EVIDENCE FOR THE MINOAN ORIGINS OF STELLAR NAVIGATION IN THE AEGEAN

Mary Blomberg
Göran Henriksson

Abstract

As part of The Uppsala project, *The development of astronomy and its significance for society in ancient Greece*, we have studied the orientations of a number of major monuments in Crete from the Middle and Late Bronze Ages (ca 2000-1200 BC) and have found evidence of long-term, systematic observations of the bright star Arcturus, the circumpolar stars at the latitude for Crete, sunrise and sunset at the summer solstice, sunrise and sunset at the equinoxes, and moonrise at the southern major standstill. As the knowledge obtained from these observations would have been adequate for stellar navigation, we reviewed the evidence for Minoan sea-worthy sailing boats and also the earliest Greek texts for references to navigation in the Bronze Age. The results of our study support earlier proposals that stellar navigation in the Aegean originated in Minoan Crete.

Introduction

In book 1, chapter 4 of his *History*, Thucydides tells us the following about the Minoan presence in the Aegean:

> *King Minos made himself master of a very great part of what is now called the Hellenic Sea, and became lord of the Cyclades islands and first coloniser of most of them, driving out the Carians and establishing his own sons in them as governors. Piracy, too, he naturally tried to clear from the sea, as far as he could, desiring that his revenues should come to him more readily.*

This 5th century BC account of a Minoan hegemony in the Aegean (Thucydides' Hellenic Sea) has been given dramatic confirmation by the past century's archaeological investigations in Crete. These have revealed to us a wealthy and advanced culture in that island during the Bronze Age, a culture with widespread contact not only with the islands in the Aegean but also with more distant Egypt, Anatolia, and the Near East from the middle of the third millennium BC.

The political and economic strategies which the Minoans reputedly used for the establishment and management of their island empire are also given by Thucydides: the earlier ruling group was driven out and replaced by the sons of Minos and the sea was cleared of pirates. Other prerequisites, of course, would have been the possession of sea-worthy sailing boats and the ability to navigate using the sun and the stars as guides. These prerequisites are not mentioned by Thucydides, but we must infer them.

Figure 1. Representations of Minoan sailing boats: 1. Early Minoan, 2. Middle Minoan, 3. Late Minoan. Photos courtesy of the Ashmolean Museum.

Minoan sailing boats

Fortunately, we have concrete support for our inference concerning the boats in the many representations of sailing vessels on Minoan sealstones from late in the Early Bronze Age until the end of the Minoan period, ca 2200-1400BC[1], a period of about 800 years (Fig. 1). Since there were no navigable rivers in Crete, these boats can only have been developed for sailing in the Aegean. The representations are not realistic but schematic a typical stylistic feature of the sealstones and the boats are therefore difficult to date [*Betts 1973*]. However, as these vessels were the products of an ever-advancing civilisation, we are justified in assuming considerable technical development through the centuries, both in the construction and in the handling of them, and this is indicated on the sealstones.

There is no feasible source in the eastern Mediterranean for the Minoan sailing boat. Early Egyptian vessels were developed for the far safer waters of the Nile and therefore they could have large sails and shallow hulls [*Basch 1987; Landström 1970*]. They were not intended, nor were they suitable, for sailing on the open sea. The first sailing ships to be used by the Egyptians for seafaring were simply their river boats which they strengthened with a series of trusses and gave deeper hulls and broader bottoms to accommodate the increased weight [*Landström 1970: 63-89*]. The Egyptians are not likely to have influenced the Minoans in the construction of seagoing sailing ships. There is evidence for contemporary sailing in the Near East, from ancient Phoenicia, and in the Indian Ocean, from Mesopotamia. We know very little of the types of vessels used in these waters, but there is no evidence that they influenced the development in the Aegean [*Basch 1987:42*]. We have, in fact, no good evidence for a contemporary more technically accomplished sea power than the Minoan in the Mediterranean area [*Basch 1987: 93-106*].

The boat frescoes from the island of Thera are dated to Late Minoan IA, ca 1650-1550 BC [*Morgan 1988:5*], and they give us a relatively realistic picture of the Minoan sailing boat at the height of its development (Fig. 2). Typical for them are a mast in the centre and a small sail in relation to boat size. These features would have contributed to stability and manoeuvrability. Good manoeuvrability would have permitted quicker

[1] There is no general agreement on the absolute chronology of the Aegean Bronze Age. The dates used here follow, with some rounding-off, those given in Manning [*1995: 217*].

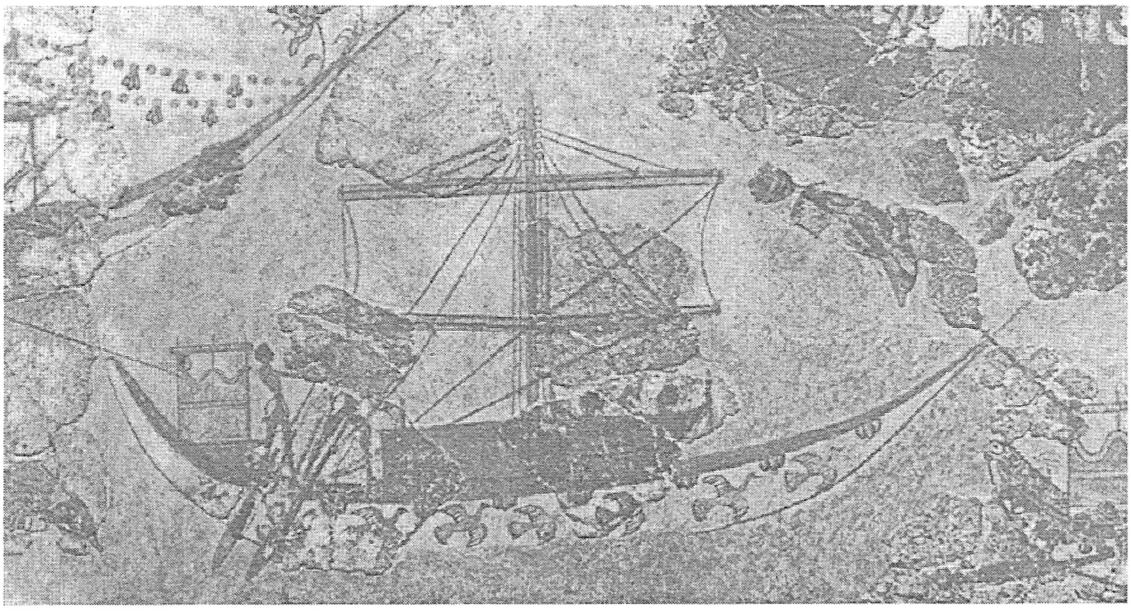

Figure 2. Late Minoan IA type sailing boat. From the miniature frescoes found at Thera (ca 1650-1550 BC). Photo courtesy of Magda Riga.

adjustment to the changing winds and sudden squalls for which the Aegean is feared still today [*Georgiou 1993:360*]. Another consistent feature of Minoan boats from the very beginning is the high prow [*Morgan 1988: 131*].

Early textual evidence

Our written support for stellar navigation in the Bronze Age Aegean comes from texts composed, not in the Bronze Age itself, but several hundred years later. The earliest occurs in one of our earliest texts, ascribed to Homer (ca 700 BC). This is the advice given to Odysseus by Calypso:

> *Gladly then did goodly Odysseus spread his sail to the breeze; and he sat and guided his raft skilfully with the steering oar, nor did sleep fall upon his eyelids, as he watched the Pleiades, and the late-setting Bootes, and the Bear, which men also call the Wain, which ever circles where it is and watches Orion, and alone has no part in the baths of Ocean. For this star Calypso, the beautiful goddess, had bidden him to keep on the left hand as he sailed over the sea (Odyssey 5:271-277).*

The author wrote these lines near the beginning of the Archaic Period in Greece. However he was relating the heroic sagas from the Mycenaean culture of the Late Bronze Age, which ended about 1200 BC. Now there has been a long debate about the survival in the Archaic Period of correct information from the Bronze Age [*for example Nilsson 1972*]. It is certain, however, that the author(s) of the *Iliad* and the *Odyssey* had access to accurate knowledge of Mycenaean armour and similar data from that culture. This is clear from a number of the descriptive details that agree with objects recovered from Mycenaean graves. The question is whether or not the account of stellar navigation can also be referred back to the Bronze Age, and specifically to the Minoans.

We also have texts from a special category of didactic poetry, the purpose of which was to give practical information to farmers and sailors. These poems told how natural signs, including the positions of the stars, could be used to tell the time of the year, for example the time to sow, to harvest, and to venture out to sea. The sailing season in the Aegean for many centuries began in May and ended in October [*Casson 1971:270-273*].

The stellar positions used by farmers were the heliacal risings and settings, the acronychal risings and the cosmical settings of bright stars or easily recognisable constellations such as the Pleiades. Hesiod's *Works and Days*, which is roughly contemporary with Homer's epics, contains information intended primarily for farmers.

In Aratos' poetic work the *Phainomena* (ca. 275 BC), the first 730 of the 1150 lines contain a very detailed account of the positions of the constellations relative to each other, to the horizon and to the four great circles: the Tropics of Cancer and Capricorn, the Equator, and the Ecliptic. This information is presented in a way that is more useful for navigation than for telling the time of the year and seems, therefore, to be intended primarily for sailors rather than farmers. For example, the detailed account of the risings and settings of constellations relative to each other is essential information for pilots navigating on the open sea at night, as it is not possible to maintain course to a distant port using only one guiding star. Not only do the stars change azimuth as they rise and set during the night, but changing winds and currents may demand that a course be frequently adjusted and other appropriate stars taken as guides. In the last 420 lines of the poem, Aratos takes up various natural signs not only celestial signs that were believed to portend the weather.

There are many problems in connection with the astronomical information contained in the *Phainomena*. The poem is the versification by Aratos around 275 BC of a prose work written about one hundred years earlier by the astronomer Eudoxos and which exists only in fragments. Many of the stellar positions in Aratos are not correct, neither for his time nor for the time of Eudoxos. A number of modern authors have argued that the information is correct, instead, for Crete in the Bronze Age [*for example Ovenden 1966; see also Dicks 1970:160-163*]. There are comments in the text that support this view, for example the explanations for the names of the two Bears and for the Crown of Ariadne, our Corona Borealis. Our own calculations, which are based on the nearly 100 stars that Aratos places relative to the Equator and the Tropics of Cancer and Capricorn, also indicate an origin in the Bronze Age. There are, however, interpretative difficulties with the data in Aratos, as the positions for the stars do not deviate in a systematic way from any specific date; that is, the deviations can not be accounted for by precession.

We have as hypothesis that with the *Phainomena* we are dealing with an oral tradition of didactic poetry going back to the Minoans in which knowledge was preserved in easy-to-remember verse and then learnt by rote. Such rote learning of lengthy works is typical of cultures with limited reliance on writing and was still customary in Greece in the Classical Period [*Vansina 1985; Thomas 1989*]. Oral transmission of the astronomical knowledge required for stellar navigation was the tradition relied upon in the South Pacific [*Lewis 1973:307-309*]. If the astronomical knowledge of the Minoans were preserved in this way, it must have been translated at some point into Mycenaean Greek, as the Mycenaeans became in the Late Bronze Age the inheritors both of Minoan culture and the Aegean hegemony. They would surely have taken up the astronomical knowledge and navigational skills needed to maintain their hegemony. The astronomical information from the Minoans, however, would have needed updating as the result of precession. Since precession itself seems not to have been understood until the second century BC, there would have been no systematic updating of all positions but only of those that created practical difficulties when they became obsolete.

If we are correct in our view of the existence of Minoan didactic poetry, then Aratos' *Phainomena* could have its origins in that tradition. There could have been a Minoan poem composed to teach the positions of the stars for stellar navigation in the Bronze Age Aegean, a poem which, because of its increasingly anachronistic data, was in parts and unsystematically updated. We think that some of the deviations in stellar position in Aratos can be explained in this way. The updating would have concerned only those positions of greatest practical importance, as the ones given in the poetry became more and more at odds with the observations. The need for translation and occasional later modernisation of the language could account for some of the other errors that we find in the *Phainomena*. We should also, of course, reckon with simple mistakes of transmission over such a long period of time.

Minoan study of the heavenly bodies

Knossos

In further support of a Minoan origin of stellar navigation in the Aegean, we would like to present evidence from Crete for systematic study of the sun, the moon and the stars from the beginning of the Middle Bronze Age (ca 2000 BC). The evidence is based on the results of our archaeoastronomical investigations of Minoan monuments and it implies an observational tradition already in the Early Bronze Age.

To date we have evaluated our measurements of six Minoan sites: the palaces at Zakros, Mallia and Knossos, the mansion of Agia Triada, and the peak sanctuaries on Petsophas and Traostalos[2]. The results are being published elsewhere, but we would like to present here the most impressive evidence that we have found for long-term Minoan study of the heavenly bodies, that from the palace at Knossos and the peak sanctuary on Petsophas. This is to show not only the antiquity of the Minoan interest in the heavenly bodies but also the advanced ways in which they used their knowledge. The Minoan achievements in this area should not be surprising, since they are in perfect agreement with the accomplishments in many other spheres of that great culture.

Of course, it is not the possibility itself of stellar navigation that is at issue. This is amply demonstrated in the ancient and still living tradition in the South Pacific [*Lewis 1973*]. The native pilots in that region can accurately navigate over hundreds of miles of empty, open water relying solely upon their knowledge of the motions of the heavenly bodies, the winds and the currents. They use no instruments at all while at sea. What we wish to show here is that the Minoans had the astronomical knowledge adequate for stellar navigation and boats capable of sailing in the Aegean, in addition to their political supremacy in the region.

At Knossos the so-called *Corridor of the House Tablets* is oriented so that the first rays of the sun, as it appears on the morning of the equinoxes above the Ailias ridge opposite, strike an unusual concave stone on the floor beside the southern door of the corridor (Figs. 3 and 4). The asterisk in Fig. 4 marks the site of the stone. If the bowl-

[2] The measurements were made with the laser theodolite SOKKIA SET 4C, and the orientation of the co-ordinate system was obtained from observations of the sun, which are accurate to < 0.01°. The use of an instrument of such precision eliminates significant errors of measurement.

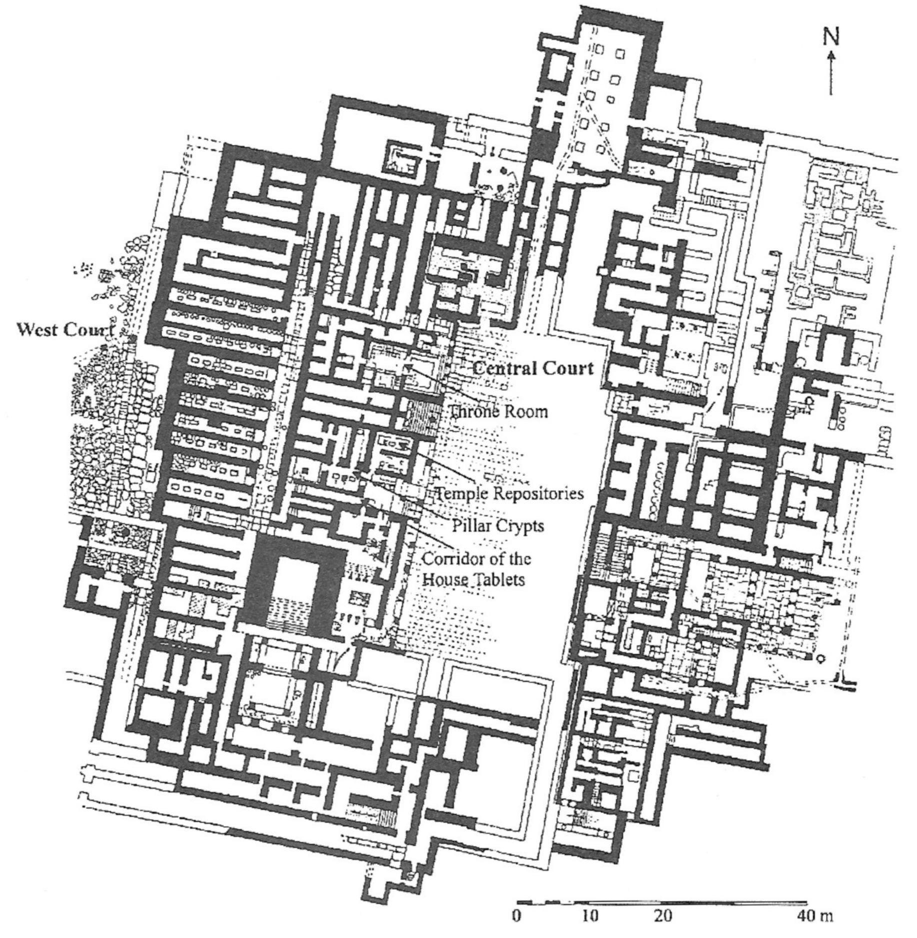

Figure 3. Plan of the palace at Knossos. Orientation 10.4° for the western side of the Central Court. With permission of the editors of "The aerial atlas of ancient Crete".

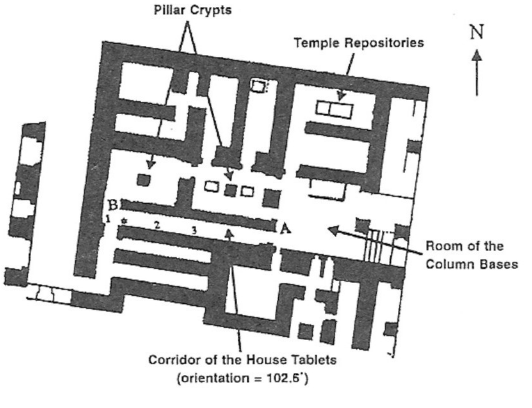

Figure 4. Corridor of the House Tablets at Knossos. The asterisk marks the position of the concave stone, and the numbers give those of the inscribed double axes. Adapted from "The aerial atlas of ancient Crete".

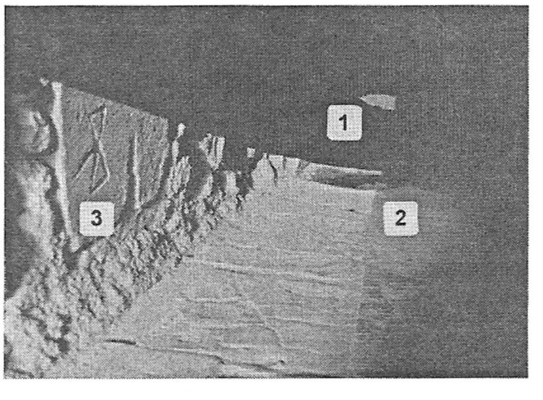

Figure 5. The reflection (1) cast on the western wall of the Corridor of the House Tablets by the first rays of the sun as they strike the surface of the water in the concave stone (2) on the morning of the autumn equinox. At the same time the shadow cast on the southern wall by the upper door frame nearly touches the inscribed double axe (3, no. 2 in Fig. 4).

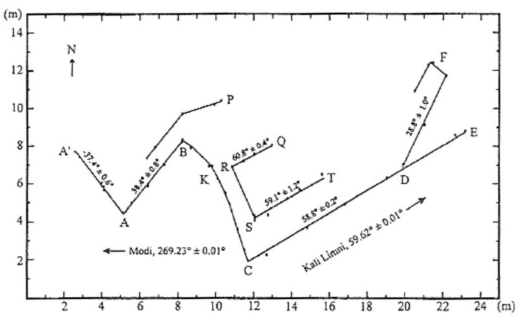

Figure 7. Petsophas. Orientation of the walls.

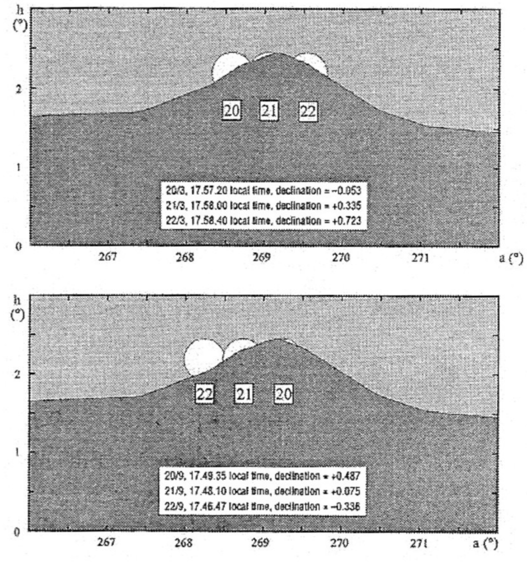

Figure 8. Sunset behind Modi at the spring (upper) and autumn (lower) equinoxes as observed from Petsophas in the year 1997 BC (refraction for t=+10°C). The relationship is valid for many centuries.

observations, whereas there is archaeological evidence which supports them. The original level of the floor, for example, was retained in this area of the palace throughout its more than 1000-year history, although it was raised elsewhere over the centuries by about a metre. Also there was no obstructive building to the east.

The first palace was built at the end of Middle Minoan IA, ca 1900 BC. This means that the observations at Knossos most likely began already in the Early Bronze Age.

Petsophas

All of the contemporary walls of the small structure on Petsophas, with the exception of the curved wall BC, were oriented to a major celestial event (Fig. 7); the wall DF is later [*Myres 1902-1903:357*]. The orientation of the terrace wall CE (58.8°±0.2°, n=8) was to the rising sun at the summer solstice, which occurred in the Middle Bronze Age just south of the highest peak on Karpathos, ca 90 kilometres away [*Henriksson-Blomberg in press*].

The walls AA' and AB were oriented to the heliacal/acronychal risings and the heliacal/cosmical settings of Arcturus, optimal for 1827 BC±77 years, which agrees well with the archaeological dating of the early years of site to about 1900 BC. We have discovered the same orientations to Arcturus also at the peak sanctuary on Traostalos, which is 7 km due south of Petsophas [*Henriksson-Blomberg 1996*]. Furthermore, an observer standing within 30 meters of the building could have observed the sun set on the day of the equinoxes behind the conical peak Modi (Fig. 8).

The calendaric importance of the risings and settings of Arcturus are known from the earliest Greek authors and continued to be used down into late Roman times [*West 1978:300,378-379*]. Because of precession, this long period of reliance created problems. For example, in the Middle Bronze Age the cosmical setting on the 11th of May and the heliacal setting on the 13th of October could have been signals for the sailing season, as these are the traditional limits in the Mediterranean [*Casson 1971:270-273*]. In the 7th century BC, however, Arcturus was no longer as suitable for this purpose, and Hesiod used the Pleiades instead [*Works and Days 618-623*]. The memory of Arcturus' connection with sailing survived, however, in the form of the superstitious fear felt by sailors for this star because of its association with stormy weather, as we learn from Aratos (lines 744-747). The heliacal rising on the 24th of August is one moon month before the autumn equinox. This means that the heliacal rising relative to the phases of the moon would have shown when it was time to intercalate a month before the new year. For example, by using the simple of thumb 'whenever the new moon appears in the evening sky on one of the 11 days following the morning rising of Arcturus, it signals the beginning of an intercalary month', it would have been possible to regulate a lunisolar calendar based on either the 8-year or the 19-year cycle. This would have been a calendar tool as useful as the one at Knossos. The fourth position of Arcturus, the acronychal rising on the 2nd of February marks midwinter, the half-way point between the winter solstice and the spring equinox.

Thus the placement of the structure on Petsophas and the orientations of all of its contemporary straight walls would have aided observations of a number of celestial phenomena of major calendaric utility as early as the first half of the nineteenth century BC: sunset at the equinoxes, sunrise at the summer solstice, the heliacal/acronychal risings and the heliacal/cosmical settings of Arcturus. These orientations presuppose, as at Knossos, a long tradition of observations.

Navigating in the Mediterranean

The astronomical knowledge accumulated by the Minoans would have been useful not only for maintaining a calendar but also, of course, for navigation. A reliable method for navigation would have been mandatory for pilots plying the waters of the Aegean, and in the Bronze Age there was no alternative to stellar navigation. The notion of island-hopping and finding the way by following the coast has entered the literature, but this is completely unrealistic. As all of the inhabited islands are very mountainous, the winds near their shores are treacherous. Many of them also have rocky coasts. When approaching, it would have been imperative to keep well at sea until heading in to port. Not only would following the coastline have been dangerous because of the sudden squalls, but the coast would often not have been visible at a safe distance at night [*Georgiou 1993:361*]. There were routes, such as those to Egypt and Thera, which could not be completed in a day's sailing.

Stellar navigation demands that pilots have mastery over the positions of the stars relative to each other and to the earth. The acquisition of this knowledge is facilitated by the arrangement of the stars into easily identifiable figures in a fixed order and by the presentation of the information in verse form. Also useful is the selection of a fixed direction to which desired courses can be related. On cloudless nights of today, the relatively bright star Polaris is the obvious choice in the Northern Hemisphere, as it is always near true north and always visible. From the Archaic Period the choice for the Greeks were the stars in Ursa Major [*Homer, Odyssey 5:276-277; Aratos, 37-38*]. In the Early Bronze Age the most likely choice would have been Thuban in Draco. Cloudy nights are not a serious problem during the sailing season in the Aegean, as they are infrequent. In the event of local cloud cover, an experienced navigator would have been able to sight on an alternative star and to rely upon current and wind patterns.

The Minoan orientations towards sunrise and sunset at the equinoxes and to sunrise at the summer solstice is likely to have had as consequence good acquaintance with the stars which rose and set in the same directions: along the Equator and the Tropics of Cancer and Capricorn. By relying on such a series of stars or constellations with the same declination or angular distance from the Equator, a fixed direction can be maintained by a pilot if he steers sighting upon these constellations as they appear low on the horizon, both when rising in the east and when setting in the west. Aratos presents in great detail the order of the constellations relative to these directions. First he names all of the constellations and gives briefly their relative positions; then he presents their order along the Tropics and the Equator; finally he gives in detail the rising of one constellation, or part of a constellation, relative to the setting of another. This is the kind of information that is absolutely essential to a pilot navigating according to the stars.

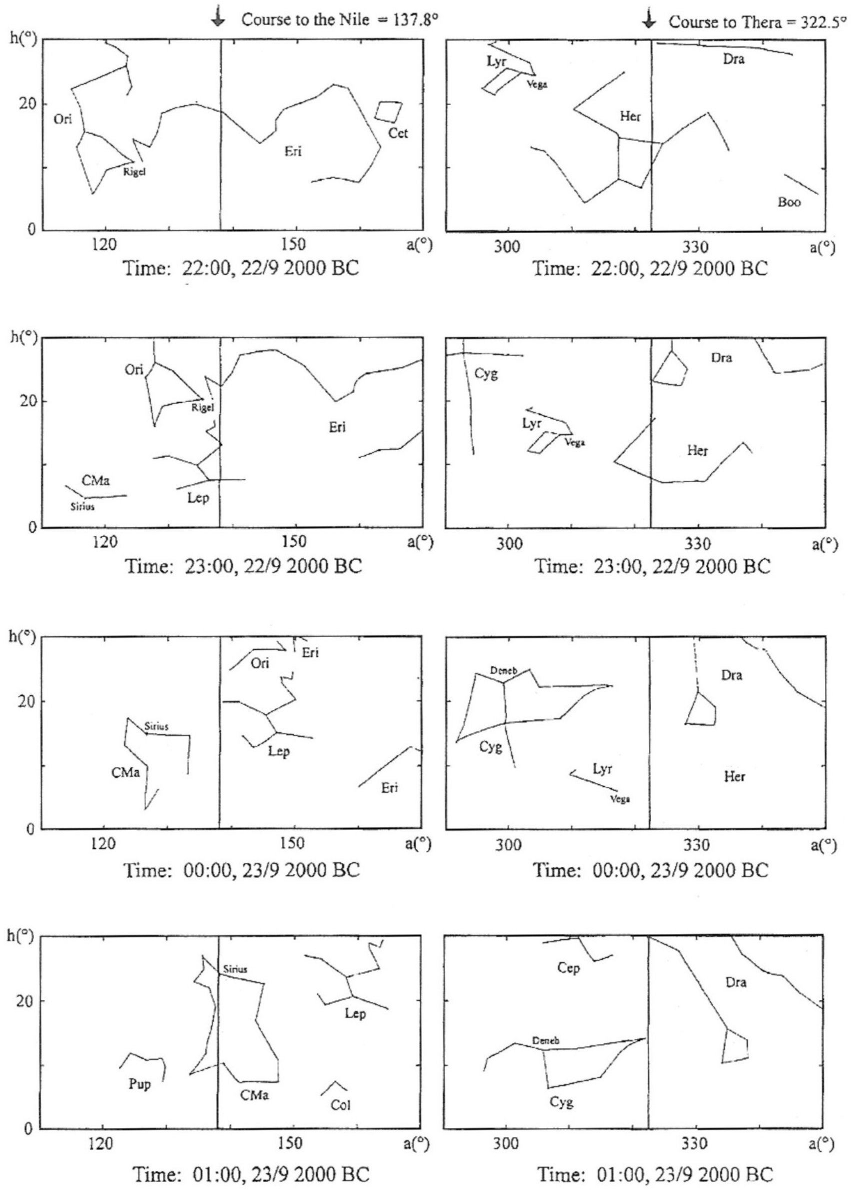

Figure 9. Constellations in the direction to the Nile Delta from the Minoan harbour town below Petsophas (left) and to Thera from Cape Sideros, just north of the same town (right).

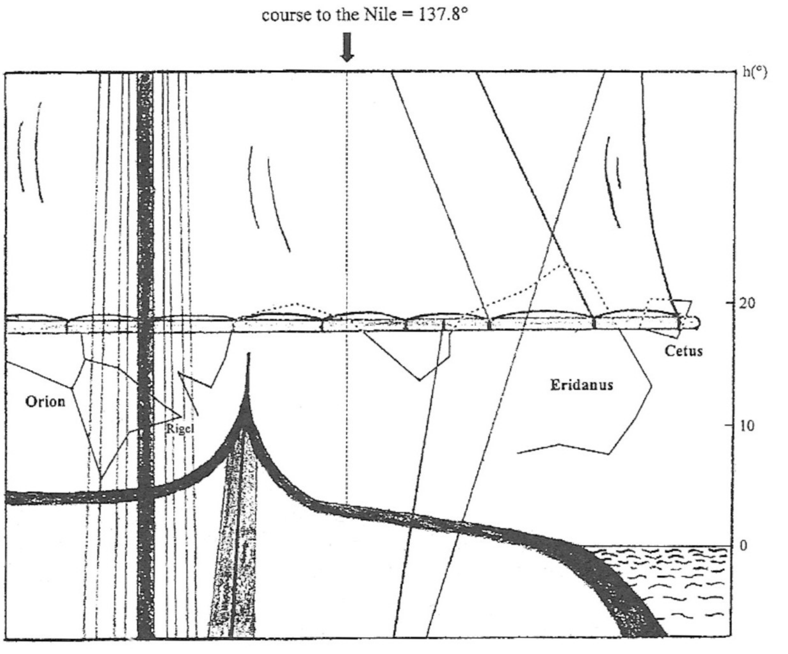

Figure 10. Illustration of the relationship between a Minoan boat of the Late Minoan Period and the constellations relevant for sailing to the Nile Delta from the northeastern coast of Crete at, for example, 22:00 on the 22nd of September 2000 BC. Drawing of the boat by Anna Wærn-Sperber.

Conclusion

In conclusion we would like to show how the sky would actually have appeared through the night on September 23, 2000 BC, to a Minoan pilot on course to the Nile Delta or to the nearest Cycladic island of Thera from the Minoan harbour town which lay near modern Palekastro, on the north-eastern coast of Crete (Fig. 9). The parameters for calculating visibility have been based on the results of Bemporad [*1904*] and Schmidt [*1865*]. We have used Schmidt's visibility calibrations for Athens of ca 1850, our era, as they were made when modern air pollution was less widespread. The course to Thera is the same as the one to Siphnos and Attika whence the Minoans were getting their silver and copper in the Early Bronze Age[4]. There is a sequence of bright stars at an altitude of between about 10° and 20°, the altitude most convenient for use in navigation [*Lewis 1973:56-57*]. The pilot would have maintained a predetermined relationship between the prow of the boat and the rigging primarily to the stars before the boat (Fig. 10). The knowledge on the basis of which the pilot planned his course would have been acquired partly from theoretical study of the stars, partly from experience at sea. The view of the night sky in Figure 10 reminds us of the following verses in Aratos:

> *Then, too, can the sailor on the open sea mark the first bend of the River (Eridanus) rising from the deep, as he watches for Orion himself to see if he might give him any hint of the measure of the night or of his voyage. For on every hand signs in multitude do the gods reveal to man (728-732).*

[4] This has been shown by lead isotope analyses.

References

Aratus

1989 *The Phaenomena,* Cambridge.

Basch L.

1987 *Le musée imaginaire de la marine antique* [Institut hellénique pour la préservation de la tradition nautique], Athens.

Betts J.H.

1973 *Ships on Minoan seals*, in: Marine Archaeology. Proceedings of the 23rd symposium of the Colston Research Society, University of Bristol, April 4-8, 1971, ed. D.J. Blackman, London, pp. 325-338.

Bemporad A.

1904 *Zur Theorie der Extinktion des Lichtes in der Erdatmosphäre*, Mitteilungen Grossh. Sternwarte zu Heidelberg 4.

Blomberg M. - **Henriksson** G.

1996 *Minos Enneoros. Archaeoastronomical light on the priestly role of the king in Crete*, in: Religion and Power in the ancient Greek world. Proceedings of the Uppsala symposium 1993, eds. P. Hellström - B. Alroth, Uppsala, pp. 27-39.

Casson L.

1971 *Ships and seamanship in the ancient world,* Princeton.

Dicks D.R.

1970 *Early Greek Astronomy to Aristotle. Aspects of Greek and Roman life*, London.

Driessen J.

1990 *An early destruction in the Mycenaean palace at Knossos* [Acta Archaeologica Lovaniensia Monographiae 2], Leuven.

Evans A.

1921 *The Palace of Minos*, vol. I, London.

Georgiou H. S.

1993 *A sea approach to trade in the Aegean Bronze Age*, in: Wace and Blegen. Pottery as evidence for trade in the Aegean Bronze Age 1939-1989, Amsterdam, pp. 353-364.

Hesiod

1977 *Works and Days,* London.

Henriksson G. - **Blomberg** M.

1996 *Evidence for Minoan astronomical observations from the peak sanctuaries on Petsophas and Traostalos*, Opuscula Atheniensia 21, pp. 99-114.

Henriksson G. - **Blomberg** M.

In press *Petsophas and the summer solstice,* Opuscula Atheniensia 22.

Homer

1984 *Odyssey*, London.

Landström B.
1970 *Ships of the Pharaohs: 4000 years of Egyptian shipbuilding*, Garden City.

Lewis D.
1973 *We, the navigators*, Honolulu.

Manning S.
1995 *The absolute chronology of the Aegean Early Bronze Age. Archaeology, Radiocarbon and History* [Monographs in Mediterranean Archaeology 1], Sheffield.

Morgan L.
1988 *The Miniature Wall Paintings of Thera. A study in Aegean culture and iconography*, Cambridge.

Myres J.L.
1902-3 *Excavations at Palaikastro, part II. The sanctuary-site of Petsofà*, Annual of the British School at Athens 9, pp. 356-387.

Nilsson M.P.
1972 *Homer and Mycenae*, Philadelphia.

Ovenden M.W.
1966 *The origin of the constellations*, Philosophical Journal 3 (1), pp. 1-18.

Schmidt J.F.
1865 *Über die Dämmering*, Astronomische Nachrichten 63, article no. 1495.

Thomas R.
1989 *Oral tradition and written record in classical Athens* [Cambridge studies in oral and literate culture 18], Cambridge.

Thucydides
1991 *History of the Peloponnesian war*, Cambridge.

Vansina J.
1985 *Oral tradition as history,* Madison.

West M. L.
1978 *Hesiod. Works and Days,* Oxford.