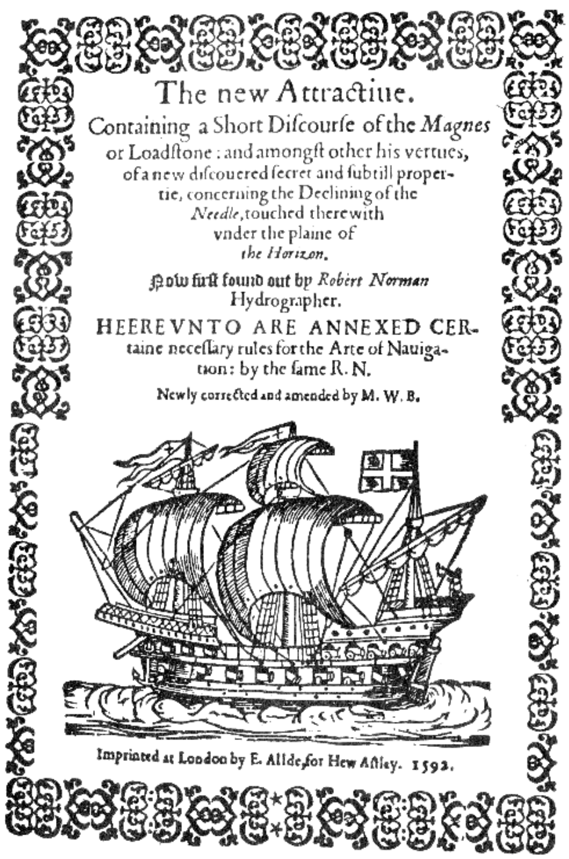


Figure 3.11. Roman brailed sail. From a relief on the tomb of Naevoleia Tyche – Pompeii, mid-1st century A.D. (from Casson 1994, 114.)

Figure 3.12. 15th-century Carrack with loose-footed square sails (from Bass 1972, 219.)

Figure 3.13. Loose-footed sails of Henry VIII's navy.
(from Bass 1972, 240.)



The new Attractiue.
Containing a Short Discourse of the *Magnes*
or Loadstone: and amongst other his vertues,
of a new discouered secret and subtill proper-
tie, concerning the Declining of the
Needle, touched therewith
vnder the plaine of
the Horizon.
Now first found out by *Robert Norman*
Hydrographer.
HEEREVNTO ARE ANNEXED CER-
taine necessary rules for the Arte of Nauiga-
tion: by the same R. N.
Newly corrected and amended by M. W. B.

Imprinted at London by E. Allde, for Hew Astley. 1592.

Figure 3.14. 16th-century English warship with loose-footed square sails
(from Bass 1972, 258.)

The diffusion of ideas and knowledge is therefore clearly recognizable in the distribution of both modern and ancient technologies, and yet the independent development of technology and its convergent evolution over time are equally observable in man's past. The Stone Age development of seagoing watercraft for example, seems to have occurred independently a number of times in quite distinct and unrelated populations. Cultural remains and debitage from Franchthi Cave in the southeast Peloponnese of Greece suggest that seafaring and purposeful water crossings occurred in the Mediterranean as early as 13,000 years ago.[93] Obsidian found at multiple levels within the cave has been traced to a source on Melos, an island in the Cyclades not connected to the mainland at any time during the last glacial period.[94] And the vertebrate of large tuna, likely to have been caught only in the nutrient rich waters of the north and northwestern parts of the Aegean, have also been recovered from the site.[95] These finds indicate that the inhabitants of the cave, or some group of individuals engaged in trade with the inhabitants, possessed watercraft and were capable of undertaking extended seaborne voyages.[96] On Cyprus, burnt seashells capping a midden-like deposit of disarticulated pygmy hippo and elephant bones, chipped-stone tools, shell beads, and formal hearths at Akrotiri *Aetokremnos* suggest that hunter-gatherers inhabited the island as early as 8500 B.C.[97] Like Melos, Cyprus was not connected to either the

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[93] Cherry 1990, 193; Van Andel and Runnels 1988, 235-36.

[94] Cherry 1981, 45; Van Andel and Runnels 1988, 236-38.

[95] Ibid.

[96] Ibid.

[97] Simmons and Reese 1993, 42.

Levant or Turkey during the last 100,000 years, and hence it is certain that these early groups also possessed seagoing watercraft.[98] The occupation and exploitation of other islands such as Mallorca (ca. 7170 B.C.), Skyros (ca. 5500 B.C.), and the Sporades (ca. 4740 B.C.), all of which similarly lacked land-bridges to the adjacent continental mass, provide additional evidence for the seafaring capabilities of the early Mediterranean peoples.[99] And while watercraft were necessarily employed in the initial settlement of these islands, it is the colonization of Crete in the late 8th to early 7th millennium B.C. and the introduction of a full farming economy there that provides the best indication of the extent to which maritime technology had been developed in the region.[100]

During the last glacial maximum and the onset of the Holocene, the paleogeogaphy and voyaging topography of the Aegean and eastern Mediterranean was much changed from that of today, with many of the islands, such as the northern Cyclades forming a single large body, and distances between other islands being greatly reduced as a result of the lower sea-levels caused by glaciation. The settlement of Crete, however, still required a formidable open-water crossing of at least 90 km.[101] Moreover, unlike Akrotiri on Cyprus, there is no indication that the earliest inhabitants of Crete exploited the indigenous or native wildlife. Rather, the faunal remains found at Knossos and other early sites in Crete, comprised almost entirely of ovicaprines, pig, and cattle,

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98 Simmons and Reese 1993, 41.

99 Cherry 1990, 148-93; 1981, 43-45.

100 Broodbank and Strasser 1991, 234; Cherry 1990, 193.

101 Broodbank and Strasser 1991, 235.

indicate that they must have brought domesticates with them.[102] There is also evidence that they introduced exotic cereal, specifically the bread wheat *Trilicum aestivum*, which combined with the animals noted represents a floral and faunal package characteristic of the Anatolian-Balkan Neolithic complement.[103]

Conservative estimates for the minimum number of individuals necessary for a colony to survive through its first season and to subsequently flourish, as at Knossos, suggest that at least 40 men and women may have made the founding trip to Crete.[104] Accompanying such a group would have been a minimum of 250 kg of grain per person and 10-20 of each the ovicaprines, the pigs, and the cattle, for a combined total weight of somewhere between 15,450-18,900 kg of additional cargo necessary for the success of the venture.[105] Given the estimated magnitude of this transport, it is likely that the initial colonizing voyage to Crete was accomplished by a flotilla of perhaps as many as 10 to 15 vessels, each bearing a portion of the total load.[106] Consequently, considering the varied

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[102] Broodbank and Strasser 1991, 236.

[103] Broodbank and Strasser 1991, 236-37.

[104] Broodbank and Strasser 1991, 240.

[105] Ibid.

[106] Broodbank and Strasser 1991, 241. Broodbank and Strasser suggest that the voyage could only have occurred during a small window of opportunity defined by the months between crop cycles, specifically the summer harvest and the autumn sowing. They further note that considering the hydration requirements of the livestock, the voyage would have been characterized by numerous legs between intervening islands rather than by a direct open water passage. As such short island to island crossings could have absorbed as much as two days, the duration of the overall journey of 105 km could have been quite lengthy. Therefore, given the small window of opportunity for the voyage and its duration, they propose it is implausible that multiple voyages, or the ferrying to-and-fro of necessary cargo could have occurred within a single

and perishable nature of the cargo, it is certain that the watercraft possessed by the intrepid pioneers of the region must have been not only watertight, but also structurally robust and generally sea-worthy.

The advent of seafaring and the evolution of suitable watercraft in the Mediterranean, however, was long predated by similar developments in the Pacific. Approximately 40,000 to 60,000 years ago, Australoid populations, evolutionary descendants of the earliest hominids in Southeast Asia, appeared in Sundaland (fig. 3.15).[107] It was these primitive peoples that expanded onto the ice age continent of Sahul

Figure 3.15. Map of Pleistocene S.E. Asia and Australia
(from Kirch 2000, 66.)

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season. Hence, they suggest a single voyage of multiple vessels.

[107] Bellwood 1979, 38-43. The Mojokerto and Sangiran sites in Java have produced skulls, jaw fragments and stone tools all associated with *Homo erectus*, and it is from this regional lineage that modern man is believed to have evolved in Southeast Asia. Although the development of *H. sapiens* from *H. erectus* probably occurred some 200,000 to 300,000 years ago (possibly through the intermediary stage of *Homo erectus soloensis* or *Homo sapiens soloensis*), conservative interpretation of the fossil record indicates that Austroloid populations first emerged in Sundaland 40,000 to 60,000 years ago.

and first colonized Australia, Tasmania, Papua New Guinea and other islands of modern Melanesia.[108] This colonization of Sahulland by Australoid ancestors required the crossing of the Wallacean divide, a water barrier that endured throughout the Pleistocene. Regardless of whether the colonists entered Sahul from the North through Sulawesi into what is now Irian Jaya, or from the South through Java, Sumbawa, Flores, and Timor onto the Arafura shelf, they would have had to make repeated water crossings varying in length from 10 to100 km.[109] Furthermore, the islands of New Britain and New Ireland were never connected to Sahul by dry land during the Pleistocene, and yet they were colonized by as early as 35,000 years before present (B.P.)[110] Only New Britain is visible from New Guinea, and so it is has been implied that the two islands were settled sequentially.[111] However, while these islands are visible from each other, Buka Island in the Solomons is not visible from either, yet it too was inhabited by no later than 29,000

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[108] Gray and Jordan 2000, 1052; Kirch 2000, 67-68. The presence of waisted axes in Huon Peninsula, dating to at least 40,000 B.P., and the existence of 154 other Pleistocene sites, spanning the entire geographical range of Sahul, 22 of which date to earlier than 30,000 B.P., suggest that the subsequent colonization of this region was early, rapid and extensive, with populations reaching the Bismarck Archipelago by 33,000 BP and the Solomon Islands by 29,000 B.P.

[109] Kirch 2000, 68. The number of water crossings necessary to reach Sahulland implies that they were not chance events and that the colonization of Sahul was not accomplished by accident. The early settlers therefore must have possessed some degree of voyaging ability, and probably also possessed some manner of simple watercraft, although there has been no such artifact preserved in the warm, moist environment of the region. Firm evidence from the *Lapita* homeland project supports the notion of purposeful voyaging.

[110] Ibid.

[111] Ibid.

B.P.[112] The travel required for the colonization of Buka island was much more demanding, and its accomplishment reflects an increasing level of skill and technology which seems to have reached its zenith with the settlement of Manus in the Admiralty Islands by 13,000 B.P.[113] The occupation of this site required an open ocean voyage of 200-230 km, of which 60-90 km would have been out of sight of any land.[114] A sophisticated journey of significant length and precision, this last event, coupled with earlier voyaging and the crossing of the Wallacean Divide, strongly imply that the Australoid peoples possessed some form of built watercraft technology designed for open-ocean use over much greater distances than those found in the Mediterranean.

Given the temporal and geographical distance between the Australoid peoples of the Pacific and the Stone Age seafarers of the Mediterranean, it is improbable that either population had contact, whether direct or indirect, with the other. Therefore, the advent of maritime activity and the development of purpose-built seagoing watercraft in the two regions must have been quite independent of each other.

The development of the sail in these two regions provides another example of man's universally creative nature and the convergent evolution of technology. Roughly contemporary with the appearance of the square sail in Egyptian iconography, about 5,500 years ago, Austronesian speaking Mongoloid groups followed the Australoids with their own expansion into the Pacific, first crossing the Formosan Strait from South China

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[112] Ibid. As evidenced by the presence of Kilu rockshelter.

[113] Ibid.

[114] Spriggs 1997, 29.

to Taiwan.[115] Descendants of these founding groups then ventured southward through the Philippines, and both west and east of Wallacea, colonizing island Southeast Asia, parts of Melanesia, Micronesia, and eventually Polynesia, reaching Tonga as early as 3,200 years ago, Hawaii 1,500 years ago, and New Zealand 1,000 years ago.[116] Like the later colonization events of the Australoids, the settlement of the greater Pacific, particularly remote Oceania, necessitated lengthy voyages devoid of reprieve or interruption, and intervisibility, the most remarkable of which was perhaps that from Pitcairn Island to Easter Island, a distance of more than 2,500 km. Certainly this was not a feat that would have been feasible by rowing or paddling alone, or by drifting. As noted in the settlement of Crete, the burden borne by the watercraft involved in this voyage must have been quite substantial in order to have secured a successful colony on Easter Island. However, the prodigious amount of additional resources necessary to sustain rowers over such great distances would have greatly exaggerated this already large load and precluded the use of manpower as the sole or primary means of propulsion. These voyages therefore suggest that the development and exploitation of sail technology that occurred in the Bronze Age Mediterranean was mirrored in the ancient Pacific. Consequently, unlike the loose-footed square sail which seems likely to

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[115] Diamond 2001, 167; Gray and Jordan 2000, 1052. The "Express Train Model" is based on the chronological appearance of not only farming technology but also domesticated animals, Neolithic tools and pottery. Although archaeological evidence and both genetic and linguistic analyses seem to support the 'Express Train Model,' mounting genetic and morphometric data from other sources suggests a rather different picture. See Gray and Jordan 2000, 1052; Oppenheimer and Richards 2001, 166; Richards et al. 1998, 1235-36; Terrel and Welsh 1997, 548-72.

[116] Bellwood 1997, 77-78; Diamond 2000, 709; Gray and Jordan 2000, 1052; Hagelberg and Clegg 1993, 163; Kirch 2000, 100, 308.

have been developed only once, the sail in general, as a broad concept, emerged in multiple locations and at multiple times independently.

It seems, therefore, that any given technology, past or present, may be either the result of independent development or the diffusion of ideas and knowledge from one culture to another. Determining which pathway provides the most appropriate explanation for a technology, however, can often be quite difficult, particularly when historical records are limited or lacking. Fortunately, some resolution of the problem may be gained by considering the nature of innovation.

Innovation is essentially a conceptual response to stimuli, typically need or natural phenomena, and as such, its degree of abstraction, the conceptual distance between the response and the stimulus that provided the impetus for its development, is inversely proportional to its possibility of being recreated or reconceived at some later point. For example, dugouts and canoes – simple, or conceptually proximal, developments likely based on the observation of buoyant bodies such as floating logs, or other large pieces of timber – have a near global distribution, having emerged countless times independently in the most isolated and unrelated regions of the world. The nuclear-powered submarine, on the other hand, represents a conceptually distant technology that probably evolved only once. Yet fundamentally, it is also an innovative response to the very same observation that gave rise to the dugout, albeit far removed by a series of sequentially complex stages. Similarly, primitive sails, such as the boom-footed square sail, were undoubtedly developed numerous times independently as a universal response to the need for long-distance travel and to the observation of the natural resistance of planar objects to air flow. Conversely, the brailed sail, with its multiple lines for manipulating symmetry, represents a conceptually distant innovation of singular origin that is a response to the same observation.

Both the submarine and the brailed sail illustrate the direct correlation between an innovation's complexity and its degree of abstraction. The greater the complexity of a development, the fewer times it should be expected to evolve independently, an assertion also borne out by the development of the transistor. Furthermore, these innovations also illustrate the fact that, typically, more advanced developments derive from simpler ones, an observation that underscores the importance of intermediate and ancestral forms. For if a technology is highly complex, not only is it unlikely to have evolved more than once, but its development must have proceeded through a series of simpler stages as its comprising concepts were successively incorporated, thereby giving rise to ancestral forms. If the technology developed independently, then these ancestral stages must have occurred within the same region as the climax technology, providing the innovating culture did not experience mass migration. However, if such ancestors are present not in the same region as the final form but rather elsewhere, then the diffusion of ideas and knowledge may be implied in the development of the complex technology.

In order for the diffusion of ideas and the influence of one technology by another to actually occur across regional boundaries, some degree of contact, whether direct or indirect, must exist between the regions involved. During the 20th century, the development of the transistor and the electronic components it inspired occurred among distinct regions of the world for which there was, and continues to be, demonstrable contact. Likewise, the development of the brailed sail and its technological descendants in the Mediterranean also occurred among cultures and nations for which there has been significant contact for more than 3,000 years. For the extra-regional influence of the batten lug's development, numerous artifacts and textual sources also suggest that certain, if not extensive, contact may have existed between the regions possibly involved.

4. REGIONAL AND CULTURAL CONTACT

The possibility of a Gallic or Indian role in the evolution of the batten lug sail is critically dependent on the existence of relations between several physically and culturally distant populations. Yet, there is a growing body of textual and archaeological evidence that indicates significant contact between the Roman Empire, India, and China may have existed prior to the appearance of the batten lug at Angkor Thom or even Borobodur. Given this evidence, it is possible that ideas and knowledge may have diffused between these regions and that technological influence may have therefore occurred.

One of the most important sources of information regarding early contact between the Roman Empire and India is the *Periplus Maris Erythraei*. A merchant's handbook for the Roman Red Sea trade, the *Periplus* was authored approximately in the middle of the 1st century A.D. by a Greek speaking resident of Egypt.[117] The text therefore predates the Ajanta fresco by approximately 600 years. It reflects the state of Roman trade in the East during the period following Augustus' conquest of the eastern Mediterranean in 31 B.C., a period that would end with the fall of Palmyra in A.D. 272.[118] At the time of the writing of the *Periplus,* the eastern provinces of the Roman Empire included Syria, Judaea, and Egypt.[119] Importantly, the *Periplus* not only mentions Arabian and African

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[117] Young 2001, 5, 6.

[118] Young 2001, 2, 18.

[119] Young 2001, 2. The eastern Roman Empire would also come to include Arabia in A.D. 106 and Mesopotamia around A.D. 200 (C. Konrad, personal communication, May 09, 2006).

ports of call, but also discusses in detail the routes, ports of call, and items traded in India:

41. Beyond the gulf of Baraca is that of Barygaza and the coast of the country of Ariaca, which is the beginning of the Kingdom of Nambanus and all of India…It is a fertile country, yielding wheat and rice and sesame oil and clarified butter, cotton and the Indian cloths made therefrom, of the coarser sorts…

45. Now the whole country of India has very many rivers, and very great ebb and flow of the tides; increasing at the new moon, and the full moon for three days, and falling off during the intervening days of the moon. But about Barygaza it is much greater, so that the bottom is suddenly seen, and now parts of the dry land are sea, and now it is dry where ships were sailing just before…

46. For this reason entrance and departure of vessels is very dangerous to those who are inexperienced or who come to this market-town for the first time. For the rush of waters at the incoming tide is irresistible, and the anchors cannot hold against it; so that large ships are caught up by the force of it, turned broadside on through the speed of the current, and so driven on the shoals and wrecked; and smaller boats are overturned…

49. There are imported into this market-town, wine, Italian preferred, also Laodicean and Arabian; copper, tin, and lead; coral and topaz; thin clothing and inferior sorts of all kinds; bright-colored girdles a cubit wide; storax, sweet clover, flint glass, realgar, antimony, gold and silver coin, on which there is a profit when exchanged for the money of that country…There are exported from these places spikenard, costus, bdellium, ivory, agate and carnelian, lyceum, cotton cloth of all kinds, silk cloth, mallow cloth, yarn, long pepper and such other things…

52. The market-towns of this region are, in order, after Barygaza: Suppara, and the city of Calliena…

53. Beyond Calliena there are other market-towns of this region; Semylla, Mandagora, Palaepatmae, Melizigara, Byzantium, Togarum and Aurannoboas…[120]

The account continues in much greater detail beyond that cited here. Of its 66 chapters, fully 25 of them are devoted to India and the trade conducted there, including mention of locations as far south as Colchi and the Pandian Kingdom where there existed pearl fisheries, and as far east as Tamluk and the Ganges where there existed great gold mines and where muslins of the finest sorts could be procured.[121] This ancient text clearly

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[120] Schoff 1974, 39-49.

[121] Schoff 1974, 46-48.

indicates that the author, and probably a substantial sector of the mercantile community in Egypt, had an intimate knowledge of India, its coast, commodities, and its peoples. And as Egypt, at the time, was a province of Rome, it seems that some fraction of the Roman Empire also possessed this same knowledge. Furthermore, while the *Periplus Maris Erythraei* was written in Greek, chapter 49 includes a list of Roman items imported by the various Indian communities. This suggests that, regardless of the ethnic lineage of the author and the merchants that mediated this particular trade, commercial and technological exchange occurred between the Roman Empire and India, even if it was only indirect.

Recent excavations from several market-towns along the Egyptian Red Sea coast, such as ‘Abu Sha’ar, Quseir al-Qadim, and Berenike (fig. 4.1), have begun to yield archaeological evidence that independently corroborates the existence of contact between the Roman Empire and India.[122] Mentioned not only in the *Periplus*, but also in Strabo’s *Geography* and Pliny’s *Natural History*, Berenike figured as a major emporium and conduit for the eastern trade of the Romans and Ptolemies from the 3rd century B.C. to the 6th century A.D.[123] Its location in the southern reaches of Roman Egypt, and its connection with the Nile via trans-desert roads, secured Berenike’s importance to the trade coming directly from India and from peninsular Arabia (fig. 4.1).[124]

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[122] Young 2001, 11, 12.

[123] Schoff 1974, 39,40; Sidebotham and Wendrich 1995, 1, 5; 1997, 445.

[124] Sidebotham and Wendrich 1995, 5.

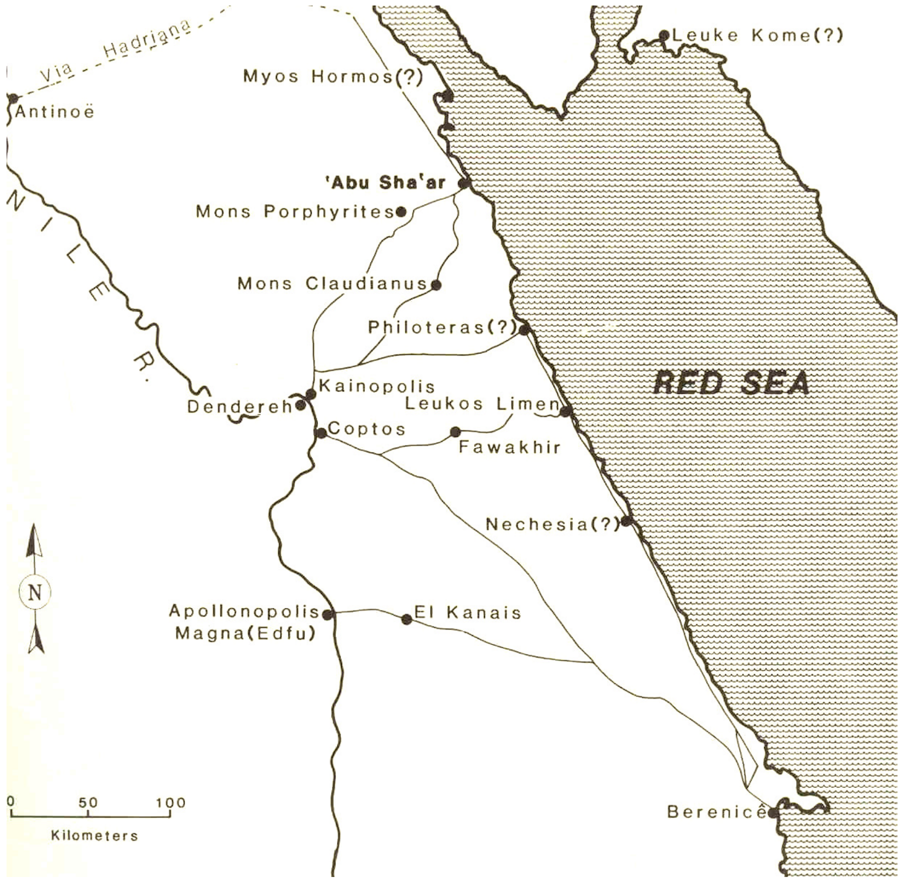

Figure 4.1. Map of Roman Egypt (from Sidebotham1991, 13.)

Beginning in 1994, Berenike was excavated systematically for five consecutive seasons, and the finds recovered from this commercial center have undoubtedly shed additional light on the Roman-Indian trade.[125] While the site has produced large amounts of predominantly local and regional items in the upper layers (5th and 6th centuries A.D.) including Late Roman amphorae, Egyptian and Nubian ceramics, Greek papyri, copper fibulae, and coins issued from mints in Alexandria, Antioch, Aquileia, Constantinople, and Cyzicus, it has also produced a small number of items that can be interpreted as

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[125] Sidebotham and Wendrich 1995, 1996, 1997, 2000.

being of Indian origin including a coconut, an Indian resist-dye textile (fig. 4.2), and a number of beads.[126]

Figure 4.2. Indian resist-dye textile (from Sidebotham and Wendrich, 1995, 66.)

The earlier layers of Berenike (4^{th} century A.D. and earlier), however, have produced numerous items of Indian origin. Sherds from more than 33 distinct coarse ware vessels of Indian form have been recovered from the site, all of which are unlikely to have been of local manufacture, as none of the fabrics utilized are Egyptian (figs. 4.3, 4.4).[127] And although no precise source can be identified for these vessels, as they are of such basic functional design that they may have occurred independently at unrelated sites within South Asia, their shapes most closely resemble coarse wares from Arikamedu – a market-town on the southeast coast of India.[128]

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[126] Sidebotham and Wendrich 1995, 30, 34, 35, 48, 51-54, 59, 63, 66, 105.

[127] Sidebotham and Wendrich 1997, 170-75, 180-81.

[128] Sidebotham and Wendrich 1997, 170, 180.

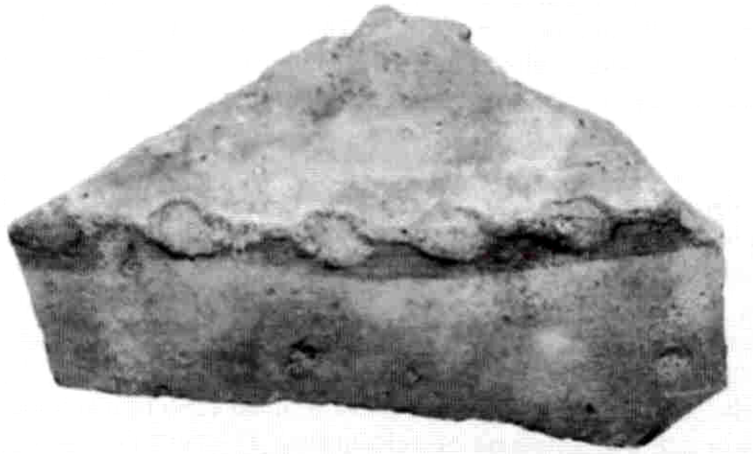

Figure 4.3. Sherd of Indian coarse-ware from Berenike. The fragment is decorated with a thumbed and applied strip (from Sidebotham and Wendrich 2000, 161.)

Figure 4.4. Joining coarse-ware fragments from Berenike. Fragments are decorated with a slashed and applied strip (from Sidebotham and Wendrich 2000, 161.)

In addition to the coarse ware, more than 16 sherds of fine ware have also been recovered from Berenike (fig. 4.5).[129] Significantly, these sherds, on the basis of their rouletted forms and distinct fabric, can be positively identified as being associated again

[129] Sidebotham and Wendrich 1997, 160-67.

with Arikamedu and the east coast of India.[130] This collection of fine ware is perhaps the most telling find from Berenike, as the small number of sherds suggests that this pottery may have been personal ware used by merchants rather than goods intended for trade. As such, these fragments hint at the possibility of an Indian presence in Berenike and consequently the direct contact between the Roman market and traders from the South Asian subcontinent.[131]

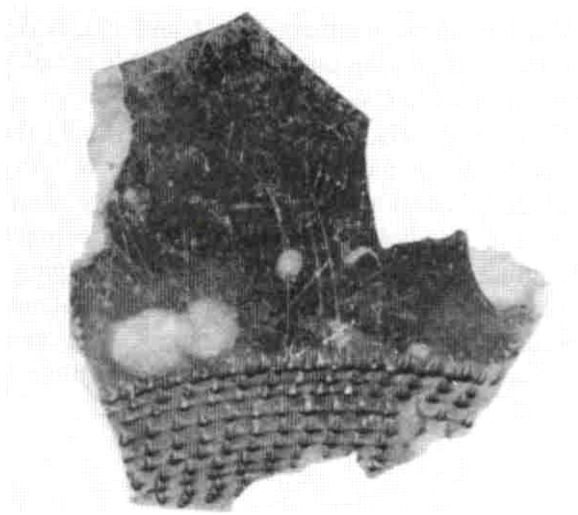

Figure 4.5. Indian fine-ware with rouletted decoration
(from Sidebotham and Wendrich 2000, 155.)

While the pottery discovered at Berenike provides critical evidence for Roman-Indian contact, other Indian commodities have also surfaced during the excavation. Large quantities of Indian teak wood of the genus *Pterocarpus* and a pole of the sacred bamboo *Bambusa bambos* were also found at the site, as were precious metals and semi-

[130] Sidebotham and Wendrich 1997, 161-65, 168-70; 2000, 166,167.

[131] Sidebotham and Wendrich 1997, 168, 169; 2000, 166, 167.

precious stones from India including agate, in the form of onyx, and blue sapphire.[132] A small number of onyx, quartz, and garnet beads are also of probable Indian origin, as well as 32 cornelian/sard beads.[133] These items, in addition to black peppercorns, coconuts, sail cloth, blue resist-dyed cotton, and pottery – all from India, imply some degree of trade, and therefore contact – whether direct or indirect, between South Asia and the eastern Roman Empire.[134]

Although Berenike has provided a windfall of information regarding these relations, there are numerous other locations that have also provided evidence for the economic and cultural contact between India and the West. Of these, the most important are located in India, where fragments of Mediterranean amphorae, caches of Roman coins and bronze statues have been discovered.[135] In total, more than 30 sites within India have produced Roman amphora fragments including at least one handle, found at Mathura, that bears the stamp *M. Livi Caustri Surus*.[136] This stamp, dated by its parallel appearance in the Grand Ribaud D wreck off the French Mediterranean coast, provides evidence for a Roman presence in India no later than the 1st century B.C.[137] Extensive excavations at Arikamedu by Mortimer Wheeler and others have likewise resulted in the discovery of

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132 Sidebotham and Wendrich 2000, 111, 112, 114, 328-32.

133 Sidebotham and Wendrich 2000, 221, 222.

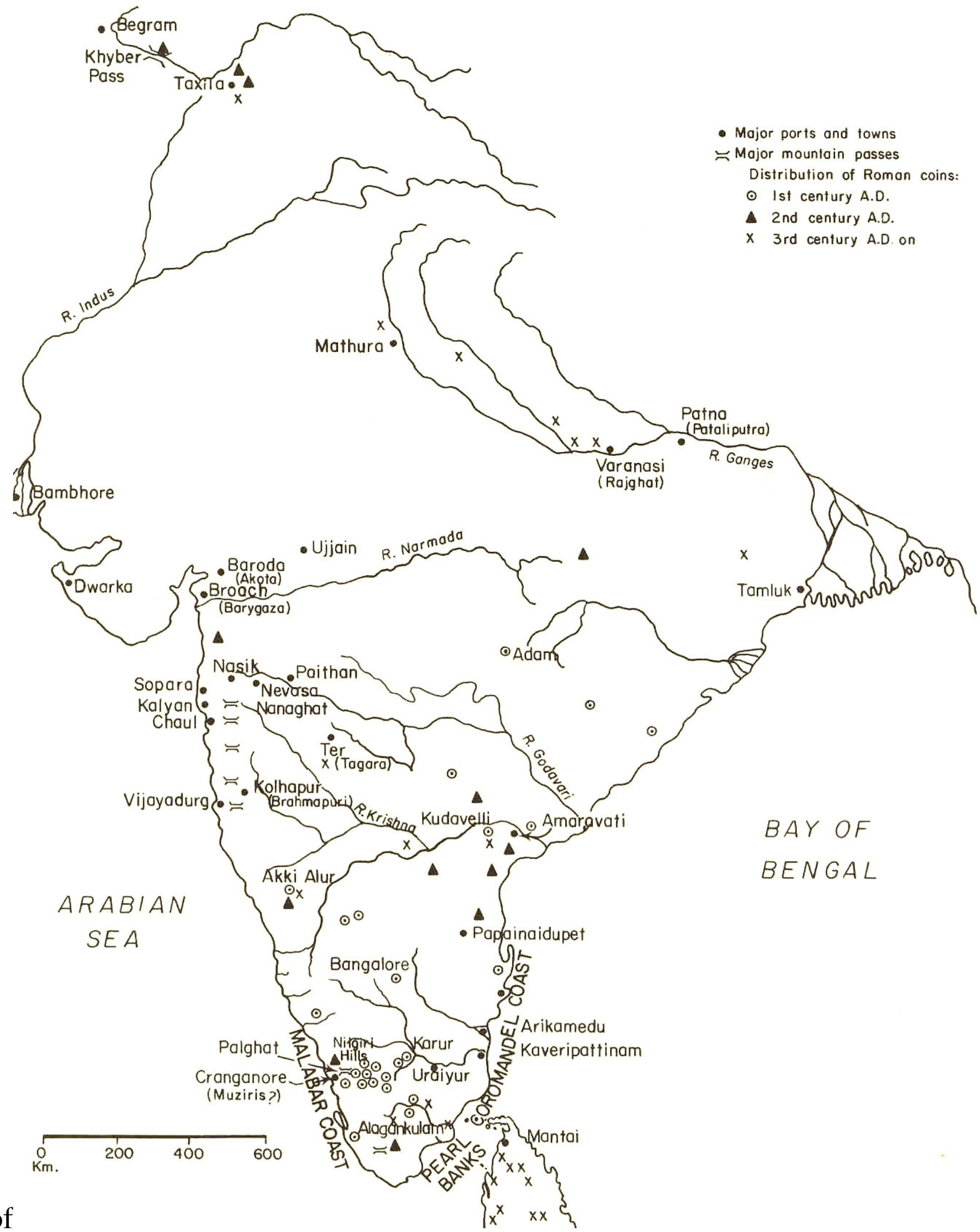
134 Sidebotham and Wendrich 2000, 271-73, 418, 419.

135 Begley 1991, 4-6; Deo 1991, 39, 40.

136 Tchernia 1997, 238.

137 Ibid.

other Roman pottery, primarily *terra sigillata*, bearing similar stamped signatures datable to the 1st century A.D.[138] Besides the large quantities of pottery discovered, Roman coin



of

Figure 4.6. Roman coin finds in ancient India (from Begley 1991, 2.)

138 Raman 1991, 125.

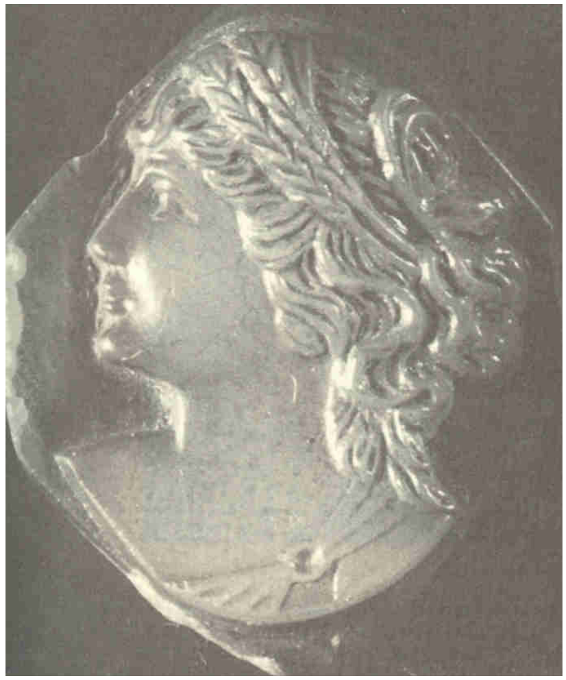


Figure 4.7. Roman cameo found in India (from Deo 1991, 43.)

Figure 4.8. Alabaster bowl with Cupid in relief, from India
(from Deo 1991, 43.)

hoards have also been found throughout India (fig. 4.6). The archaeological distribution of coins from the 1st, 2nd, and 3rd centuries A.D. provides further proof for what increasingly seems to have been strong commercial and economic contact between the Roman Empire and India.[139] In addition to these finds, several sites in western India have produced a large number of yet other significant artifacts, including *aurei* and silver coins of Lucius Verus, Septimius Severus, Antoninus Pius, Augustus, and Tiberius (fig. 4.6), bronze mirrors, colored glass items (including beads and bottles), a Roman cameo (fig. 4.7), an alabaster bowl with Cupid carved in relief (fig. 4.8), and a bonze statuette of

Figure 4.9. Bronze statuette of Poseidon (from De Puma 1991, 83.)

[139] Raman 1991, 125.

Poseidon (fig. 4.9).[140] Considering these artifacts and finds, and the content of the *Periplus Maris Eryhtraei,* it seems that substantial contact may indeed have existed between Rome and India during the Imperial period.

Furthermore, it is possible that Gaul, as an extension of the Roman Empire, may also have had contact with India, if only indirectly. The *terra sigillata* found in India is also frequently found in repositories throughout the Rhine and Danube valleys and throughout France.[141] And some of the sherds found at Arikamedu, namely those bearing the stamp *ITTA* (Lyon), are of specifically southern Gallic origin, as are many of the Augustan and Tiberian coins favored by certain Indian populations (those minted in Lugdunum, or Lyons, in Gaul).[142]

In addition to the evidence for contact between the Roman Empire and India, several ancient Hindu and Chinese texts also attest to the early and significant contact between these regions and China. The *Ramayana,* a 3rd-century B.C. classical Sanskrit epic, for example refers to China as "the land where grows the worm which yields the threads of silken clothes."[143] While this passage does not at first seem to necessarily suggest contact, it should be noted that the mention of silk cloth implies knowledge of that textile, a knowledge that could only have been obtained through trade or observation, both of which imply a knowledge of China or Chinese merchants. Additionally, this section of the *Ramayana*, known as the *Kishkindha Kandam*, relates directions given for

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140 De Puma 1991, 82-104; Deo 1991, 39-43.

141 Comfort 1991, 134.

142 Slane 1991, 207.

143 Mookerji 1962, 38, 39.

the recovery of a hostage that has been most likely hidden in the land of the *Koshakarsa*, or China.[144] The knowledge of eastern Asia here implied provides further evidence for early contact. Another ancient Indian text, the *Milinda Panha*, relates that during the 2nd century A.D., presents from the Kshatrapa dynasty were being conveyed by sea to the Chinese courts of Hoti (A.D. 89-105) and Hiwanti (A.D. 158-159), indicating a type of tribute trade, a trade also undertaken by many other Indian sovereigns during this period.[145] And in the 5th century A.D., China is again mentioned as the land of silk fabrics in the *Sakuntala*, the most noted work of the ancient playwright Kalidasa.[146]

Chinese accounts provide even more evidence for significant contact with India prior to the emergence of the batten lug sail in regional iconography. Unlike the Indian texts, however, which are mostly narrative, the Chinese accounts come primarily from imperial documents. It is in the collection of official histories that India appears more frequently than any other foreign place, including Sumatra and even the closer *Zhenla*, or modern Cambodia and Thailand.[147] India appears in eight separate histories including the *Houhan Shu* (the *History of the Eastern Han Dynasty* – A.D. 25-220), the *Song Shu* (the *History of the Song Period*), the *Liang Shu* (the *History of the Liang Period*), the *Tang Shu* (the *History of the Tang Dynasty* – A.D. 619-907), the *Xin Tangshu* (the *New History of the Tang Dynasty* – A.D. 619-907), each of which predate both the Bayon at Angkor

[144] Ibid.

[145] Mookerji 1962, 114, 115.

[146] Mookerji 1962, 45.

[147] Deng 1997, 54.

Thom and the reliefs from the temple complex at Borobodur.[148] In A.D. 82, Ban (ch. "*Dili Zhi*, *Juan Ershiba*" in the *Han Shu,* or *History of the Han Dynasty*) includes India in a list of places, including Sri Lanka and east Africa, subject to the diplomatic undertakings of the Chinese Empire.[149] This same account also relates the margin of profit enjoyed by the imperial court in its trade with India.[150]

While it is obvious from these ancient texts that there were indeed strong economic and probably cultural relations between India and China at least as early as the 1st century A.D., what is perhaps even more surprising is the evidence, albeit limited, for direct contact between China and the Roman Empire. In the "*Daqin Zhuan*" chapter of the *Han Shu* (A.D. 82), the returns on trade with the Roman Empire (Daqin) are noted as having been as much as tenfold.[151] The Roman Empire is again mentioned, in A.D. 97, as a region of important diplomatic activity.[152] Almost 200 years later, in approximately A.D. 285, Chang Hua relates that "the ambassador of the Han, Chang Chhien, won through across the Western Seas to reach Ta-Chhin (also Daqin, the Roman Empire).[153] Furthermore, Khang Thai, in his book *Wu Shih Wai Kuo Chuan*, or *The Record of Foreign Countries in the Time of the State of Wu*, from A.D. 260, notes that in the seas off one of the southern countries were great junks with no less than seven sails traveling

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[148] Deng 1997, xxiii, 54.

[149] Deng 1997, 12.

[150] Deng 1997, 110.

[151] Deng 1997, 110.

[152] Deng 1997, 12.

[153] Needham 1971, 550.

to and from Ta-Chhin.[154] Whether or not this passage refers to Chinese vessels is unclear, but it is certain that there must have been a Chinese presence in the region in order to explain the initial observation. Given the contact implied by these texts, the appearance at Berenike of a ceramic vessel bearing Chinese inscriptions is less puzzling as initially held, and provides additional support for the possibility of direct contact between China and the Roman Empire.

Consequently, the archaeological record and these textual sources, together, indicate that extensive and enduring contact may have existed between the Roman Empire – and possibly Gaul, India, and China during the Imperial and early Medieval Periods. With this contact, it is possible that the Chinese shipwright of antiquity may have had the opportunity to have directly observed the tall lugs of India and the batten-bearing sails of Gaul, or to have been exposed to verbal, diagrammatical, or textual accounts of them. Thus it is possible that these rigs may have influenced the development of the batten lug sail. And in addition to the artifacts and texts already discussed, there are a number of finds that are of particular significance to the argument for the diffusion of ideas between populations and the subsequent influence of one region's technology by another's. The discovery of two sherds of terra sigillata possibly bearing Indian graffiti is such an example (figs. 4.10, 4.11).[155] Although this type of ware is known to have been manufactured in the heart of the Roman Empire, as seven surviving stamps indicate sources in Lyon (fig. 4.12), Pozzuoli (fig. 4.13), Pisa (fig. 4.14), and central Italy, the presence of Indian graffiti on two fragments suggests that

[154] Needham 1971, 602.

[155] Comfort 1991, 139, 141, 149.

some of these vessels perhaps belonged to locals, or were at least in use by them.[156] In either case, the adoption of Roman goods by Indian populations would seem to be implied.

Figure 4.10. *Terra sigillata* sherd with possible Indian graffito (from Comfort 1991, 142.)

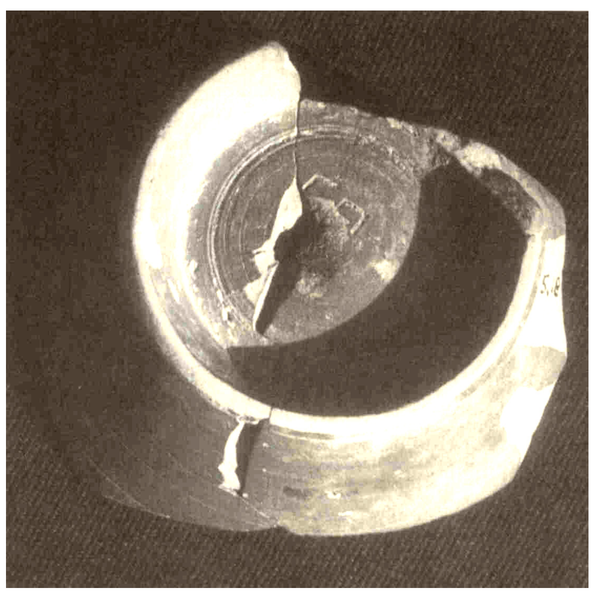

Figure 4.11. Roman pottery fragment with graffito, from India (from Comfort 1991, 140.)

156 Begley 1991, 4.

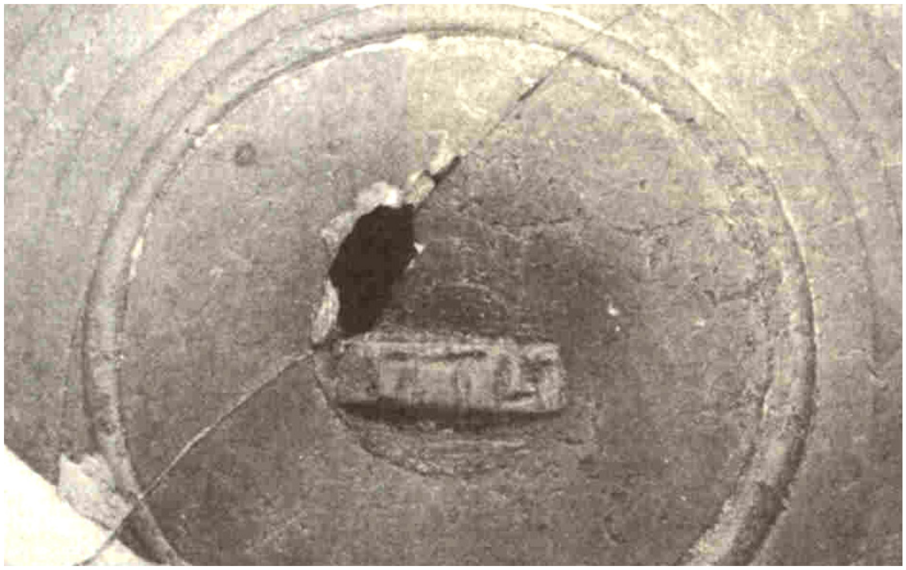

Figure 4.12. Sherd bearing a Lyon source stamp (from Comfort 1991, 140.)

Figure 4.13. *Sigillata* fragment bearing a Pozzuoli source stamp
(from Comfort 1991, 142.)

Figure 4.14. *Sigillata* sherd bearing a Pisa source stamp
(from Comfort 1991, 139.)

This adoptive practice and the cross-cultural influence it reflects is perhaps better illustrated by the local manufacture of rouletted ware (figs. 4.15, 4.16), a ware that has been unequivocally associated with the eastern coast of India, from Coromandel to the Ganges delta.[157] There is no precedent for this unique style of pottery in Indian ceramics however, and there has been no discovery of a developmental stage for it in South Asia.[158] On the other hand, its diagnostic rouletted bands and concentric lines have numerous parallels in the classical world, parallels dating from the 4th century B.C. to Imperial times.[159] It seems that Indian rouletted ware, therefore, was initially an import, but from where it is unknown. What is important to note, however, is that this ware, and

157 Begley 1991, 176.

158 Begley 1991,176.

159 Begley 1991, 176; Hayes 1973, 426-34, 446, 451, 460-62.

the technology associated with it, seems to have been adopted and subsequently modified by local artisans.[160]

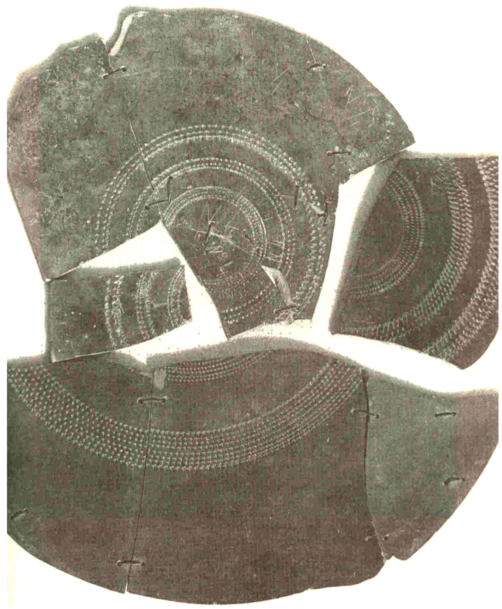

Figure 4.15. Rouletted ware from Arikamedu (from Begley 1991, 179.)

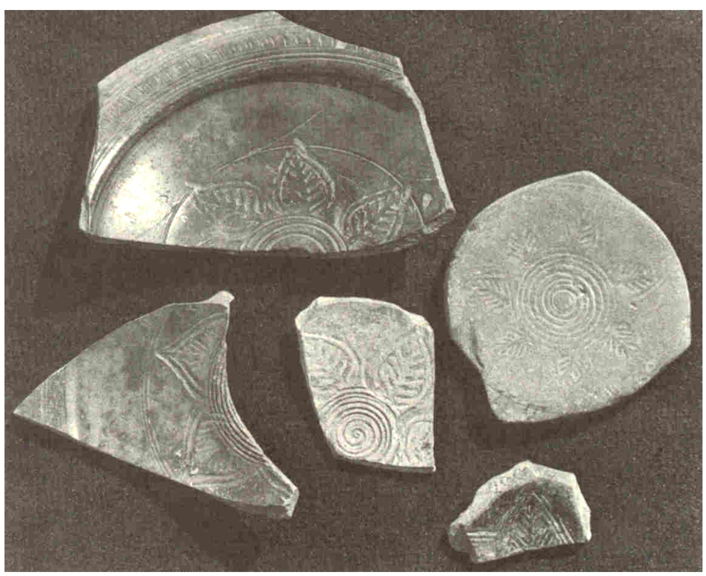

Figure 4.16. Highly decorated fragments of rouletted ware (from Begley 1991, 183.)

[160] Hayes (1973, 450, 467-68) suggests that the "Eastern *Sigillata*" products manufactured in Syria, Gaul, and Britain, emerged in a similar manner likely having been influenced by, or copied directly from, the Arrentine ware of Italy.

Another find from India that indicates native communities assimilated foreign innovation, particularly Roman, and modified it to their own purposes, is the terracotta and metal *bullae* found in numerous locations throughout the Deccan and North India (figs. 4.17, 4.18).[161] Although these *bullae* were imitations of Roman coins, primarily of

Figure 4.17. Roman-like *bullae,* from northern India and the Deccan (from Deo 1991, 41.)

[161] Deo 1991, 40.

Figure 4.18. Terracotta *bulla* found in India (from Deo 1991, 42.)

Tiberius and Augustus, they did not have the utilitarian purpose of the originals. Rather than being used as mediums of exchange and taxatiion, they were frequently used or worn as ornamental and perhaps protective pieces.[162] The *bullae*, therefore, like the rouletted ware and some of the terra sigillata, represent an extra-cultural innovation, or development, that was adopted and or modified by local populations.

Considering the substantial contact between the Roman Empire, India, and China, and given the evidence for the assimilation of foreign innovation by various populations in antiquity, it is not surprising to find other possible instances of technological imitation and influence. For example, the vessel depicted in the Ajanta fresco carries a fore-mast and sail reminiscent of the Roman artemon (fig. 2.18), and in light of the above discussion it seems indeed possible that this technology may have initially been

[162] Deo 1991, 40.

introduced by merchants from the Mediterranean.[163] Likewise, there is no precedent in China for the loose-footed square sail depicted at Wan-Fu Ssu temple (fig. 3.10), and therefore it also seems possible that this sail's development may well have been influenced by the contemporary and ubiquitous loose-footed rig of the Mediterranean. Similarly, given the lack of a regional ancestor, the possibility of diffusion, and the certainty of contact, it seems likely that the tall aspect lugs of India and the batten-bearing sails of Gaul were ancestral to, or influenced the development of the Chinese batten lug sail.

[163] Needham 1971, 455.

5. SUMMARY AND CONCLUSIONS

With its ease of reefing, subtle control, and its unmatched ability to generate thrust effectively in both severe and minimal weather, the Chinese batten lug is perhaps one of the most sophisticated sails in history. Complex and abstract, it is conceptually distant from the basic stimulus that gave rise to the general notion of wind driven propulsion. As such, the batten lug, in its development, must have progressed through a series of increasingly complex evolutionary stages before having emerged as a mature technology in China.

Medieval and post-medieval depictions of the batten lug sail indicate that, for centuries, this sail has been comprised of distinct and intricate bodies that render it both highly efficient and capable of fine control, bodies that are themselves networks of smaller components that function together in subtle harmony. Yet it is the presence of battens, a fore-and-aft lug design, and a relatively tall aspect ratio that defines this sail. These features have been conservatively retained for more than 1,000 years, and they are what distance the batten lug from all other sails. Consequently, the variable presence of these elements defines the evolutionary stages of this unique rig, such that the proximal phase is characterized primarily by tall-aspect lugs and tall-aspect batten-bearing sails.

However, there is no evidence for the regional existence of such ancestral forms in either China or indeed the greater Pacific. Thus it would seem that some portion of the batten lug's development occurred elsewhere. The discovery of two unique sails in the iconography of India and the Roman Empire seem to substantiate this notion. A ship portrayed in a fresco from the Ajanta temple complex of northwestern India carries a sail that is more similar to the batten lug than any sail found in the Pacific. Tall and somewhat narrow, the sail is also clearly of lug design. Another sail, depicted in a carving and a mosaic from Gaul in the western reaches of the Roman Empire, also seems to be quite similar to the Chinese rig of later periods. Carried by a vessel quite distinct from Roman watercraft, and likely constructed of leather, this sail not only has a relatively tall aspect ratio but also bears battens. Consequently, both of these sails possess two of the three essential features characteristic of the batten lug, and therefore potentially represent proximal stages of its evolution. Furthermore, as they both seem to predate the batten lug, it is possible that either one or both of them may have influenced its development in China.

That ideas can diffuse between populations and that the technology of one region can influence the technology of another appears certain. Following its invention in 1948, the transistor influenced and inspired the development of countless electronic components that came to be produced all over the world. Likewise, the initial development of the brailed sail was followed by its widespread adoption in the Mediterranean, and its loose-footed design continued to influence maritime innovation in the region for more than 3,000 years. Furthermore, the use of coinage, introduced to the Indian subcontinent by the Romans, was adopted and modified by several local Indian populations during the Imperial period. These examples, along with the spread of corn, the sweet potato and other plants and their associated knowledge during the prehistoric period, suggest that the diffusion of ideas and knowledge can and does indeed occur if there is demonstrable contact between the regions or populations involved.

Numerous artifacts and several textual sources indicate that extensive and significant contact may have existed between the Roman Empire, India, and China during the Imperial and early Medieval periods. The *Periplus Maris Erythraei*, Strabo's *Geography,* and Pliny's *Natural History* all suggest that the mercantile community of Rome's eastern provinces were well acquainted with India, its peoples and its trade goods. This implied contact is borne out by finds from Berenike on the Red Sea Coast. Various artifacts of Indian origin have been discovered at the site, the most important of which perhaps being personal wares not intended for trade, as they suggest the presence of Indian merchants in Roman territory. Similarly, several sites in India, including Arikamedu, have produced a number of artifacts that provide substantial evidence for the presence of Romans or Roman subjects in the subcontinent, thereby again indicating cultural contact between these regions. India is also mentioned in several official Chinese histories; and, China is likewise mentioned in a number of Indian literary works. While indirect contact between Rome and China may be implied as a result of their shared relations with India, evidence for the direct contact between the two empires also exists and is again provided by the official Chinese histories. Given these accounts, artifacts, and finds, it seems likely that sufficient contact existed between these regions during the Imperial and early Medieval periods to have allowed the diffusion of ideas to actually occur.

Considering, therefore, the complexity of the batten lug sail, the absence of ancestral forms in China and their presence in India and Gaul, the eventuality of diffusion, and the certainty of contact between these regions, it seems indeed possible that the tall lugs depicted at Ajanta and the batten-bearing sails of the Sarre/Moselle and

Rhine River valleys could have influenced the development of the batten lug sail. And given the fact that both the sails and the contact between these regions seem to predate the appearance of the batten lug as a climax technology, influence seems not only possible but probable by virtue of parsimony.

If we accept this premise, then several different schemes may be suggested for the development of the batten lug sail in China. The first possibility is that only the tall-aspect lug of India influenced the development of the batten lug. As such, the last attribute to be incorporated by the Chinese shipwright in the final evolution of the sail would have been battens, or stiffening timbers. This scheme possesses merit based on the fact that the vessel depicted in the temple fresco is almost certainly a seagoing craft. As such, it is a strong parallel for the multitude of Chinese boats and ships that are fitted with the batten lug and that navigate the coastal waters of East Asia. Hence, its earlier influence on the development of their rig may have been greatly facilitated by virtue of a common purpose or function. This influence is also consistent with the first appearance of the batten lug sail at Borobodur, where it is depicted in association with a seagoing ship. The scheme is also supported by the geographical proximity of India to China (relative to the great distance between the western reaches of the Roman Empire and China), which could be conceived of as having resulted in an increased likelihood of contact and thus technological influence.

The second possibility is that only the tall-aspect batten-bearing sails of Gaul influenced the development of the batten lug. As such, the last attribute to be incorporated by the Chinese shipwright in the final evolution of the sail would have been a fore-and-aft lug morphology. This scheme is supported by the fact that the sails depicted in Gaul possess perhaps the most abstract element of the climax form, namely battens. Consequently, the conceptual innovation required of the Chinese shipwright in the final phase of evolution would have been significantly less. And, while these rigs are essentially square sails, one of them appears to be oriented along the length of the bearing vessel and thus set possibly fore-and-aft. Therefore, the last attribute to be incorporated in the final stage may have already been approximated in the ancestral form, requiring only the canting of the yard to have become a true balanced lug.

Although the riverine nature of the rigs depicted in Gaul does not seem to favor their influence in the development of the seagoing sail that appears at Borobodur, a number of considerations substantially moderate this theoretical weakness. First, batten lugs are borne by nearly every vessel type in China, including boats confined to rivers, canals and lakes, and it is possible that the sail's use on seagoing vessels was a later adaptation by Chinese shipwrights of what had initially been developed for inland utilization. Second, the *Bugpforte* upon which the sail depicted in the Rhine River mosaic is likely borne is representative of a type of vessel that, with its relatively flat bottom and steep sides, is in form quite similar to a majority of Chinese junks, both seagoing and inland. Significantly, each of the two vessel types is well adapted for use in shallow waters characterized by frequent shoals or tidal oscillation. Consequently, the *Bugpforte* may also be considered a strong parallel for the junk of antiquity, and its influence on the development of the batten lug may again have been facilitated by a commonality of both form and function. Third, although Caesar's comments regarding Gallic watercraft correlate well with the *Bugpforte* and its sails, they were inspired by his observations of the oceangoing vessels of the Veneti, a maritime people of western Gaul.

Consequently, the batten-bearing rig of this region may not have been purely riverine, but rather both inland and seagoing, much like the later sail of China.

These considerations therefore, more than simply moderating theoretical weakness, support the possibility of a Gallic influence in the development of the batten lug. Likewise, the harsh environmental conditions that dictated the character of many Gallic watercraft and sails, as described by Caesar, seem to be quite similar in severity to the seasonally tempestuous waters of the Indian Ocean and the South China Sea - a circumstance that also supports this scheme. Furthermore, a Roman, and perhaps Gallic, presence in India significantly compensates for the unfavorably great distance between the western Roman Empire and China.

The third possibility is that the sails of India and Gaul both influenced the development of the batten lug. As such, the sole innovation required of the Chinese shipwright in the final evolution of the sail would have been to combine the essential features present in each ancestral form. The merit of this scheme is derived from that of the previous two. And it is also supported by the relatively minimal innovative requirement levied upon the Chinese shipwright, which can be conceived of as having facilitated the final evolutionary step.

One further possibility is that the batten-bearing sail of Gaul influenced the development of the lug of India. As such, the sails portrayed at Ajanta could be viewed as true batten lugs. Although there are no stiffening timbers depicted in the fresco, many other elements of rigging are also omitted. This omission may be the result of the fact that the temple complex was located well inland among pristine surroundings in order to enable the monks to meditate undisturbed. Consequently, it is likely that the portrayals were constructed from memory rather than the concurrent observation of seagoing watercraft. But, given that the temple complex was located close to main trade routes, it may also be that the images were constructed from the descriptions of visiting monks, pilgrims or passersby. In either case, some loss of detail may be expected. Therefore, if the sails depicted at Ajanta represent batten lugs, then the later appearance of these sails in China may be the result of technological adoption rather than influence. This scenario is supported by the presence of Roman, and possibly Gallic, merchants or artisans in India, and by the fact that the Ajanta temple complex was first mentioned in the writings of a Chinese pilgrim.

While each of these developmental schemes is possible, determining which actually may have occurred is not. In the absence of further evidence, no such deduction can be confidently made. However, the mention of foreign ships bearing tall fore-and-aft sails that could be readily reefed, and vessels with multiple masts sailing to and from Syria (which at the time was under Roman influence) in Chinese literature suggests that it is very likely that the batten lug of China is the developmental result of an evolution that began elsewhere. And given that the sails mentioned in these texts may implicitly possess the three essential features of the batten lug sail, it seems possible this technology may have emerged in its mature form somewhere between China and the eastern provinces of the Roman Empire by the 3rd century A.D.

In discussing the development of this sail, one last note should be added on the nature of battens. As performance enhancing elements, like the lines of the brailed sail, battens are conceptually external to the sail itself. Their use, therefore, reflects not simply the modification of some pre-existing form, as do the majority of fore-and-aft rigs, but the purposeful creation of a novel entity and the subsequent introduction and incorporation of that entity into the design of the sail itself. As such, the batten-bearing sail represents an innovation of significant complexity and abstraction. Consequently, it is unlikely to have evolved more than once. Furthermore, the obvious benefits imparted to the sail by the battens, as noted for the lug sail of China, would encourage the adoption of their use by other populations exposed to the unique technology.

However, if the material comprising a sail requires reinforcing or supporting timbers over its expanse in order for the sail to be produced or utilized, then the battens are no longer conceptually external to the sail, and their use, as a response to material limitation, can no longer be regarded as abstract. In this context, the batten-bearing sail may have evolved more than once independently. The discovery and recognition of the benefits afforded by the presence of battens, therefore, may also have been purely serendipitous.

This circumstance must be considered for the parallel appearance of battens in Gallic and Chinese sails. As noted, it is likely that the use of battens in the Gallic leather sails would have facilitated their construction and provided reinforcement and support in severe weather. Likewise, due to its mat composition, the Chinese batten lug may also have originally required regular spaced timbers for its construction. And it is probable that the strong winds prevalent during the monsoon seasons would have necessitated additional support for this same rig. Consequently, it is possible that the use of battens in Chinese sails may have emerged quite independently. However, this is far from certain, considering there is still no evidence for the regional evolution of the batten lug, or indeed any intermediate or ancestral form possessing battens in China.

Like all theories, the suggestion of an Indian or Gallic influence in the development of the Chinese batten lug sail is critically dependant on available evidence. For China and India, the archaeological horizon from which this evidence is drawn is vastly incomplete, and any theory or conclusion drawn there from must be considered with appropriate reserve. Given the reduced complexity of intermediate forms, they are relatively more likely to develop independently multiple times than is the climax technology. Consequently, it is possible that critical evidence for some ancestral or intermediate form of the batten lug sail may yet come to light in China or the greater Pacific. With such a discovery, a regional lineage or evolution could then be confidently proposed for the batten lug. Indeed, such a discovery would see the ancient Warring States text revisited, in which regional sails were described as hanging like an open fan, for the temporal distance between the two occurrences would be far less and the passage could then be conceived of as referring to a shouldered batten lug with an aggressively reduced luff, a sail similar to many found in Southern China today. The development of the batten lug sail could then be pushed back to the 3^{rd} or 4^{th} century B.C. and possibly much earlier. However, such evidence does not yet exist, and we do not know the true distributions of this sail or its ancestral forms in antiquity. Thus, even with the knowledge that a single additional discovery could necessitate the theory's abandonment, I propose that the sails of India and the western Roman Empire may indeed have influenced or inspired the development of one of China's most remarkable maritime technologies, the batten lug.

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