MARY BLOMBERG* - GÖRAN HENRIKSSON*

FURTHER EVIDENCE FOR THE MINOAN ORIGINS OF THE GREEK CALENDARS**

In a paper delivered at the Uppsala Symposium of 1993, we presented evidence for Minoan contributions to Greek astronomy. Part of the evidence came from our archaeoastronomical investigations of the peak sanctuary on Petsophas. On the basis of this and textual evidence, we suggested that the Greek lunisolar calendar originated on Crete and was conveyed to the Greeks via the Mycenaeans.¹ Later investigations of the peak sanctuary on Traostalos gave further indications of systematic Minoan astronomical observations, of the

bright star Arcturus in particular. Here we present the results from our investigations so far of the palaces at Knossos and Zakros, with an interpretation of their significance for later Greek calendar traditions. These results strengthen the hypothesis that the Minoans were using a lunisolar calendar. We also suggest that the Minoans may have been the source of what have come to be known as the parapegmata, calendars or almanacs in which particular positions of the stars indicate specific weather prognostications.

The evidence indicates that the Minoans in their daily life were relying on a lunisolar calendar and specific positions of bright stars in a manner similar to that of the later Greeks, to keep the months recurring in the same seasons and to time important events in the year.

Knossos
In the palace at Knossos, the longer axis of the central court is not oriented due north-south, but rather 10.4° east of north, for the western facade. The so-called corridor of the house tablets is oriented so that the first rays of the sun, just as it appears above the Aillas ridge at the equinoxes, strike an unusual concave stone on the floor beside the southern door of the corridor (figs. 1-3). For this event to have occurred when the corridor was newly built, four conditions must have obtained:
1) The floor level of the corridor was about the same as it is today.

4. The deviation of the palaces’ orientation from the cardinal points has been noted often; see, for example, J. W. Shaw, “The orientation of the Minoan palaces”, AntC 1, 1977, 47-59.
5. The ridge lies to the east at a distance of about 775 m. and its angular altitude above the plane of the horizon is 10.4°. The sun appears above the ridge on the morning of the equinoxes 53.5 minutes after sunrise at the unobstructed horizon at sea level. We presented the results of our measurements and computer calculations at the congress; we were first able to confirm the results by video on the autumn equinox, a few days following the congress. We are very grateful to Dr. Karetzou for making it possible for us to videofilm sunrise at the autumn equinox.
6. On the floor level see S. Mirei, Das Thronraumareal des Palastes von Knossos (Saarbrücker Beiträge zur Altertumskunde, 26), Bonn 1979, 40-44.
2) The part of the east wing opposite had no more than two stories.
3) There was a doorjamb or pillar on the northern side of the present-day eastern doorway into the corridor (A in fig. 3).\textsuperscript{7}
4) The height of the corridor’s eastern doorway was nearly the same as the present-day restored height (2.1 m).\textsuperscript{8}

We know of no archaeological evidence against these conditions.

The question is whether or not the concave stone is the remnant of an installation of some kind which existed in the Minoan period to heighten the effect of the sun’s rays. For example, liquid in the stone causes in a dramatic way a sharp reflection on the western wall of the corridor when the rays of the sun strike the liquid at sunrise (fig. 4).\textsuperscript{9} At the moment when the rays strike the stone, the shadow cast by the upper part of the doorway on the southern wall touches the uppermost tip of the western-most of the two double axes inscribed in the wall (fig. 3, no. 2, figs. 5, 6). When the rays have just left the stone, 10 minutes later, the shadow touches the midpoint of the two blades of the axe. We have here independent evidence that the restored height of the door is close to

\textsuperscript{7} The wall AB in fig. 3 seems not to have existed as an unbroken partition in the earliest phase of the corridor, as pointed out by J. Driessen, An early destruction in the Mycenaean palace at Knossos, Leuven 1990, 103-105, esp. n. 364. It seems likely, however, that there was a support or jamb at A, ibid., 105, fig. 9.

\textsuperscript{8} If the ratio 1:2 is logical for the width of a Minoan door, and if we accept a Minoan foot of about 30-31 cm, then the restored height of 2.1 m. would be close to an original doorway with a width of 3.12 and a height of 7 Minoan feet. On the Minoan foot see J. F. Cherry, “Putting the best foot forward”, Antiquity 57, 1983, 52-56, which contains references to the results of Graham and Preziosi.

\textsuperscript{9} The concave stone is considered to be original, according to Marina Panagiotaki. We are very grateful to Dr. Panagiotaki for discussing with us the floor of the corridor. From the diary of the excavation, it seems possible that the stones of the floor were lifted in the search for cists. Although we can not be certain that the lifted stones were replaced exactly in their original positions, our astronomical computations and video-filmed documentation strongly indicate that the concave stone is original and lies today very close to its original position. The use of a liquid, which always has a horizontal surface, to cast a reflection would mean that slight changes in the position would not affect the occurrence of the reflection. See D. MacKenzie, Day-book of the Excavations at Knossos - 1903, entry for Thursday 28th May (copy of the hand-written record of the excavations, preserved in the Department of Antiquities, Ashmolean Museum). We would like to thank Michael Vickers, keeper of the Department, for permission to study the Day-book and Nicoletta Momigliano for help in interpreting the handwriting in difficult sections.

There is a star inscribed in the base of the western jamb of the doorway in the southern wall, below the reflection (fig. 3, no. 1).
that of the original. In fact the original height must have been within ± 1 cm of the restored height if this phenomenon was intended and the stone with the double axe is in its original position in the wall.

The sun's rays reach the concave stone only on the 11 days preceding and following the spring and autumn equinox, respectively. There is an important coincidence at the autumn equinox, however, which indicates that it was of primary interest. Since the difference between the solar year and 12 synodic lunar months is 11 days, the phase of the moon on the 11th day following the autumn equinox will be the same as on the day of the next autumn equinox. This is not the case at the spring equinox. At the autumn equinox, the rays of the sun fall for the first time since the spring equinox on the concave stone. Eleven days later the sun appears at the southern jamb of the door, illuminating the stone for the last time until the 11th day before the next spring equinox (fig. 7).10 This relationship between the sun and the phases of the moon would have been useful in two important ways: 1) to regulate a lunisolar calendar on the basis of the 8-year or the 19-year lunar cycle, as the day of the autumn equinox could be determined by direct observation and the phase of the moon on that day could be known one year in advance, and 2) for determining the beginning of the new year, if the new year began in connection with the autumn equinox.

Epigraphic evidence from the Classical period has been interpreted to mean that the year on Crete in that period began at the new crescent moon following the autumn equinox.11 Crete was in this respect an exception to most areas of Greece, where the year began at the first sight of the new crescent moon after either the spring equinox or the summer solstice. As we now have evidence at two Middle Minoan sites, Petsophas and Knossos, for observations which would have provided the information necessary for determining the time of the autumn equinox and for regulating a lunisolar calendar based on the phase of the moon at that time, we conclude that the custom in Crete in the Classical period of beginning the year in connection with the autumn equinox goes back to the Minoans and that this equinox was the primary object for the orientation of the corridor of the house tablets.

10. Figs. 7, 12 and 13 are based on astronomical calculations and measurements made with a digital laser theodolite, which gives an error of only a few millimetres. The orientation error is less than 1/100 of a degree. Such exact measurements reduce the likelihood that errors are introduced into our calculations from this source.

We conclude, furthermore, that the general orientation of the palace was due to the need for a reliable method of determining by direct observation the day of the autumn equinox and the phase of the moon on that day for calendrical and religious purposes. The continued use of the method would have required the retention of the original floor level in the room of the column bases and the corridor of the house tablets. This may explain the present-day difference in the floor level of this area and that of the central court (fig. 8).

Zakros
The western side of the central court at Zakros is oriented 37.6° east of north. Nearly perpendicular to it is the northern-most corridor of the western wing, which provides access to the important rooms in the wing (figs. 9, 10). The orientation of the corridor (129.4°) is close to the azimuth for the bottom edge of the cliff opposite where it meets the sea (126.49°), distance ca 710 m. (fig. 11). Moreover, this is very near the azimuth to the southern-most point (southern major standstill) for the upper limb of the full moon at the summer solstice at the beginning of the Middle Bronze Age (126.27°). The cliff can have been used as a foresight for moonrise at the southern major standstill for many centuries around the beginning of the Middle Bronze Age by observers standing near the remains of an older wall or foundation on the southern side of the corridor (fig. 12). This wall has a mean orientation of 127.1°. The observation would have been especially impressive in the case of the full moon at the summer solstice (fig. 13). The view to the cliff seems to have been left unobstructed through the entrance to the open court opposite (fig. 12). A wall on the eastern side of the court can have had a height of ca 1.5 m without interfering with the observation.

Our results so far from Zakros indicate that the orientation of the palace and its position on the plain were determined by the wish to know when the moon had reached its southern-most point at the horizon. The reason could have been religious, perhaps having to do with the fact that the moon gives the appearance

---

12. Calculated for 2034 BC. The next time the full moon rose at the southern major standstill at the summer solstice was in 1643 BC. The moon no longer rises so far south due to the change in the inclination of the earth's axis. The possibility of such a relationship between the palace and the moon was mentioned earlier by Shaw (supra n. 4), 59.
13. The remains of the older wall or foundation could be evidence that the southern wall was an exterior wall at some earlier period. Cf. N. Platon, Zakros. The discovery of a lost palace of ancient Crete, New York 1971, 131.
of being closest to the earth at the southern major standstill. The religious significance of the moon for the Minoans is indicated by some of the figurines found on Petsophas and Traostalos and by the orientations of the Late Bronze Age graves at Armenoi. In all but one marginal case of the more than 220 chamber graves at Armenoi, the orientations lie within moonrise at the major standstills as observed from that particular place. That is, the orientations take into account the shift to the south of moonrise due to the profile of the mountain Vrysinas opposite, just as the orientation of the corridor of the house tablets at Knossos takes into account the delay of sunrise and the shift of its appearance to the south due to the Ailias ridge.

Interpretation
The results presented here are important complements to those of our earlier investigations of the peak sanctuaries on Petsophas and Traostalos. At Knossos, the interrelationships of the orientation of the corridor of the house tablets, the position of the concave stone on the floor of the corridor, the positions of the doorjams of the eastern doorway, the height of the doorway, and the retention of the original floor level in the cult area have clearly been arranged with a high degree of precision with respect to sunrise above the Ailias ridge at the equinoxes. For example, changes of only a few centimetres in the placement of the stone nullify the effects. There is the additional precise relationship to the inscribed double axe on the southern wall of the corridor. These relationships and the orientation at Zakros presuppose several centuries of observations of the motions of the sun and the moon as well as the phases of the moon, and a method for preserving the data. The alignment of the long axis of the main room on Petsophas to sunrise at the summer solstice with Kali Limni on Karpathos as a foresight, and the positioning of the structure in relation to sunset at the equinoxes behind Modi are equally precise. The poor

16. On the methodology of alignment studies in archaeoastronomy see C. Ruggles, "New approaches to the investigation of astronomical symbolism within the ritual landscapes of the
condition of the relevant walls on Petsophas and Traostalos in addition to the variable atmospheric extinction and brightness of the sky complicate the evaluation of the degree of intended precision for the alignments to Arcturus; but they are sufficiently precise for calendrical use.

The archaeological evidence for the palaces does not contradict the archaeoastronomical indications of deliberate precise alignments to the equinoctial sun at Knossos and to the moon at the southern major standstill at Zakros. Both sites lie in areas populated since the Neolithic period. Thus there was time enough for the generations of inhabitants to have become well acquainted with the particular relationship of their landscape to celestial phenomena and to have built up traditions for the development, preservation, and transmission of acquired knowledge concerning these phenomena. The religious respect for the heavenly bodies, which seems to exist in all early societies, is likely to have encouraged these activities and given them the individual stamp of local beliefs. We think it likely that the benefits to be gained by knowledge of the motions of the heavenly bodies, in connection with religious attitudes towards those bodies, are adequate incentives for deliberate orientations to the sun and the moon when the first palaces were built at Knossos and Zakros.

We have results so far from our archaeoastronomical studies of four Minoan monuments. Combined with the investigations at Armenoi, they indicate:
1) use of the moon’s major standstills at Armenoi and Zakros,
2) precise knowledge of the sun’s position at the equinoxes at Petsophas and Knossos, which implies knowledge of the positions of the solstices,
3) use of the positions of the heliacal rising and setting plus the acronychal rising and the cosmical setting of Arcturus at Petsophas and Traostalos.

17. Henriksen and Blomberg (supra n. 2).
19. The equinoctial points, which are midway between the solstices, cannot be observed as an azimuth limit at the horizon, but must be calculated in some way from the solstices. The orientations to the equinoxes at Knossos and Petsophas indicate that the Minoans had made this calculation.
From these results, we begin to discern the unique character of the Minoan calendar with respect to those of the Egyptians and the Mesopotamians. It seems that only on Crete was there in the Bronze Age a lunisolar calendar which was based on the combined use of the motions of the sun, the moon, and a bright star. Such a calendar presupposes both long-term systematic observations and a method for intercalation of months or days. Accurate and simple methods for determining when intercalation of a month was necessary have been found at Petsophas, where the phase of the moon at the heliacal rising of Arcturus would have indicated this, and at Knossos, where the phase of the moon on the 11th day following the autumnal equinox would also have provided the information needed. The Egyptian calendar was based on observations of the heliacal rising of Sirius and knowledge of the length of the solar year; the existence of a contemporary lunisolar calendar is disputed. The Mesopotamian calendars seem to have been lunar calendars—based on the cycles of the moon and having a method of intercalation to keep the months in the right seasons. Although this implies knowledge of the length of the solar year, the calendar is said to have been based on the lunar cycle.

If we have interpreted our results correctly, then another important feature of the Minoan calendar would be its similarity to the later Greek calendars, including the calendrical use of the stars such as we find in the earliest texts. Hesiod, for example, tells us that the acronychal rising of the bright star Arcturus occurred 60 days after the winter solstice and that its appearance was the signal for farmers to prune their vines. According to the same author, the heliacal setting of the Pleiades, the Hyades, and Orion told the time to plough and to beach boats for the winter. Thucydides used the heliacal rising of Arcturus to report the time of the year when the Peloponnesians reduced their siege of Plataea. By the Archaic period, the settings of Arcturus, due to precession, were no longer appropriate as indicators of the sailing season, as they would have been in the Middle Bronze Age for the Minoans. They

23. Thuc. 2.78.2. The use of such references is also indication that the intended audiences would have understood them.
24. Henriksson and Blomberg (supra n. 2). On the sailing season in antiquity see L. Casson, Ships and seafaring in ancient times, London 1994, 123; idem, Ships and seamanship in the
continued, nevertheless, to be associated with storms by both seamen and the
astronomers.25

The early Greek astronomers not only used the positions of the stars to tell
the time of the year, but they also gave weather prognostications on the basis
of them.26 They published this information in what were called parapeg mata by
the Greeks.27 For example, we read in a passage from the parapegma of
Eudoxos, as reported by Geminos: “Arcturus rises in the morning and the wind
blows for the following seven days, fair weather for the most part”.28 This is a
typical statement for the parapegmata.

There survive in Greek and Roman texts a number of stellar positions which
do not agree with the date of their authorship, but which would have been
correct in an earlier period.29 We conclude, therefore, that the origins of the
practical use of the positions of the stars are likely to have been much earlier
than the Archaic period and that the most likely place and time would have
been the advanced Minoan culture in Crete in the Bronze Age.

Summary

Our archaeoastronomical investigations at Knossos and Zakros provide
additional evidence of systematic long-term astronomical observations by the

ancient world, Princeton 1971, 270-273. On the appropriate season for sailing from Crete today
see C. Lambrou-Phillipson, ‘Seafaring in the Bronze Age Mediterranean: the parameters
involved in maritime travel’, in Thalassa. L’Égée préhistorique et la mer (Actes de la troisième
rencontre égéenne internationale de l’Université de Liège, Station de recherches sous-marines et
océanographiques (StaReCo), Calvi, Corse, 23-25 avril 1990), eds. R. Laffineur & L. Basch
25. Aratus. Phaen. 744-747 (p. 264, ed. Loeb Library; note a should read (acronychal) rising,
not (cosmical) setting, as the cosmical setting occurred at the end of May at the time of Eudoxos,
the work of whom Aratos has translated.
26. Vitr. De Arch. 9.6.3.
27. From παραπτίγμαμι, to fix beside or near. The term is thought to derive from the way in
which the parapeg mata were published, in the beginning on wooden boards and later on stone,
with a hole beside each day for a movable peg. See Rehm and Dicks (supra n. 3). For fragments
of stone parapegma found at Miletos see H. Diels and A. Rehm, “Parapegmenfragmente aus
Milet”, Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften. Berlin
1904:1, 92-111.
29. See, for example, M. Blomberg, “The meaning of Χέλιδόν in Hesiod”, OpAth 19, 1992,
53f.
Minoans and their interest in achieving high precision orientations to the heavenly bodies. These results give us greater confidence in proposing that the Minoans by the Middle Bronze Age had developed a calendar which answered to the particular needs of their society. Whatever exchange of astronomical ideas they may have participated in with the cultures of Egypt and the Near East, their calendar was unique. It was a lunisolar calendar with elegant methods of intercalation based on knowledge of the motions of the sun, the moon, and Arcturus. It also used the positions of Arcturus, and probably other stars as well, as signs for important times in the economy, such as the beginning and end of the safe period for sailing in the Aegean.

It seems likely to us that this calendar of the Minoans and their astronomical knowledge were handed down via the Mycenaeans to the later Greeks, perhaps in the form of an oral tradition in verse.
Fig. 1. Knossos area indicating the location of the Aialias ridge in the east. The ridge is several hundred metres long and roughly parallel to the long axis of the central court of the palace. With permission of the editors of *The aerial atlas of ancient Crete*. 
Fig. 2. 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*. 
Fig. 3. Knossos. Corridor of the house tablets. Orientation 101.6°. The asterisk marks the position of the concave stone, and the numbers give those of the inscribed star (1) and double axes (2, 3). Adapted from The aerial atlas of ancient Crete.
Fig. 4. The reflection cast on the western wall of the corridor of the house tablets by the first rays of the sun on the morning of 22nd September 1996. As this was about half a day before the true equinox, only one half of the stone is illuminated. It is completely illuminated when sunrise occurs near the true equinox. In 1998, the sun will rise very close to the true equinox. The dark area in the stone is water.
Fig. 5. The shadow on the southern wall of the corridor of the house tablets touches the upper edge of the double axe at the moment the sun’s rays strike the concave stone at sunrise.
Fig. 6. A frontal view of the double axe in figure 5.

Fig. 7. The sun as it appeared from the concave stone in the corridor of the house tablets at the autumn equinox (upper left) and 11 days afterwards (upper right). Local solar mean time.
Fig. 8. View of the Ailias ridge from the corridor of the house tablets. Note the difference in ground level between that of the central court and the room of the column bases.
Fig. 9. Area of the palace at Zakros. Adapted from *The aerial atlas of ancient Crete.*

Fig. 10. Plan of the palace at Zakros. Orientation 37.6° for the western side of the central court. With permission of the editors of *The aerial atlas of ancient Crete.* Orientation of the northernmost corridor is 129.4°.
Fig. 11. Photo of the view to the cliff from the northern part of the west wing at Zakros.
Fig. 12. The cliff as it would have been seen from the corridor, through the doorway in the eastern wing opposite.

Fig. 13. The full moon rising at the southern major standstill as it would have been observed from the northern-most corridor in the west wing of the Palace at Zakros at the summer solstice 23 June 2034 BC, local solar mean time.