BRONZE AGE SHIPS AND RIGGING

1. Introduction

The subject of ship design and sailing in the Bronze Age is fraught with misconceptions. It is widely believed that both the technology and the sailors were extremely limited. The problems stem from ancient literary sources such as Hesiod as well as from interpretations of naval technology predating the discovery and analysis of the ship procession painting in the West House at Akrotiri, Thera [1].

My aim is to present a technical analysis of the ways in which Bronze Age boats were equipped to sail. Of particular importance is the rigging of the ship depicted under sail on the Thera painting [2]. Local weather conditions and geography are crucial factors in the design of ships and rigging. They will have influenced the way in which the earliest navigators traveled in the Aegean. Thus, some theories about trade and communication will also need to be re-evaluated, in particular those which do not address actual sailing conditions.

The archaeological evidence for increasingly systematic sea communication in the Mediterranean during the Bronze Age is indisputable. Furthermore, the expansion and sharing of technological information between coastal sites is well documented for the LBA [3].

I have argued elsewhere that professional sailing, and by extension trading by sea was not a haphazard activity limited by seasons, weather conditions or time of day [4]. The Aegean islands did not have autonomous economies although they may have come close to it in the

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1 L. MORGAN, *The Miniature Wall Paintings of Thera: a Study in Aegean Culture and Iconography* (1988), 121-142 (LC I).

2 H.S. GEORGIOU, *A Sea Approach to Trade in the Aegean Bronze Age*, in C. ZERNER (ed.), *Pottery as Evidence for Trade in the Aegean Bronze Age: 1939-1989* (A Conference sponsored by the American School of Classical Studies and the British School of Archaeology at Athens, December 2-3, 1989 [forthcoming]). More recent studies have been devoted to the carpentry of hulls, VINSON, "Ships in the Ancient Mediterranean", *Biblical Archaeologist* 53,1 (1990), 13-18. 1990:13-18.

3 *Minoan Coarse Wares and Minoan Technology*, in O. KRZYSZKOWSKA & L. NIXON (eds), *Minoan Society* (1983), 75-92; P. WARREN, "The place of Crete in the Thalassocracy of Minos", in R. HÄGG & N. MARINATOS (eds), *The Minoan Thalassocracy. Myth and Reality. Proceedings of the Third International Symposium at the Swedish Institute in Athens, 31 May-5 June, 1982* (1984), 39-44; H.S. GEORGIOU, *Ayia Irini: Specialized Domestic and Industrial Pottery. Keos* VI (1986), 38, 52-53; T.R. SMITH, *Mycenaean Trade and Interaction in the West Central Mediterranean 1600-1000 B.C.* BAR.International Series (1987), 371; N. HIRSCHFELD, *Fine Tuning: An Analysis of Bronze Age Potmarks as Clues to Maritime Trade, INA Newsletter* 17, 1 (1990), 18-21; W.-D. NIEMEIER, "Creta, Egeo e mediterraneo agli inizi del bronzo tardo", in *Traffici Micenei nel mediterraneo. Problemi storici e documentazione archeologica. Atti del convegno di Palermo (11-12 maggio e 3-6 dicembre 1984)* (1986), 245-270.

4 GEORGIOU, *op. cit.* (*supra* n. 2) and *Bronze Age Sailing and Homeric Evidence. Archaeology and Heinrich Schliemann: A Century After His Death. International Congress, Athens 1990* (forthcoming).

EBA and the early MBA. As communities became larger, they were apt to become more reliant on trade. The spread of obsidian and later the common use of bronze and increased technological sophistication demonstrate that contacts were sought beyond the confines of island communities. Given the absolute need for efficient communication by sea, one cannot assume that boat design evolved haphazardly over the centuries. The development of designs allowing for more predictable handling of ships was undoubtedly given considerable attention. Ships were essential for supplies, for communication, and for war. The economic and political growth of islands such as Crete, Santorini, Melos and Kea is inconceivable without efficient sea contacts. This essential need will have influenced ship design.

It is especially important to establish the ability of BA boats to sail to windward. The wind is the power that drives a sailing ship. The efficient use of this force will be the primary concern of a ship builder and a sailor. A major misconception about square sails is that they can only be used for running before the wind. The concept of ancient navigators running South with the aetesian winds in the summer and north with the southerlies in the winter is both simplistic and unpractical. Unfortunately, it has influenced theories about communication and trading systems in the Aegean [5].

2. Technical factor and historical evolution: depictions of ships and known wrecks

The major sources of information about Aegean BA boats are models, images on miscellaneous objects, ceramics, seals and wall paintings, recent studies of Bronze Age wrecks, and the Homeric poems [6]. Concordances between the rigging in the Thera ship painting and standard Homeric rigging terms have been discussed in detail elsewhere [7]. Traditions were undoubtedly strong and many images exist as testimony to designs of earlier periods [8].

A hull propelled by oars has other requirements than a hull propelled by wind or by a combination of the two. White points out the obvious difference in equipping a fighting ship or a cargo ship: oared cargo vessels are unpractical because crew and equipment occupy space at the expense of cargo [9]. While cargo ships may include oars, they will be fewer and less permanently installed. The hull will be designed for maximum capacity and not for the accommodation of rowers.

Increased flexibility and stability in conjunction with optimum hull speed have always been the main stimuli for changes and developments in the design of hulls and rigging. The simplest way to achieve balance in the hull design of a flat keeled ship is to create a symmetrical

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5 *Ibid.* Typical are R.L.N. Barber's comments, *The Cyclades in the bronze Age* (1987), 17-18: "ancient navigation seems to have been a seasonal affair" ... "it is necessary always to keep in sight of land and suitable shelter". For similar opinions see also J.L. DAVIS, "Minos and Dexithea: Crete and the Cyclades in the later Bronze Age", in J.L. DAVIS & J. CHERRY (eds), *Papers in Cycladic Prehistory* (1979), 143-157) and E. SCHOFIELD, *Plus and Minus Thera: Trade in the Western Aegean in Late Cycladic I-II, Temple Universiuty Aegean Symposium* 7 (1982), 9-14. See K.D. WHITE, *Greek and Roman Technology* (1984), 143-145 on sailing to windward with square sails.

6 MORGAN, *op. cit.* (*supra* n. 1), 121-142 passim; GEORGIOU, *op. cit.* (*supra* n. 2 and 4); G.F. BASS, "Cape Gelidonya: a Bronze Age Shipwreck", *Transactions of the American Philosophical Society*, 57, part 8 (1967); G.F. BASS, C. PULAK, D. COLLON & J. WEINSTEIN, "The Bronze Age Shipwreck at Ulu Burun: 1986 Campaign", *AJA* 93 (1989), 1-29.

7 GEORGIOU, *op. cit.* (*supra* n. 4).

8 MORGAN, *op. cit.* (*supra* n. 1), 121, fn. 2; C. BROODBANK, "The Longboat and Society in the Cyclades in the Keros-Syros Culture", *AJA* 93 (1989), 319-337 passim.

9 K.D. WHITE, *Greek and Roman Technology* (1984), 141.

hull with the greatest beam and depth at the center. On a beamy hull, it is best to avoid extremes of fineness or fullness forward in order to achieve better balance.

Masted ships that rely on wind power require different types of calculations than oared ships. The center of buoyancy will be different. The center of gravity must fall within the same fore and aft line as the center of buoyancy otherwise the ship will sink by the stern or the head. Even the simplest sailing ship design requires a practical knowledge of these facts. Once a functioning hull design is achieved, it can be used repeatedly and refined. LBA designs surely reflect knowledge acquired by trial and error [10].

The same can be said for rigging, but here experimentation is less costly of both labour and materials and is likely to be more effective. The rigging of a ship is the most crucial aspect of the design. Because it is not a permanent construction as is the hull, it can be fine-tuned and altered by pressure according to need, individual judgment, wind and weather conditions, and angles of sail. Bronze Age rigs from the various sources mentioned and those described in the Homeric poems were easily adjusted.

Design of the rigging and considerations such as the height of the mast on BA boats are limited by specific technical considerations :

1. center of gravity above the waterline,
2. weight of the rigging,
3. type of rigging [11],
4. balance.

Of course, all of these points are related, and in order to create a sea-worthy ship, the shipwright must take all into account.

A major concern has been and still is to increase the angle which a ship can sail effectively to windward. Downwind runs and broad reaches are easier to accommodate with almost any type of rigging, especially with square sails. However, a sea going sailing ship must have the flexibility to confront changing weather conditions. Although in theory the highest speeds may be attained when running before the wind, in practice, higher speeds can be consistently achieved in reaching winds. A reach is the fastest and smoothest tack. Thus, although one might suppose that with a square sail rig following winds might have been preferred, in actuality, they can be extremely dangerous, particularly in combination with high seas, rapidly leading to a loss of control. A large sail area will make matters worse. There is always a fear of broaching and swamping. Due to their rigging and low freeboard, Bronze Age boats would have been subject to these problems in addition to considerable lateral drift, especially on

10 Continuity can be seen in the elongated shape shared by the EC ships and the Thera ships. V. McGEEHAN LIRITZIS, "Seafaring Craft and Cultural Contact in the Aegean during the 3rd Millennium B.C.", *IJNA* 17 (1988), 237-256. For iconography and earlier bibliography see BROODBANK, *op. cit.* (*supra* n. 8), 327-329.

11 It is presumed that BA boats did not have permanent running rigging. Yet this may not be an important factor in the seaworthiness of the ships. Unsupported masts set in tabernacles are still common today, the catboat rig is an example. But the mast must be solid and relatively short in addition to being supported by vertical extension to the keel. The issue of stays, especially shrouds which can be rigged before setting sail, needs to be reconsidered and the iconographic evidence on this point reviewed. Although in Homer there is no mention of side stays, Minoan glyptic may provide other clues. When three stays are depicted on either side of the mast one pair may represent shrouds. Examples include *CMS* VII, no. 104 (= MORGAN, *op. cit.* [*supra* n. 1], fig.80, MM IIa), V.E.G. KENNA, *Cretan Seals, with a Catalogue of the Minoan Gems in the Ashmolean Museum* (1960), 94, no.49, 50, pl.3, S. MARINATOS, "La marine créto-mycénienne", *BCH* 57 (1933), pl. 15, no. 32 (= MORGAN, *op. cit.* [*supra* n. 1], fig. 87, MM I-II) and pl. XV, no. 29, 30, 34, 36, 37, 38, 39.

downwind tacks. Thus downwind is not the easiest angle to sail, nor is it necessarily going to get you to your desired destination.

a. Egyptian Ships

Some of the best comparative material comes from Egypt [12]. Egyptian merchantmen at the beginning of the New Kingdom are depicted with the mast planted amidships, and the sail attached to two very long yard arms made of two poles each and tied together at the mast [13]. Such exceedingly long yards naturally suggest a vast sail area, ballooning out from the mast to carry the ship downwind on smooth waters with maximum speed. This rigging may well have been practical for linear N-S passages on the Nile and the Red Sea as well as hauls close to shore in the Levant south of Cyprus. In general, these areas are characterised by mild winds, calm seas and predictable coastal currents [14]. The destinations are clear, the ports are few and the options limited. Even in the Red Sea, winds tend to blow parallel to the shores and do not generally reach the forces common in the Aegean. It is quite another matter to set out for the purposes of trade, barter or piracy among the Aegean islands.

Indeed, the Aegean has very different weather conditions for which considerable flexibility is required. This island studded sea with its variable wind and water currents, its rocky shores and hidden shoals is subject to sudden changes in the weather [15]. In unpredictable and stronger winds a smaller sail area will be safer and more flexible.

b. The Ulu Burun wreck

Given that bottoms are flat on these ships, ballast and disposition of the cargo is especially important to the handling of the boat under sail. The evidence of the Ulu Burun ship is most informative on this point [16]. Although the timbers have yet to be raised, some observations are possible. The volume of the cargo is evident as well as its disposition: the heaviest items appear to be placed along the longitudinal axis and centered near the mast. The loading of the ship indicates practical knowledge that concentrated ballast will reduce the effect of fore and aft pitching. In the opinion of G. Bass, this ship probably capsized as a result of a sudden off-shore squall [17]. She may have been running along a lee shore and have broached in response to a sudden wind increase on the square sail, causing the boom to reach the waterline and the ship to heel, thus shifting the ballast beyond the point of recovery for the particular hull shape, center of gravity and weight. The rigging was obviously not strong enough to resist the

12 R.O. FAULKNER, "Egyptian Seagoing Ships", *JEA* 26 (1940), 3-9; B. LANDSTROM, *Ships of the Pharaohs* (1970); L. CASSON, *Illustrated History of Ships and Boats* (1964), 16; S. WACHSMAN, *Sea Going Ships and Seamanship in the Late Bronze Age Levant*, Jerusalem: The Hebrew University, Unpublished Ph.D. Dissertation (1989).

13 CASSON, *ibid.* In addition to sail power, Hatschepsut's boats are equipped with 15 rowing stations on each side.

14 *Mediterranean Pilot V. Comprising the Coasts of Libya, Egypt, Palestine and Syria, the Southern Coast of Turkey, and the Island of Cyprus* (London, Admiralty Hydrographic Department, Third ed. Supplement no. 8, 1949), 8-23.

15 *The Mediterranean Pilot Vol. IV. Comprising the Islands of the Grecian Archipelago, with the adjacent Coasts of Greece and Turkey from Cape Tainaron on the West to Kara Burun on the East, Including also the Island of Kriti* (London, Admiralty Hydrographic Department, Seventh ed. Supplement no. 5, 1950), 5-19.

16 G.F. BASS, C. PULAK, D. COLLON & J. WEINSTEIN, "The Bronze Age Shipwreck at Ulu Burun: 1986 Campaign", *AJA* 93 (1989), fig. 2. G.F. BASS, "Nautical Archaeology and Biblical Archaeology", *Biblical Archaeologist* 53 (1990), 4-10 believes this may be a royal shipment of cargo dating to the second half of the 14th century or the very early 13th century.

17 Bass, personal communication.

sudden stress of a series of squalls which can hit before the ship and the helmsman are able to respond and adjust. Failure of the rigging would result in loss of power and control of the ship leaving it to the mercy of high winds and choppy seas which will have hurled it on the rocks. Oars would have been useless in such conditions. The ship was not able to recover. The picture is indeed very dramatic and is to be repeated throughout the centuries along the coasts of the Aegean and the Mediterranean. This wreck is sure to yield additional valuable information on BA ship construction as excavation proceeds.

c. The Theran sailing ships

Iconography

At present, the Akrotiri ship painting is still the best source of information. It includes three masted ships and five others with lowered masts and rigging [18]. Although the ship under sail is very fragmentary [19], enough remains to suggest the original appearance [20]. Iconographically, the Egyptian and Thera depictions share an attention to detail which aids interpretation [21]. However, certain artistic conventions apply and one cannot expect abbreviation to shift to photographic realism whenever convenient to the interpretation. The requirements of art do not coincide with those of a technical manual on naval architecture. First and foremost, questions about rigging must be put to the test of what can and will work.

Hull

The masted boats have long, narrow hulls with a curving prow which appears to narrow towards the tip. There is an affinity with earlier Cycladic designs in that the shape favours a variety of angles to the wind [22]. The pointed bows are also effective in slicing through waves. More importantly, a shallow and narrow hull with a relatively small angle of heel will perform reasonably well when reaching as opposed to running downwind or close hauled.

On the sailing ship, three deck hands are seated forward of the mast, partially hidden by a raised deck structure and all are, of course, looking up at the sail. The crew is placed forward for greater stability. Two other men stand at the stern. One handles the tiller attached to the steering oar, and the other may be handling the second steering oar and the sheets. Other oars or paddles are conspicuously absent. In this respect the sailing ship is unique among the larger craft and may well be a cargo ship [23].

In the reconstruction, a passenger is shown seated in a protected area in the stern. This cabin is a feature common to all the larger ships in the scene but may not accurately belong here [24].

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18 MORGAN, *op. cit.* (*supra* n. 1), 121-142. The ethnic origin of these ships is not an issue here.

19 MORGAN, *op. cit.* (*supra* n. 1), fig. 70 (Pl. XXI, a here).

20 MORGAN, *op. cit.* (*supra* n. 1), fig. 71 and pl. XXI, b here. Compare Pl. XXII.

21 E.N. DAVIS, "The Iconography of the Ship Fresco from Thera", in W.G. MOON (ed.), *Ancient Greek Art and Iconography* (1983), 3-14 addresses the specific character of the narration. MORGAN, *op. cit.* (*supra* n. 1), 124 believes that the representation is to be taken to the letter because the patrons and the artist are assumed to be familiar with ships and their use. See S. WACHSMAN, "The Ships of the Sea Peoples", *IJNA* 10 (1981), 198 for related problems in Egyptian iconography.

22 BROODBANK, *op. cit.* (*supra* n. 8), 327-329 includes earlier bibliography; McGEEHAN LIRITZIS, *op. cit.* (*supra* n. 10), 251, 255.

23 See note 9 *supra*.

24 I see no indication of it in the original fragments.

The stern projection attached to the larger paddle propelled ships has been the subject of extensive speculation [25]. The high, upward curving shape of the stern does not favor the placement of a boarding plank in this position. The argument that the journey undertaken is short [26] cannot account for a boarding plank being engaged horizontally at sea level while a ship is under way. This is tantamount to traveling with the ship's ladder down. There has to be a nautical reason for this option. Visually and functionally, it is an extension of the hull to the stern. It lengthens the waterline without increasing hull size and may act as a stabiliser. Whatever the final word on this option may be, any explanation must take into account its usefulness in the handling of a ship in motion.

Placement of mast

The placement of the mast here is very important: it is set just forward of the center. It is not a coincidence that the mast of the Ulu Burun ship may also be placed just forward of center [27]. The Theran shipwrights were surely aware that placing the mast forward allows a ship to sail closer hauled and provides more stability in downwind situations. This significant technical advance marks an improvement over contemporary Egyptian boats and serves to demonstrate that the island and coastal populations of the Aegean were motivated and successful in seeking to improve the performance of their ships.

Mast

The mast is made of a single pole. The means of support is not visible in the painting, presumably because it is located behind the gunwale. The extant mast-heads on the larger sailing ships have five sockets or pegs on either side. At least ten lines can be accommodated.

Rigging

-Yards, sail area

The rigging of a sailing or cargo ship of the Theran type must be relatively stiff, the mast as straight as possible and the sail area proportionately reduced in order to avoid stress. The importance of the shape of the sail and its flexibility cannot be underestimated. It is the essential tool for increasing manoeuvrability.

Theran sailing ships have two yards. The lower yard is the boom. Unlike Egyptian examples, each yard appears to be made from a single pole. There is nothing in the fragments of the ship under sail or in the other masted ships to indicate that the yards consist of two joined poles [28]. Furthermore, the yards are proportionately shorter than the Egyptian ones, indicating a smaller sail area. The hull is also proportionately shorter. The sail area remains greater in width than height, but is considerably smaller compared to Egyptian merchantmen of the same date. A longer boom with a squatter sail will be relatively stable, but a narrower sail will be more effective in sailing to windward. The reduction of the sail area indicates a preference for greater manoeuvrability over speed in order to facilitate sailing at a closer angle to the wind. Indeed, small adjustments in design all seem to share this goal.

25 MORGAN, *op. cit.* (*supra* n. 1), footnote 105 and p. 135-137 concludes that it is a boarding plank. See this discussion for bibliography.

26 MORGAN, *op. cit.* (*supra* n. 1), 137.

27 Bass, personal communication.

28 MORGAN, *op. cit.* (*supra* n. 1), 124 suggests that the yards may consist of two poles each.

-Halyards and lines

Square sails are rigged with the same number of lines on either side of the mast. On the sailing ship, two halyards run parallel to the best preserved side of the mast [29]. Therefore, one can reconstruct at least two lines on either side. The artist may have abbreviated the actual number of lines needed.

Four lines are insufficient to handle the rigging of a sailing ship with two yards [30]. Anywhere from two to seven or eight lines are seen on various examples in glyptic and on other ships of the Thera fresco. In the Odyssey, a double headstay rig with one yard and possibly without brails will have at least nine lines running through the mast [31]. Brails will require at least two more lines. A ship with a double yard rig and brails, single back and forestays and side stays needs ten lines and this accounts for the five loops on each side of the mast-head (Pl. XXII).

Two topping lifts connect the upper yard with the mast on either side. They are for hoisting the upper yard and the sail which it supports. These are the heaviest lines in the running rigging because they carry the entire weight of the sail. In Morgan's reconstruction (Pl. XXI, b) they appear to connect the upper yard with the mast-head rings [32]. Yet Morgan recognises that the topping lifts must have been fed through the rings and run parallel to the mast - they cannot be permanently attached between yard and mast as shown in her drawing because there would be no way to raise or lower the entire sail from the deck [33].

Sheets control the lower part of the sail [34]. The downhauls or braces attached to either side of the upper yard are for lateral adjustments. These are attached to the yards and do not need to connect to the deck through the mast-head rings.

-Brails, reefing, furling systems

The sail is outfitted with brails or leechlines for reducing sail area (reefing). The brails cross the sail together at a diagonal leading from the end of the boom to the center of the yard. It is logical to assume that they passed through the rings in the mast-head at this point. The brails either attach to the boom or pass under it. In the latter instance, the sail could be rolled around the boom for furling and reefing. In the unrestored fragments of the sailing ship, the brails on both sides of the mast terminate at the edge of the boom and not above it as in Morgan's reconstruction. Thus, the brail lines can conceivably pass under the boom, through a small loop or even a tie in order to ascend diagonally on the other side of the sail. This will allow the boom to be rolled while being supported by the brails. In the Cycladic islands, sails of wind-mills were furled this way in the past. In any case, each line must then pass independently through a mast ring and continue down to the deck. When reefing, the boom is adjusted by tightening or slackening of the brail lines through the mast rings. In addition, the system of topping lifts will allow the upper yard arm to be lowered and adjusted accordingly. Both yards or the boom alone can be adjusted when reefing.

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29 The rigging of this ship has been reconstructed by MORGAN, *op. cit.* (*supra* n. 1), fig. 71 (reproduced in Pl. XXI, b 2 here).

30 Morgan concurs (*op. cit.* [*supra* n. 1], 125).

31 GEORGIOU, *op. cit.* (*supra* n. 4).

32 MORGAN, *op. cit.* (*supra* n. 1), fig. 71. The reconstructed rigging diagram is difficult to interpret, possibly due to the size of the printed figure.

33 MORGAN, *op. cit.* (*supra* n. 1), 125.

34 The terms stays, braces, and sheets are synonyms.

The other masted ships in the Thera painting demonstrate that the upper yard was lowered to furl and stow the sail. Thus, to reef the sail, the lower yard is raised or both are adjusted. To furl the sail, the upper yard is lowered by slackening the topping lifts. In later examples at Medinet Habu and later Greek illustrations, the single yard remains stationary and the lower part of the sail is raised for reefing. But these sails had reefing points which could be secured.

Brails were effectively used in later squaresail rigs for reducing sail area and for changing the shape of the sail. A combination of two yards with brails will allow the shape of the sail to be changed in order to take advantage of various wind directions [35].The reefing system proposed in Pl. XXII has great potential for sailing to windward. One side of the sail could be reduced by narrowing the space between the two yards to form a triangular sail area with a leech (Pl. XXIII). The raising and lowering of the topping lifts also serves to change the angle of the entire sail and the way in which it will perform. This is surely the first step in the development of the lateen rig [36]. The double yard rig is clumsy but it gives the sail rigidity and shape. Tacking with this rigging is difficult but feasible [37]. I suspect that jibing would be preferable, using the steering oars to pivot the boat. Most importantly, this rigging will allow the boat to sail on a close reach [38]. The Kyrenia ship though differently rigged and with a single upper yard sailed far closer to windward than any one had expected [39].

At Medinet Habu the lower yard arm has been eliminated, and a more complicated system of brails has been introduced to reef the sail upwards [40]. Indeed, even the Egyptian boats depicted at Medinet Habu are a new type of warship [41]. This change may have occurred as a result of influences from the Aegean [42]. Another possible source may be the inhabitants of the NE coasts of the Mediterranean in the second half of the 13th century B.C. [43]. Clearly, ethnic origin of the boats or of the design cannot be determined from the Medinet Habu depictions alone. To determine the origins of the invention, some examples must be found of similar rigs in earlier contexts. The rig with a single upper yard arm and with a loose-footed sail adjusted by brails is a major breakthrough in sailing which could not have occurred without prior experimentation. The iconographic record of the Aegean gives some indication that this may have been the case.

Either the lower yard was abandoned in the Aegean prior to this time (LH III C) [44], or, there must be earlier evidence for loose-footed rigs. The earliest depiction that I know of is

35 I agree with MORGAN, *op. cit.* (*supra* n. 1), 124, fn. 19, that convention requires the sail to be depicted parallel to the gunwale. My concern is not with the angle at which this sail is depicted but with the angle that it can potentially achieve.

36 Casson alludes to this, regarding a ship with a single yard (L. CASSON, *Ships and Seamanship in the Ancient World* [1971], 277, fig.188).

37 See A.E. CHRISTENSEN & I. MORRISON, "Experimental archaeology and boats", *IJNA* 5 (1976), 275-284 for experiments with square sails.

38 CASSON, *op. cit.* (*supra* n. 12), 16 and *op. cit.* (*supra* n. 36), 274.

39 G. Bass, verbal communication. My experience with flat cut spinnakers designed to sail as close as 15 degrees to the wind suggests the same.

40 WACHSMAN, *op. cit.* (*supra* n. 21); A. RABAN, "The Medinet Habu Ships: Another Interpretation", *IJNA* 18 (1989), 163-171.

41 E. LINDER, "Naval Warfare in the El-Amarna Age", in D.J. BLACKMAN (ed.), *Marine Archaeology* (1973), 319-322; RABAN, *op. cit.* (*supra* n. 40), 168.

42 CASSON, *op. cit.* (*supra* n. 36), 37 supports neither an Egyptian nor Aegean origin while RABAN, *op. cit.* (*supra* n. 40), 167 suggests that it is a composite type of rig combining Cretan and Canaanite modifications. WACHSMAN, *op. cit.* (*supra* n. 21), 214 believes the source to have been Syria.

43 RABAN, *op. cit.* (*supra* n. 40), 170-171.

44 WACHSMAN, *op. cit.* (*supra* n. 21), 201-202 for LH III C Skyros ship with loose-footed sail.

dated to MM IIa [45]. In fact, both the single and double yard rigs are documented in the Aegean prior to the Late Bronze Age [46].

Improvements on the single yard rig probably led to its eventual predominance. A single yard is described in the Odyssey [47] and continues to be preferred subsequently. I suspect that the double yard became technologically obsolete and was replaced by the more efficient system depending exclusively on brails for adjusting the shape of the sail. There are many advantages in making the running rigging lighter and more easily manoeuvrable.

-General

The presumed lack of standing rigging raises interesting questions about the way that ships traveled. Morgan believes that it is evidence that voyages (or the specific voyage depicted in the Thera painting) were of short duration [48]. This does not necessarily follow. One cannot be sure that all the actual lines are depicted on the painting. When moored or under oar power, fore and back stays are not needed. Unfortunately, the fragments of the ship under sail are of no help here. But stays and shrouds would have to be rigged and tightened before hoisting the sail.

Organic rope or cable kept under permanent pressure is easily undermined and consequently unreliable. For instance, Agamemmnon's rigging at Troy is out of commission, presumably from exposure and lack of replacement parts [49].

3. Conclusions

New finds may yet provide us with new information about rigging. At present, the hull and rigging designs do indeed suggest that a reach was the preferred angle to the wind and not a downwind run. This conclusion has important implications for the way in which ships traveled and for the routes they followed.

The visual sources underline the different ways in which designs evolved in neighboring and communicating cultural areas. Although the Egyptians traveled in the Mediterranean, their ships were not among the most seaworthy. For the most part, they were large and heavy merchantmen, not swift warships. It is the pirates, the raiders and the traders, namely the island and coastal populations, in particular, the inhabitants of the Aegean who were surely the most innovative and experimental boat designers. Their position demanded this.

The rigging system of the sailing ships in the Thera painting demonstrates Bronze Age experimentation with sail shape in order to achieve a closer angle to the wind. Greater flexibility was possible than previously thought. This is borne out by the material evidence for trade and contacts in the LBA in the eastern Mediterranean. Trade to and from islands involves ships. We

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45 *CMS* VII, no. 254.

46 Single yard: HM sealing no. 146 from Knossos in *PM* II, 244, fig.141b and 140 (= *PM* IV, 827, fig. 806, = MARINATOS, *op. cit. [supra* n. 11], 78, no. 54, pl. XVI [MM III?]; *CMS* VII, 254 (MM IIa); MARINATOS, *op. cit.*, Pl. XIII, no. 16 (LH III). Double yard: *PM* I, 254, fig. 190c (LM?); KENNA, *op. cit.* (*supra* n. 11), no. 107; *PM* II, 243, fig. 139 (LM I); *CMS* VII, no. 104 (LM II); MARINATOS, *op. cit.*, Pl. XVI, no. 52 (LM); *CMS* II.1, 287 (MM I-II); *PM* IV, 828, fig. 807 (LM I); *CMS* VIII, 106 (LM Ib); MORGAN, *op. cit.* (*supra* n. 1), fig. 80; J.H. BETTS, "Ships on Minoan Seals", in D.J. BLACKMAN (ed.), *Marine Archaeology. Proceedings of the 23rd Symposium of the Colston Research Society held in the University of Bristol, 4-8 April 1971* (1973), 325-328, fig.9 (LMI?); MARINATOS, *op. cit.*, Pl. XVI, no. 44.

47 Od. V. 254.

48 MORGAN, *op. cit.* (*supra* n. 1), 126.

49 Il. II. 135.

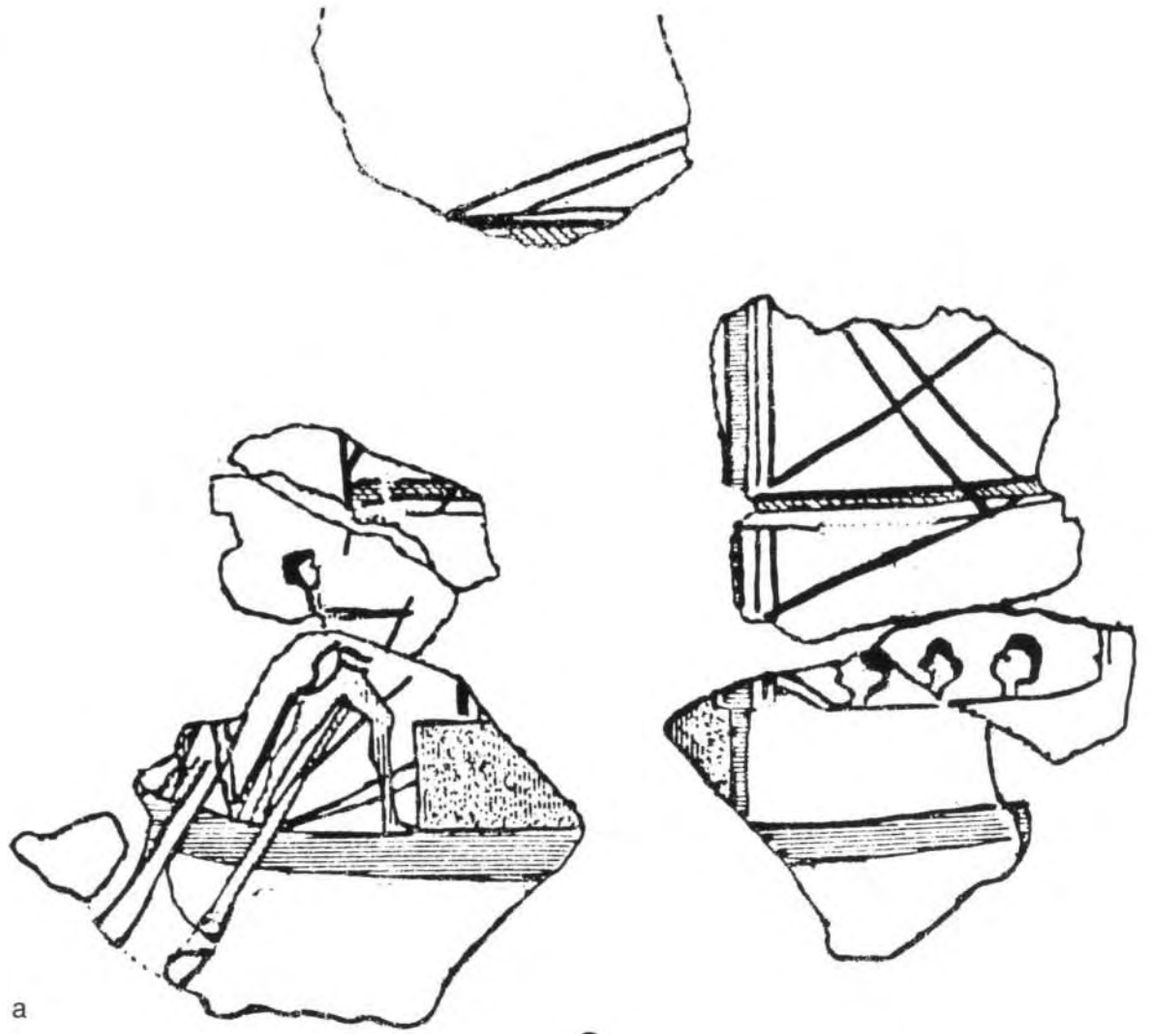
should not underestimate the ships or the naval sophistication of those who built and used them. Even the earliest seafarers must have had some general concept of desired landfall. Thus, they could not have been entirely at the mercy of the winds, changing destinations as they went along. It was necessary to design ships that would allow for maximum flexibility and swift manoeuvres.

Although these developments may have taken several generations to evolve, they were surely intentional technological changes brought about by skilled craftsmen and sailors who relied on experience and knowledge of the seas. It is clear that they created ships to fit the environment in which they ventured every day and in all seasons for subsistence and profit.

HARA S. GEORGIOU

LIST OF ILLUSTRATIONS

Pl. XXI, a : Extant fragments of Thera sailing ship (after L. MORGAN, *The Miniature Wall Paintings of Thera: a Study in Aegean Culture and Iconography* [1988], fig. 70).
Pl. XXI, b : Reconstruction of the rigging of the sailing ship by Morgan (after MORGAN, *op. cit.*, fig. 71).
Pl. XXII : Rigging diagram showing full sail.
Pl. XXIII : Rigging diagram showing triangulated sail.



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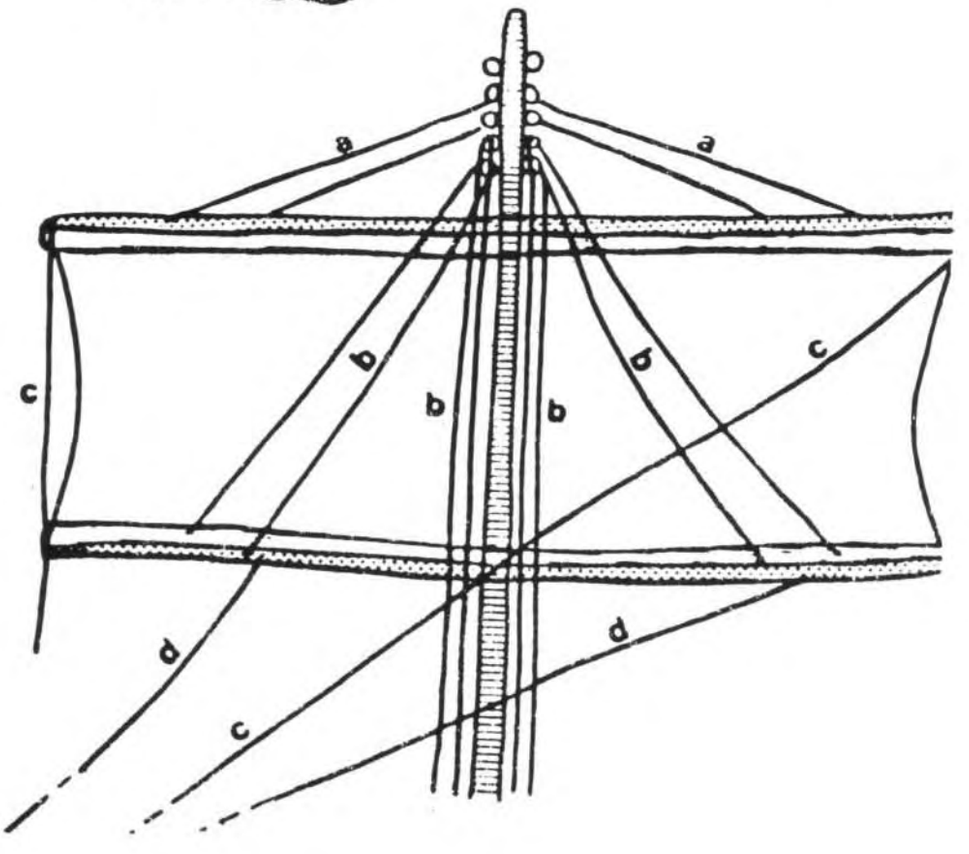

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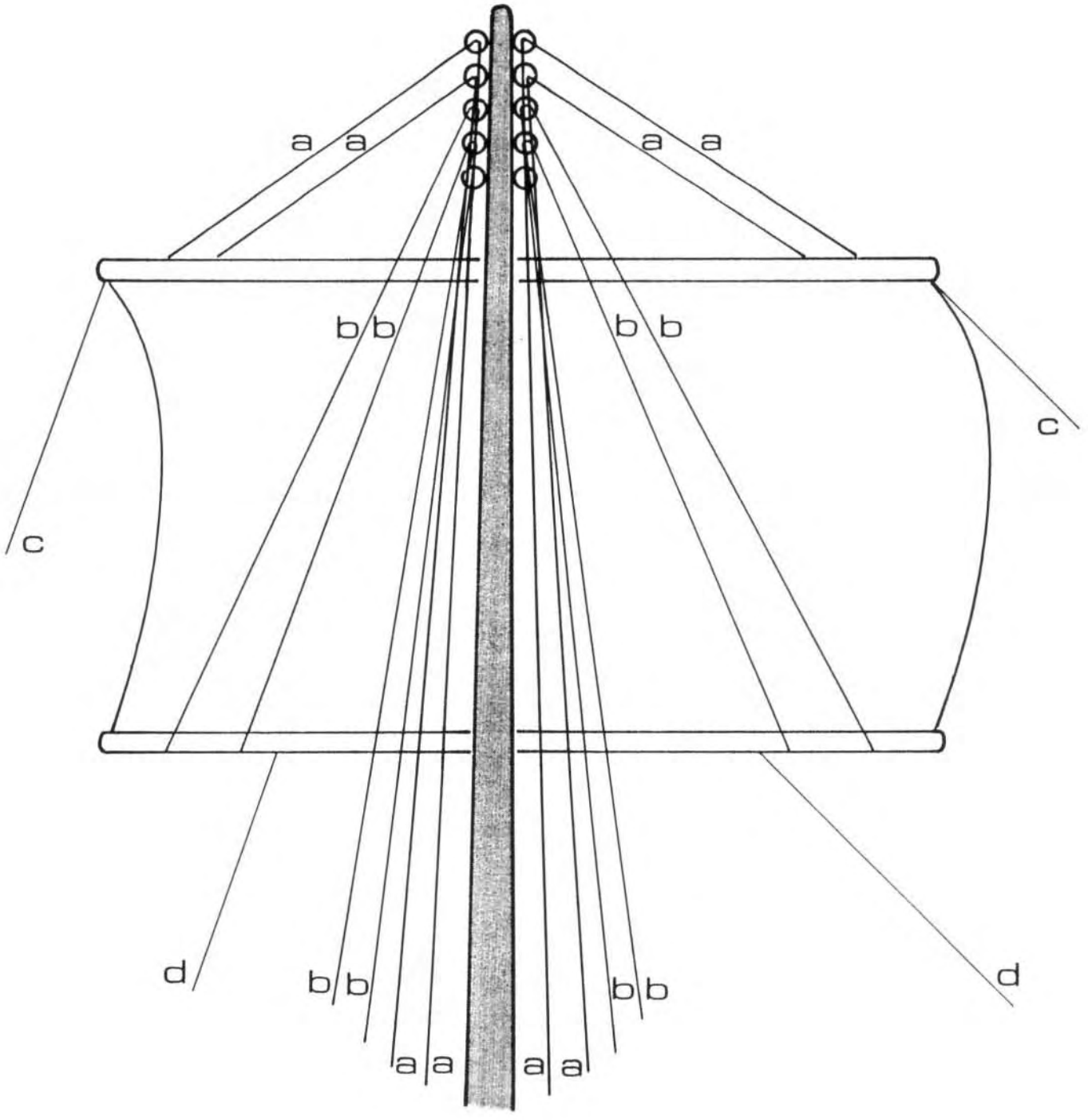
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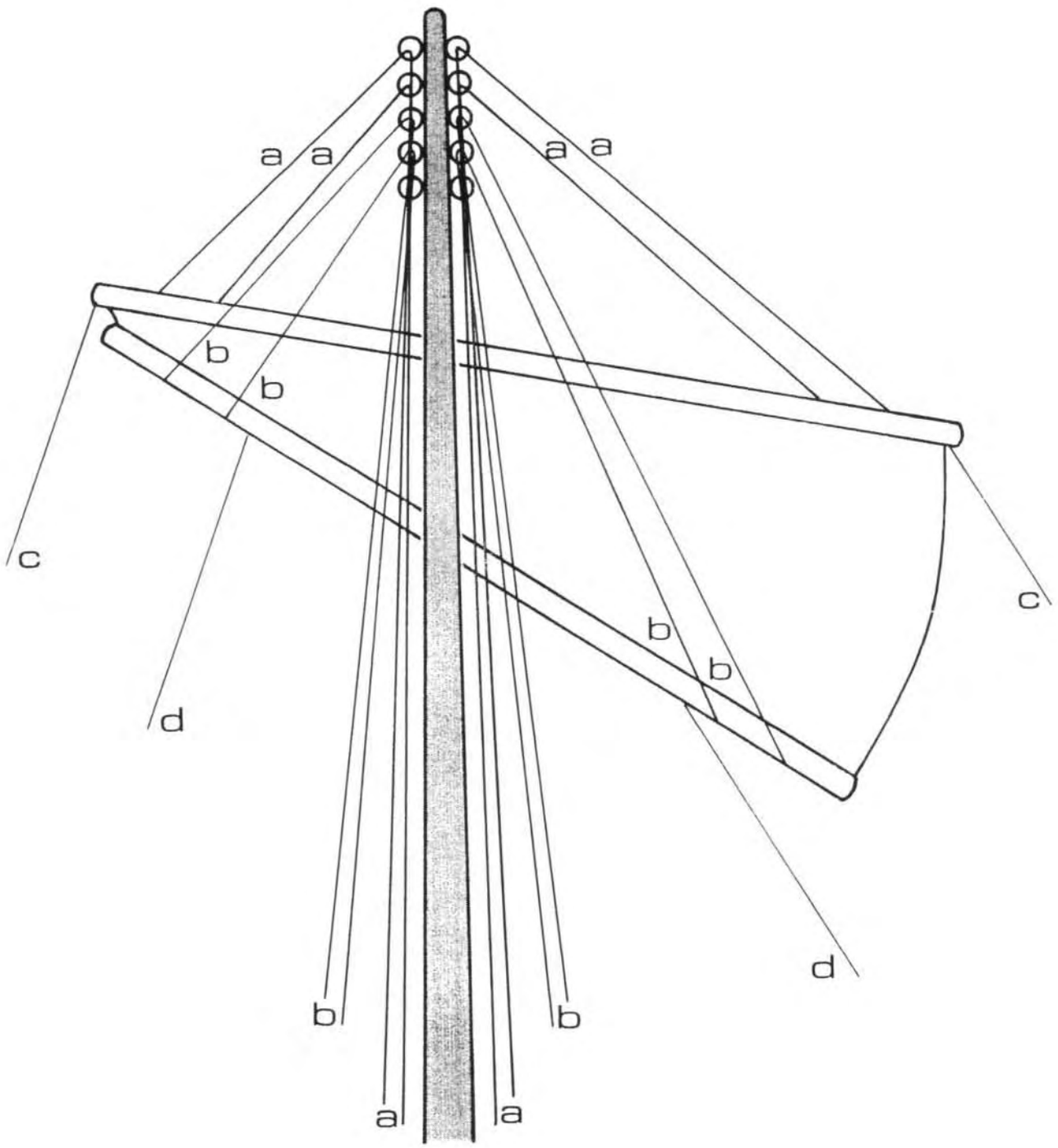
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