

THE ROLE OF ASTRONOMICAL ALIGNMENTS IN THE RITUALS OF THE PEAK SANCTUARY AT KOKINO, MACEDONIA

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Abstract: The archaeological locality 'Taticev Kamen' (Tatic Rock) is located in the north-eastern part of Macedonia, near the village of Kokino. During the Bronze Age, it was used as a mountain sanctuary by the people living in the region. The large number of excavated artefacts have confirmed the practise of several different cults. The site also has many characteristics of a megalithic observatory. The detailed archaeoastronomical analysis of the locality indicates that the periodic movements of the Sun and other celestial objects were observed from three different platforms, and their positions on particular dates were marked by notches on the nearby stone blocks. From the first platform, a marker for the midsummer sunrise was carved for the purpose of performing the ritual that has solar characteristics. The second platform is a central site from which the Sun was observed throughout the year, and the extreme sunrise positions on the days of the solstices and the equinoxes were marked. The newly-discovered third platform contains evidence of ritual activities similar to those at the Minoan peak sanctuaries on Crete. Using this platform as an observational site, we found four markers that pointed to the rising of Aldebaran over an interval of several centuries (from 1900 BC to 1500 BC). The heliacal rising of this star before summer and its rising in the evening sky in early autumn were probably connected with vegetative cycles and the organization of agricultural activities.

Keywords: Megalithic astronomy, stone carvings, solstices, equinoxes, heliacal rising

1 INTRODUCTION

The interest of ancient peoples in different objects in the sky was deeply influenced by their religious beliefs, social structure and the need to produce more food and gain more wealth. The never-ending cycles of the Sun, the Moon and the stars provided a feeling of security, and their continuous reappearance in the same positions in the sky promised the renewal of birth and death cycles in nature (Belmonte, 2010). A union of Earth and the heavens was reflected in the influence of the celestial bodies on the events in terrestrial and divine worlds. The coincidence of the menstrual cycle of women and the monthly lunar cycle has led to the thinking of a direct connection between human destiny and celestial bodies. The stars played an essential role in following vegetational cycles and in the organization of agricultural activities. In searching for cosmic order, the ancient 'astronomer-priests' observed the positions of the bright stars over several centuries. Eventually, they divided the sky into regions and made the first maps containing constellations. The periodic motion of the Sun and the Moon made possible the creation of simple calendars based on the solstice and equinox points and changes in the phases of the Moon. Although these calendars were initially made for religious/social/agricultural purposes, eventually they led to the development of astronomy and navigation (see Ruggles, 2005).

A lot of research has been conducted on the astronomical importance of megalithic structures in the Bronze Age. During this period, the population in Britain used a calendar that had 16 'months' consisting of 22 to 24 days each. It was made by dividing the year by the solstices and equinoxes, and then each of these four into two, then into two again (Ruggles and Hoskin, 1999: 2). The work of Hawkins (1963) on one of the greatest monuments of this period, Stonehenge, revealed several alignments pointing towards the ex-

treme rising and setting positions of the Sun and the Moon. In addition, a method was suggested for using the Aubrey holes to predict lunar eclipses by moving markers from hole to hole (Hawkins, 1964). Although Hawkins' results, and the later surveys by Alexander Thom at this site (e.g. see Thom et al., 1974; 1975) and other megalithic sites in Britain (Thom, 1969; Thom and Thom, 1978), attracted some controversy (e.g. see Atkinson, 1966; 1975; Ruggles and Hoskin, 1999), they undoubtedly proved the significant role of celestial objects in the religious and social life of Bronze Age people. The findings from Stonehenge also encouraged the search for similar megalith structures all over Europe.

It is possible that during the Bronze Age, Minoan people on the Mediterranean island of Crete built their palaces, sanctuaries and even graves according to astronomical alignments. As many researchers agree, the central courts of the main palaces were oriented toward the rising Sun on major calendar events, equinoxes or solstices. It has been suggested that some of the orientations in the palace at Knossos provided a simple method for regulating a lunisolar calendar and determining the beginning of the Minoan year, which coincided with the appearance of a specific phase of the Moon, most probably the new crescent moon following the autumn equinox. The method included the use of reflection which occurred at the precise moment of sunrise at the equinoxes and during the eleven days before the spring equinox and after the autumn equinox (Blomberg and Henriksson, 2001; Henriksson and Blomberg, 2011). Minoans oriented most of their graves towards the east and the rising Sun on solstices and equinoxes (Papathanassiou et al., 1992).

There is a significant possibility that the peak sanctuaries on the tops of the sacred mountains were also built according to astronomical alignments. For ex-



Figure 1: Sherds of a vessel that contains representations of the Sun (courtesy: National Museum, Kumanovo, Macedonia).

ample, it has been suggested that the axis of the main room in a small structure constructed around 2000 BC at the peak sanctuary of Petsophas was oriented towards the sunrise on the summer solstice at that time. The placement of the sanctuary was presumably with respect to the top of the conical-shaped mountain Modi, behind which the sunset at the autumn equinox occurred, and the remains of two walls are oriented toward the heliacal rising and setting of the bright star Arcturus (Blomberg and Henriksson, 2001). The heliacal rising of Arcturus also coincided with the festival of the grape harvest in early September (West, 1999), which was preceded by the sowing of the land around the autumn equinox.



Figure 2: The archaeological locality 'Taticev Kamen', near the village of Kokino.



Figure 3: Stone seats (thrones) on the first platform.

The characteristics of a Bronze Age mountain (peak) sanctuary, located in the centre of the Balkan Peninsula, on the top of the hill 'Taticev Kamen' (Tatic Rock), near the small village Kokino, will be presented in this paper. At the beginning of the second millennium BC it was the religious centre for the population in the surrounding region which had just abandoned a nomadic life style and adopted agriculture and stock-breeding. Since its discovery in 2001 (Stankovski, 2002), evidence of two Bronze Age religious cults has been identified, one of which has solar characteristics (Stankovski, 2007). Strong confirmation that some of the rituals in Kokino were related to Sun worship is revealed by the discovery of sherds of a vessel decorated with wavy lines combined with representations of the Sun (see Figure 1). These ornamental wavy lines are found in the early Bronze Age throughout the wider Balkans region, as well as in North-West Asia Minor, but never in combination with representation of the Sun (Blegen et al., 1950). Archaeological research on the recently-discovered ritual platform on the northern terrace at the Kokino sanctuary proves that a third religious cult was associated with it. In this paper we present an archaeoastronomical analysis of the locality and then discuss the possibility that it was used as a megalithic observatory. By measuring the celestial coordinates of several prominent markers that were artificially carved into stone blocks, we will consider whether they were made to point toward the rising positions of the Sun or other bright objects in the sky on particular dates.

2 THE PEAK SANCTUARY AT KOKINO

The peak sanctuary near the village of Kokino is located in the north-eastern part of the Republic of Macedonia, on the top of a large volcanic rock. With an altitude of 1013m it dominates the surrounding landscape (Figure 2). The excavated archaeological material dates from all phases of the Bronze Age, and was deposited during religious rituals that were performed over a period of around one millennium. In addition to the archaeological evidence, many topographical and archaeological characteristics of the site confirm its use as a sacred mountain. The position of the path leading to the top of the hill is on the south-eastern side, the side lit by the Sun. The large radius of visibility from the top of the mountain and the absence of nearby Bronze Age settlements that can be related to the material from that period found at the mountain-top site also confirm the prehistoric use of the locality as a huge extra-urban sanctuary for the people in this region.

Since Neolithic times, the people in the Mediterranean and Black Sea areas conceptualized the rocky mountain tops as places for communication with the gods, and even before the appearance of the first mountain cults, their stones were considered as sacred places inhabited by the gods. With the establishment of mountain cults, they acquired solar-chthonic characteristics, and researchers agree that most of them were related to the fertility cult of the Great Mother Goddess (Rutkowski, 1994). Hence, one of the rituals intensively performed at the Kokino sanctuary from the twentieth until the ninth century BC was probably related to this cult. Offerings, such as entire or fragmented vessels, ceramic weights, stone tools, moulds for casting bronze objects, and whorls were deposited

in the natural fissures in the rocks on the highest part of the mountain. Once deposited, the structures were enclosed with earth and small stones and delimited with flat stones, thus creating ritual pits. The very same rituals appeared in the Early Minoan II period (between 2800 and 2400 BC) on the peak sanctuaries in Crete (Nowicki, 1994).

The preliminary archaeoastronomical analysis of the Kokino sanctuary suggested that during the second millennium BC, and especially in its first centuries, the locality was used as an astronomical site where the motions of the Sun and the Moon were observed, and it is for this reason that it has been called ‘megalithic observatory’ Kokino (Cenev, 2006). Geological analysis of the locality indicates the presence of andezite rock, which was formed from indurated volcanic lava and has a natural predisposition to crack vertically and horizontally. This enabled ancient peoples to relatively easily carve out the religious platforms and stone markers that are the subject of our research.

3 THE FIRST AND THE SECOND PLATFORMS

The first platform is located on the west side of the mountain, with a latitude of $\varphi = 42^\circ 15' 47''$ and a longitude of $\lambda = 21^\circ 57' 9''$. The platform was also a ritual site arranged for the purpose of performing the second Kokino cult. The andezite rocks were flattened and a few large stone seats (thrones) were carved into the stone blocks (Figure 3). The thrones are aligned in a north-south direction, so that the people sitting on them look at the eastern horizon and towards a vertical rock that is about 20m higher than the platform.

A stone marker is carved into this rock, forming an aperture which was probably covered in the past. Using modern geodetic instruments, we measured its horizontal coordinates from the thrones’ position and calculated its declination using the following formula:

$$\sin \delta = \cos A \cos \varphi \cos h + \sin \varphi \sin h \quad (1)$$

where A is the azimuth measured from the north horizontal point, h is the altitude over the horizon and φ is the observer’s geographical latitude. The horizontal coordinates of the stone marker were: $A = 76^\circ 05' 10''$ and $h = 12^\circ 01' 40''$. When a small correction ($\rho = 4.6'$) due to atmospheric refraction is taken into account, the calculated declination of the object filling the aperture of the stone marker is $\delta = 18.26^\circ$. At present this coincides with the declination of the Sun in mid-May and at the end of July (31 July or sometimes 30 July). Due to precession, at the beginning of the second millennium BC the Sun rose through the marker a few days later, i.e. at the beginning of August on the second date.

Archaeological analysis confirmed that the second date coincided with the last days of the harvest in this region. This was the most likely time of the year when a ritual that had solar characteristics would be arranged on the throne’s platform (Stankovski, 2007). The end of the harvest had a special meaning for the Bronze Age agricultural peoples living in the surrounding valley. At the beginning of August the rising morning Sun passed through the aperture in the notch on the highest point of the site and along the right edge of an artificially-cut trench, creating the effect of a sunray (Figure 4 and Figure 5). This ray fell on the lower throne platform, illuminating just one seat (the second

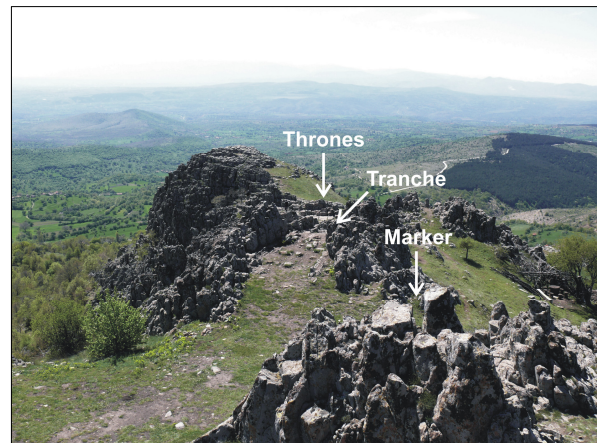


Figure 4: Ritual marker viewed from the highest, eastern part of the locality.

from the left), upon which the person who had a principal role in the execution of the ritual probably sat. This could have been the tribal leader, in the role of the chief priest, and it may be that we are dealing with an explicit illustration of ‘hieros gamos’, a concept of a sacred union of the celestial divinity, the Sun with the Great Goddess Mother, a union that would provide a rich harvest and a cyclic renewal of nature. There is also evidence of ‘hieros gamos’ on Crete, and it has been suggested that it took place during the celebrations around the autumn equinox (Koehl, 2001).

The second platform, which consists of a flattened stone block (Figure 6), is located near the platform with the thrones. No archaeological artefacts have been found on it, which leads us to conclude that it was not used for ritual activities. However, several

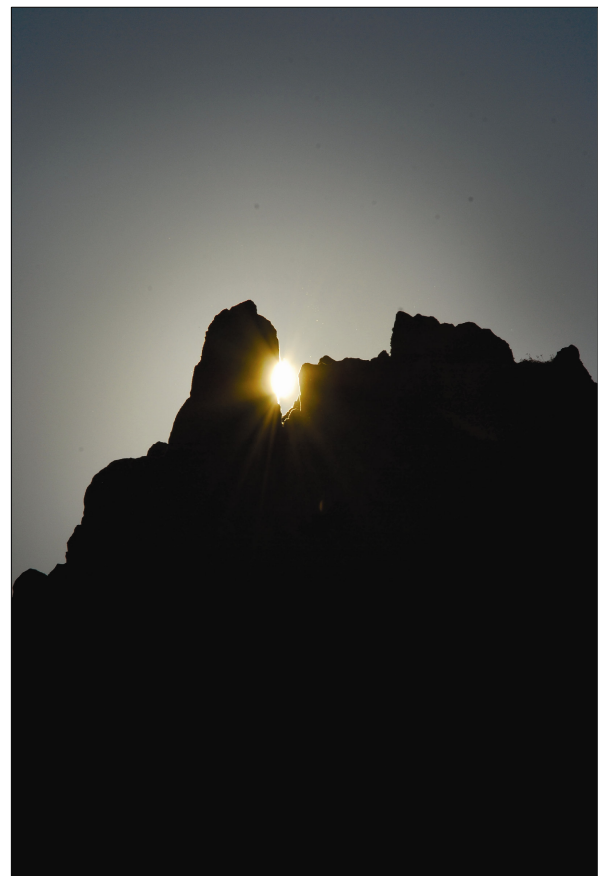


Figure 5: Rising Sun in the ritual marker at the end of July.



Figure 6: The observing position on the second platform.

prominent notches can easily be recognized on the nearby vertical rocks that represent the eastern horizon (skyline) for the observer standing on this platform. We measured their horizontal coordinates and calculated their declination using equation (1). The results showed that the declinations of the two markers coincide almost exactly with the declination of the Sun



Figure 7: Sun markers observed from the central position (the second platform). S1 (left) = Sun summer solstice, S2 = Sun spring and autumn equinox; S3 (right) = Sun winter solstice.

Table 1: Declinations of the Sun markers measured from the second platform, compared with the theoretical values of the Sun declinations at summer and winter solstice and vernal and autumn equinox for the year 2000 B.C.

	Theoretical Declination (°)	Measured Declination (°)
Sun summer solstice	23.9	24.1
Sun winter solstice	-23.9	-23.9
Sun vernal and autumn equinox	-0.11	-0.19



Figure 8: Rising Sun on the day of summer solstice.

on the days of the summer and winter solstices, and the declination value of the third matches the Sun's declination on the days of the spring and autumn equinoxes (Figure 7). In Table 1 the declinations of the three markers are compared with theoretical values of the Sun's declinations at the solstices and equinoxes for the year 2000 BC. In Figure 8, the Sun is seen to rise in the notch that marks the summer solstice.

These findings indicate that the second platform was probably not used for cult activities, but was a central position from which the sunrise was observed throughout the year. Only one man could stand on the platform, and he would communicate with another person who would carve the notches on the nearby stone blocks that marked the three special positions of the rising Sun on the solstices and equinoxes, according to instructions provided by the observer on the platform. Undoubtedly, as with other similar ancient observatories, the purpose of this observational platform was not to provide scientific knowledge. In ancient times interest in objects in the sky usually had a religious dimension, and the sky-watchers were the local priests who in such a way determined the timing of the seasons and the natural cycles that depended on them. The Kokino priests probably found a connection between the periodic movement of the Sun and the vegetative cycles, and by marking its position at certain times of the year they were able to determine the 'right moments' for organizing agricultural work and performing related religious rituals. In the religious system of the Bronze Age people, the Sun God had a significant role in the periodic changes of the vegetative cycles, and its movement was carefully followed by the local priests. The returning of the sunrise point from its extreme positions in summer and winter guaranteed the renewal of nature, and the equinox points marked the change of the summer and winter seasons.

4 THE THIRD PLATFORM

The third recently-discovered ritual platform is located on the northern terrace, where circular stone constructions resembling tumuli were discovered (Figure 9). They are marked by large stones and have diameters of between 0.9m and 2.0m. Ceramic fragments, several vessels and stone tools covered with earth and fragments of stone were found inside. Some of the stone constructions cover the ritual pits that were formed around natural fissures. The fact that in both structures (the ritual pits and circular stone constructions) chronologically and typologically similar archaeological material has been found allows us to conclude that for a long period both types of structures coexisted. Some of the fragmented ceramic material had traces of burning, and this fact and the remains of two fireplaces indicates the use of fire during ritual activities. A funnel-like vessel was also found, which was probably used for pouring out fluids. The numerous stone hand mills, as well as fragments of movable ovens (puranoi) lead us to conclude that ritual food was prepared.

Although the meaning of such rituals could not be precisely determined from the archaeological findings, there are some obvious similarities to the construction and cult practices of early Minoan mountain sanctuaries on Crete (originating from the period 2200-1900 BC), where in a restricted circular area, animal and human figurines, pottery and scattered pebbles were

discovered (Rutkowski, 1988). Most of these were identified as landmarks because of their location on the landscape. The shape and height of the rocks at the Kokino site, as well as their volcanic origin, makes them unique and they are very conspicuous from the surrounding valleys.

In that context, an important finding that relates the Kokino sanctuary to those of the early Minoans is the discovery of three ceramic figurines on the recently-excavated northern terrace: a female torso, an animal figurine and a lower part of a human leg with a foot. They are almost identical to the figurines from the peak sanctuary at Traostaloss in Crete (Faure, 1963). The Cretian figurines (which are no bigger than 20 cm in size) are shaped like animals or parts of the human body, and their main function was to provide fertility and good health. Since the beginning of the Minoan mountain religious practices they have usually been burnt and then stored in the sanctuaries (Nowicki, 1994). As for the use of peak sanctuaries as astronomical observatories, it has been suggested that some of the terracotta figurines and body parts found could be explained as representations of different constellations or their component parts (Blomberg, 2009).

The preliminary examination of the Kokino site indicated that the rocky hill in front of the third platform on the northern terrace contained artificially-made notches. Around 16m higher, its stone blocks cover the southeast horizon of the observer who is standing on the third platform. Therefore, we performed detailed astronomical analysis in order to find out whether the notches mark the position of some celestial objects. Precise measurements of the positions of several noticeable notches were made. The central position, which was assumed to be the observing site of the ancient skywatcher, is the ritual site on the third platform (Figure 10), with the following values of the latitude and longitude, respectively: $\phi = 42^{\circ} 15' 48''$ and $\lambda = 21^{\circ} 57' 10''$. In the process of performing the measurements and drawing conclusions from the results, we were aware of the significance of choosing particular stone markers for investigation. Since some cracks in the rocks were made naturally, we paid attention to markers with signs of human intervention, as well as to those which were undoubtedly noticeable on the night (or day) horizon. From the horizontal coordinates of the selected stone markers (Figure 11), we calculated the declinations of astronomical objects from equation (1). The horizontal coordinates of the markers and their declination values, along with the corrections due to the astronomical refraction, are presented in Table 2. It can be seen that the calculated values of the declination of the object appearing at these markers in the past, show a remarkable coincidence with the declinations of the star Aldebaran in the constellation Taurus, taken from the 5000-year star catalogue of Hawkins and Rosenthal (1967: 147), in hundred-year intervals. This coincidence remains for the period from 1900 BC until 1500 BC, which is from the beginnings of the usage of the site as a sanctuary and as an observatory, and through the Middle Bronze Age. The positions of stars on the celestial sphere vary slowly in the course of the centuries, and the possibility of 'placing' another star with similar brightness as Aldebaran in all four markers in this time period is practically negligible.



Figure 9: Circular stone constructions at the north part of the locality.

According to the archaeological evidence found at the locality and on the northern terrace, the Aldebaran markers were made in a period of intensive religious practise, and in one of the cults that was arranged on the throne's platform the periodic motion of the Sun played a crucial role. Unfortunately, no written records were found on the site dating from the Bronze Age, so we can only speculate on the exact time of the year when the appearance of the main star in Taurus was observed, as well as its connection to the cult. Aldebaran is one of the brightest stars at these latitudes with a magnitude of 0.89, and it rises in the



Figure 10: The central observing position on the third platform.



Figure 11: Stone notches that mark the position of Aldebaran and the 'doubled' marker for the Sun's spring and autumn equinoxes (dashed lines).

Table 2: Horizontal azimuth and altitude, astronomical refraction corrections and declinations of the four markers observed from the third platform on the northern terrace. The markers' declinations are compared with the declinations of the star Aldebaran for the years 1900, 1700, 1600 and 1500 B.C., taken from the 5000-year star catalogue (Hawkins and Rosenthal, 1967: 147).

Marker Number	Azimuth	Altitude	Refraction correction (')	Declination (°)	Catalogue declination (°)	Year (BC)
1	105°15'44"	17°40'13"	3.02	1.03	1.03	1900
2	103°40'44"	17°32'46"	3.02	2.02	2.10	1700
3	101°06'17"	15°51'49"	3.32	2.64	2.62	1600
4	99°23'31"	14°56'14"	3.43	3.21	3.15	1500

at dawn before summer, or after sunset in autumn and winter. Hence, one should not be surprised that its position in the sky was marked by the megalithic people in Kokino. A question arises about the role of Aldebaran in their religious beliefs and in the organization of their everyday life and agricultural activities. Was it simply a prominent celestial object whose rising at particular times of the year coincided with the land cultivation processes, on which the survival of the community depended? Or was it a part of a more complex picture of the sky that the Kokino priests developed, as around 2000 B.C. the constellation of Taurus and its principal star were positioned very close to the vernal equinox point?

Supporting the latter possibility is the discovery of another noticeable marker near those that point to Aldebaran, and this is shown by dashed lines in Figure 11. It is the most prominent of all those observed from the third platform as it is 'doubled', consisting of two parallel markers of identical shape, carved one in front of the other on two different stone blocks. According to the measured values of its azimuth, $A = 106^{\circ} 58' 14''$ and altitude $h = 18^{\circ} 02' 42''$, and taking into account the refraction corrections ($\rho = 2.7'$), we calculated the declination of the celestial object rising in the past through this marker. It is $\delta = 0.14^{\circ}$ and coincides well with the declination values of the Sun on the days of the spring and autumn equinoxes. The existence of identical notches on two blocks creating an effect of a sunray, as in the ritual marker on the first platform, also confirms the idea that the 'doubled' marker was most probably pointing to the sunrise on these particular calendar dates.

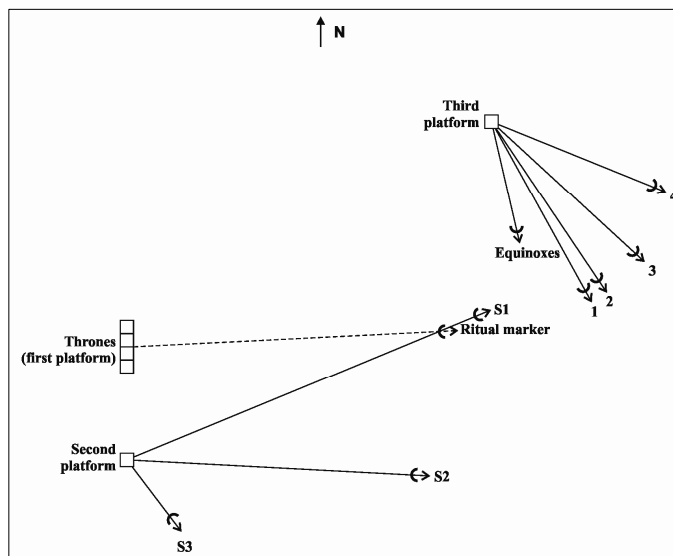


Figure 12: Map of the locality with the three platforms and markers' alignments. S1 = Sun summer solstice, S2 = Sun spring and autumn equinox, S3 = Sun winter solstice; 1.2.3.4 = Aldebaran's markers.

The position of the third platform and the alignments of its markers relative to the other two platforms are shown on Figure 12.

5 DISCUSSION

The brightest star in the constellation of Taurus and the prominent open star cluster close to it, the Pleiades, are considered to be among the first objects in the sky observed by man (Rappengluck, 1999). The seven brightest stars in the Pleiades, followed by Aldebaran ('aldebaran' means 'follower' in Arabic), were important to many ancient cultures (Worthen, 1995). Their rising after sunset or before sunrise marked the beginning of new seasons and was used in the creation of the first calendars (Ruggles, 2005: 45, 177-178, 183, 267-269, 322). There is strong evidence that prominent star patterns were recognized by hunter-gatherers in the Palaeolithic era (from 33,000 to 10,000 BC). On a panel in the cave La-Tête-du-Lion, and on a similar one in the cave Lascaux, there is a painting of a female bovine looking toward the east. It represents the constellation Taurus, where the eye of the bovine marks the red Aldebaran, and two clusters of dots on the face and above the animal relate to the Hyades and Pleiades open clusters respectively (Rappengluck, 1999). For Palaeolithic man these star patterns were used for orientation in space- and time-reckoning, and they played a significant role in his spiritual life (Belmonte, 2010). In Indian astronomy, the fourth of the 27 Nakshatras (asterisms) in the lunar path is Rohini (Aldebaran), or 'the rising one'. Her other name was Suravi, meaning 'the celestial cow'. From around 2300 BC, the ancient Chinese people celebrated the full moon passing the Pleiades around the autumnal equinox (Kistemaker and Xiaochun, 1997). In ancient Egypt the constellation Taurus and its main red star were related to Hathor, the cow goddess, connected with the inundation of the Nile and the abundance of the grape harvest (Muller, 2004). In Bronze Age Europe, the rising of Taurus and its prominent stars above the eastern horizon during October-November coincided with the period of ploughing and sowing the land in the Mediterranean area.

From approximately 4000 BC to 2000 BC, the vernal equinox point was located within the boundaries of the zodiacal constellation Taurus and near to its main star. There is strong evidence that the twelve constellations surrounding the ecliptic were formulated over the period of several millennia (Rogers, 1998) and named not according to their outward appearance, but as memory markers of areas in the celestial sphere which include four special positions of the Sun on its annual motion along the ecliptic: the spring and autumnal equinoxes and the summer and winter solstices (Gursh-

tein, 1993). The period of the year when the Sun was in the vernal equinox was the starting point of creating many ancient calendars. As a symbol of male fertility, the bull had been an important animal of worship for many Indo-European cults since the seventh millennium BC, influencing various aspects of ancient Egyptian religion, as well as the famous legend of the Minotaur on Crete. Around 2000 BC., precession shifted the sunrise at the spring equinox inside the boundaries of the constellation Aries. Our research shows that the Aldebaran markers in Kokino were made within this 'transition period'.

By no means are we suggesting that the constructors of Kokino were familiar with the phenomenon of precession. However, the markers found on the second astronomical platform and the newly-discovered equinox marker on the third prove that they observed the annual motion of the Sun and empirically determined its extreme rising positions at the solstices and equinoxes. Having small altitudes above the equator, i.e. very small declination values (around 1 arc degree at 1900 BC), Aldebaran was close to its intersection with the ecliptic—the equinox point. However, at the spring equinox Aldebaran rose in the east after the Sun and it was not possible to observe it on this exact date. We guess that the equinox marker was probably made according to observations from the second platform, which was used strictly for this purpose and not for rituals. The markers pointing to Aldebaran could determine another very important event—its heliacal rising in the weeks following the spring equinox.

The heliacal rising of a celestial object defines the period of the year when it first becomes visible above the eastern horizon, just before sunrise, after a period of time when it had not been visible. The heliacal rising of certain bright stars marked the beginning of time and agricultural cycles in many ancient civilisations. The most famous example is the heliacal rise of Sirius that occurred just before the annual flooding of the Nile, during the period of the Middle Kingdom (e.g. see Dodd, 2005; Schaefer, 2000). The ancient Egyptians based their calendar on this event and devised a method of telling time during the night according to the rising of 36 different stars (Parker, 1974). The peak sanctuaries of Petophas and Traostalos on the island of Crete were oriented towards the heliacal rising of the bright star Arcturus (Blomberg and Henriksson, 2001). According to some scholars, the civil New Year in the agricultural regions of the Indus Valley in the fourth millennium BC started with the autumnal equinox (Abhyankar, 1998), but there are some opinions that it was in connection with the heliacal rising of Aldebaran after the spring equinox (McIntosh, 2008; Subhash, 2010). The heliacal rising of Aldebaran also marked the forthcoming wet season, and it was later replaced by the Pleiades.

According to computer simulations of sky maps with the latitudes of the Kokino sanctuary, the heliacal rising of Aldebaran in the Early Bronze Age occurred between the spring equinox and the summer solstice. Using *Redshift 4* software, we determined the variation of the altitude of Aldebaran above the astronomical horizon at sunrise, starting from the day of the spring equinox for the year 1900 BC, which is approximately when the first marker was made (Figure 13). *Redshift 4* uses the Julian calendar for 1900 BC, so the

spring equinox does not occur on 21 March, but near 7 April. On this day, the Sun was near the Pleiades in Taurus, but in front of Aldebaran, so that the star could not be seen on the sky. As the weeks progressed, the Sun moved at an average rate of 0.99° per day along the ecliptic to Gemini and then towards Cancer. According to Figure 13, about 35 days from vernal equinox, Aldebaran rose at the eastern astronomical horizon for a brief moment before sunrise, but it could not be seen by the observer at the third platform because it was hidden behind the stone blocks. The 'real' heliacal rising occurred some 67 days after the equinox, when it first appeared in the stone marker at dawn. For the observer standing on the third platform, the rock hill with the markers on top was his apparent eastern horizon and Aldebaran's passage through the marker determined its actual heliacal rising for this observer. The dividing day between the two situations, when the star cannot be seen at dawn and when it clearly appears in the stone marker some short time before sunrise, is the day of its heliacal rising. The eastern sky at dawn on the day of heliacal rising of Aldebaran in the epoch 1900 BC as seen from the third platform is shown in Figure 14. Aldebaran is precisely in the position of the stone marker. Very similar results were obtained for the periods of making the other markers. Bearing in mind the impact of atmospheric refraction and absorption, we can conclude that Aldebaran's heliacal rising above Kokino in the first centuries of the second millennium BC was some 67 ± 3 days after the vernal equinox.

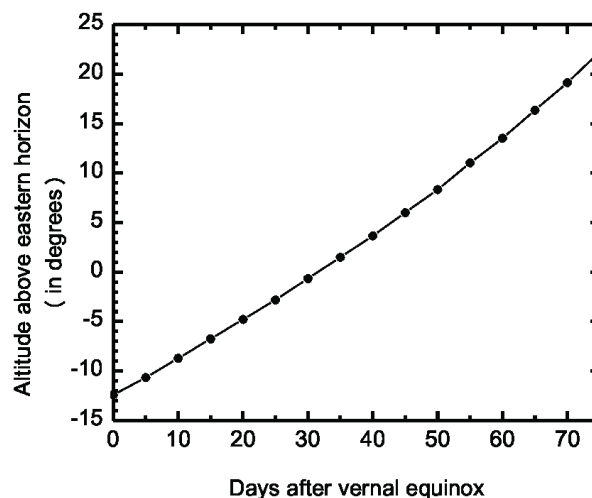


Figure 13: Altitude of Aldebaran above the eastern horizon during sunrise as a function of days after the vernal equinox.

It was a unique event that happened just once a year during the ripening of the crops. Hence it is quite possible that the star's morning appearance was a part of the annual cycle of agricultural activities with which the religious practice was related. Due to precession and proper motion, changes in the positions of stars in the sky were only noticeable over long periods. The Kokino sanctuary was active for more than one millennium (from around 2000 BC until 800 BC) and so it is not surprising that more than one marker for Aldebaran was made. As the star moved over the centuries it shifted more and more from the old marker (and from the equinox point), and the differences between the current observations of the Kokino priests and those performed by their predecessors would have be-

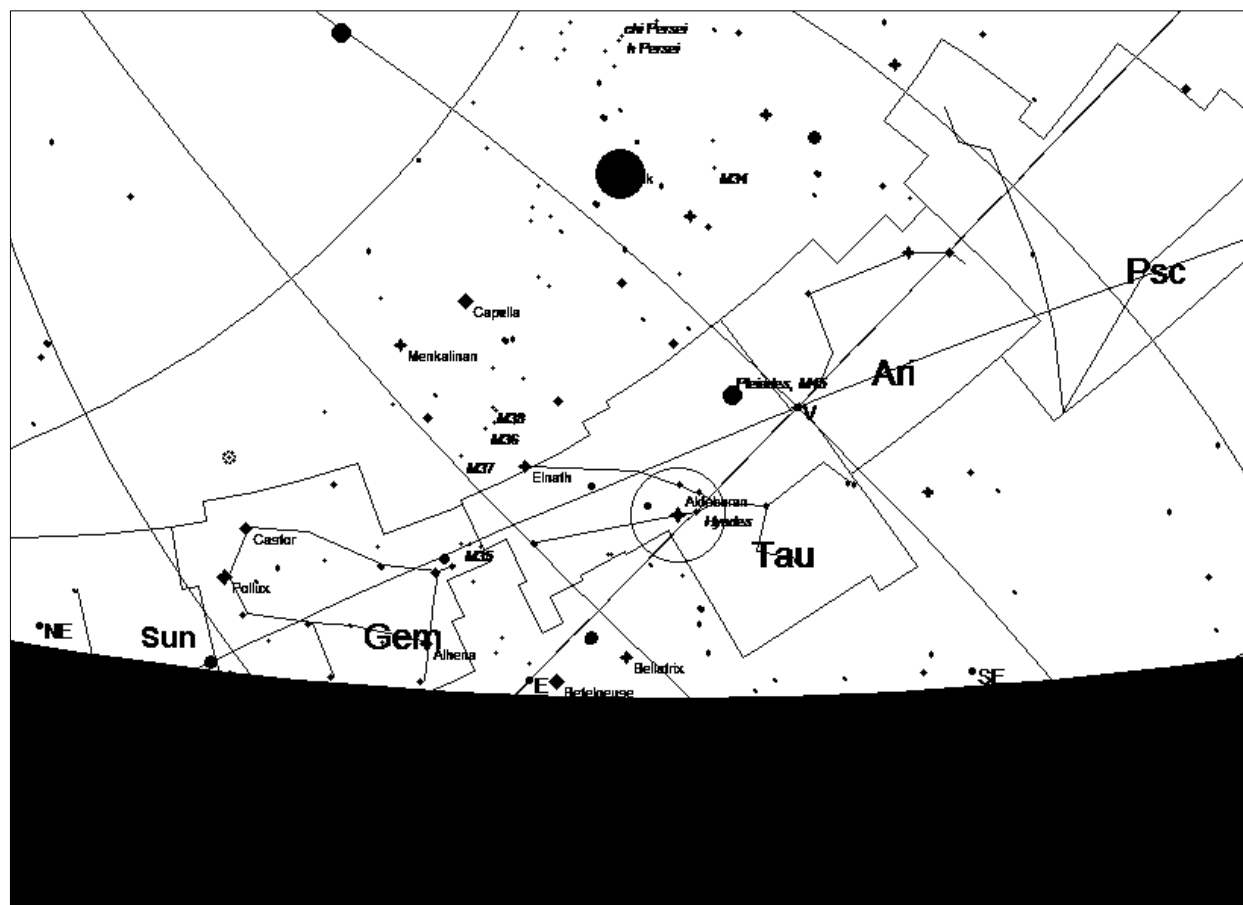


Figure 14: The eastern sky at the time of sunrise 67 days after the vernal equinox in 1900 B.C., as observed from the third platform. Aldebaran can be seen in the centre of the circle as it heliacally rises in the marker position. The image has been generated using *Redshift4* software.

come increasingly obvious, despite their not knowing the source, the limitations of the primitive observational techniques and the constancy of tradition. These differences were probably attributed to the will of the gods, and eventually would lead to the carving of a new marker, as the old one was no longer useful. If Aldebaran was related to the equinox point, then its displacement in time from this special position of the Solar God could be the reason that no markers were found that dated after 1500 BC. The absence of newer markers could also have been connected to the fact that, eventually, the locality lost its importance as an astronomical observatory.

It is also possible that Aldebaran was observed in early autumn. It was one of the brightest stars dominating the eastern evening sky around the days of the autumn equinox. At this time of the year, it rose above the eastern horizon soon after sunset, and appeared from behind the stone blocks and in the markers some time later, with the Pleiades above it. As previously mentioned, this was the period of the year for sowing and ploughing of the land in the Mediterranean area, and for the grape harvest. The appearance of such a bright star could signify that the priests had to perform rituals at the sanctuary and light fires that would be used as indicators by the farmers in the surrounding area to start particular agricultural activities.

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