Archaeo-astronomical characteristics of the Kokino archaeological site

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Abstract. In the North-East part of Macedonia, near to the peak Tatikjev Kamen, an archaeological site with vast quantity of artifacts, dated in the Bronze Age, was discovered in 2001. For the first time in Republic of Macedonia (FYROM), comprehensive archaeo-astronomical analysis of this site, providing extraordinary important results, was performed in 2002. The site contains a lot of materials typical for a megalithic observatory, 3800 years old. Three stone markers, pointing out the places of the sunrise on the days of the summer and winter solstice, as well as the vernal and autumn equinoxes, were found there. Four stone markers, indicating the places of the full Moon rise above the horizon, are recognized too. They are used in the days when the Moon has maximum or minimum declination - two of them in the summer and two of them - in the winter. There are also two other stone markers used for measuring the length of the lunar month in winter - when it has 29 days, and in summer - when it has 30 days. These markers give clear evidences that the ancient Balkan inhabitants used the observatory not only to monitor the movement of the Moon, but also to develop the lunar calendar with 19-year cycle. The archaeo-astronomical analysis presents also an evidence for the existence of one very characteristic stone marker, used for pointing out the sunrise position in a very important ritual day. This is the day when special ceremonies related to the end of the harvest, as well as to the ritual unification of the community leader with the God Sun, were performed. (Colour versions of the illustrations are presented as Appendix on the site of the journal.)
Key words: archaeo-astronomy, Kokino

Архео-астрономически характеристики на археологическото находище Кокино

Гьоре Ценев

През 2001 г. в северо-източната част на Македония, недалеч от връх Татикев камен, беше открито археологическо находище с много голямо количество артифакти, датирано в Бронзовата ера. През 2002 г. за първи път в Република Македония, беше направен всестранен анализ на това археологическо находище, дал множество извънредно важни резултати. Находището съдържа множество материали, типични за една мегалитна обсерватория на възраст 3800 г. При изследването бяха намерени три каменни маркера, отбелязващи местата на слънчевия изгрев в дните на лятното и зимното слънцестоене, пролетното и есенното равноденствие. Бяха намерени и четири каменни маркера, отбелязващи местата на изгрева на пълната Луна над хоризонта в дните на максимална и минимална деклинация на Луната - два за през лятото и два за през зимата. Има и два други каменни маркери, използвани за измерване на лунния месец през зимата, когато той има 29 дни и през лятото, когато той има 30 дни. Това са ясни свидетелства, че древните обитатели на Балканския полуостров са използвали обсерваторията не само за наблюдаване на моментите на появата на Луната, но и за създаване на лунен календар с 19 годишен цикъл. Архео-астрономическият анализ представя също така свидетелство за съществуването на много характерен каменен маркер, използван за отбелязване на позицията на слънчевия изгрев в един много важен ритуален ден. Това е денят на провеждането на специални церемонии, свързани с края на прибирането на реколтата и свързани с унификацията между лидера на общността и Бога Слънце. Цветни версии на илюстрациите са представени като Апендикс на сайта на журнала)

Introduction

In the North-East part of Macedonia, on the footpath of a mountain peak Tatikjev Kamen, near the village of Kokino, an archaeological site from the Bronze Age was discovered in 2001. This site has the following geographical coordinates: latitude $\varphi =$

Фиг. 1. Kokino Megalithic Observatory

$42^{0}\, 15'\, 47''$ and longitude $\lambda = 21^{0}\, 57'\, 32''$. In the space this site is oriented to West-East and its dimensions are 90 m length and 50 m width (Fig. 1). The geological analysis has shown that we are dealing with one andezite neck (indurate lava in the volcano channels) that most probably can be dated in the youngest phase of the volcano activities traced in the Kratovo-Zletovo area in the time of latter Pliocene (Doredevic 2003). The andezite rocks have natural disposition to crack vertically and horizontally and to create quadrangle pillars and platforms out of the indurate lava. These natural structures and characteristics of the andezite rocks most probably simplified the work of the ancient inhabitants, while they carved and created this place as a sacred mountain, but also as an ancient observatory.

All movable materials on the site are located on two scaled platforms with 19 m elevation of difference between them. Due to their size and specific shape four stone seats made in the rock, with North-East alignment (Fig. 2), are dominant on the lower platform. Today they are known as thrones. In that way a person seated on one of the thrones is turned toward the east horizon, thus among the archaeologists arose an idea of existence of a possibility that celestial objects rise to be observed in that way (Stankovski 2002).

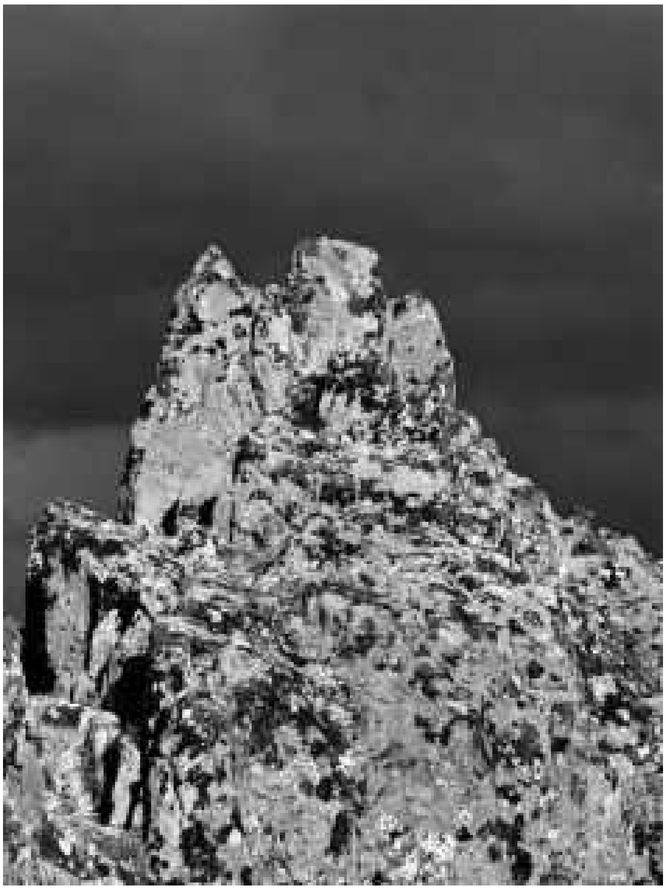
For the first time in Republic of Macedonia (FYROM) comprehensive archaeo-astronomical analysis of an archaeological site was performed in 2002(Cenev 2002). The analysis confirmed that this extraordinary place contains a lot of materials typical for one ancient observatory dated in the time of so-called megalithic culture. At the same time, the analysis showed that places for observations of the Sun and Moon movements are located on the lower platform, and all other markers for observation and marking

Фиг. 2. The thrones of Kokino

the rise of the Sun and full Moon are located on the upper platform. Some of the stone markers were found preserved in almost their original state, but some of them were damaged in great extension, probably as a result of the catastrophic earthquakes happening in Macedonia every 500 years in average.

Measurements and results

While conducting archaeo-astronomical analysis of the site, the references and methodology of Professor Gerald Hawkins used during his archeao-astronomical analysis of the famous site Stonehenge in England were utilize (Hawkins 1963). Even during the first visit of the site specially carved markers in dominant stone block on the upper platform were noticed (Fig. 3). For the observer located in the lower platform these stone blocks are actually his/her East horizon, and in the past this marker marked the place of the rise of Sun and the full Moon. Therefore, it was very natural to try to find one central position that will provide view over all stone markers. The lower platform of the site encloses three clearly carved places presumably used as central position for observations of Sun and Moon movements. The first and most suggestive places are the stone seats or the thrones, where the ancient person was sitting and observing the sky and celestial objects. The other two places are carved in such a way that only one man can be placed there in a standing position. The analysis made in all possible directions



Фиг. 3. Sunrise stone marker in the solstice day

(Fig. 4) showed that place number three is the only place from where all East horizon markers, marking the positions of Sun and full Moon rise, can be seen.

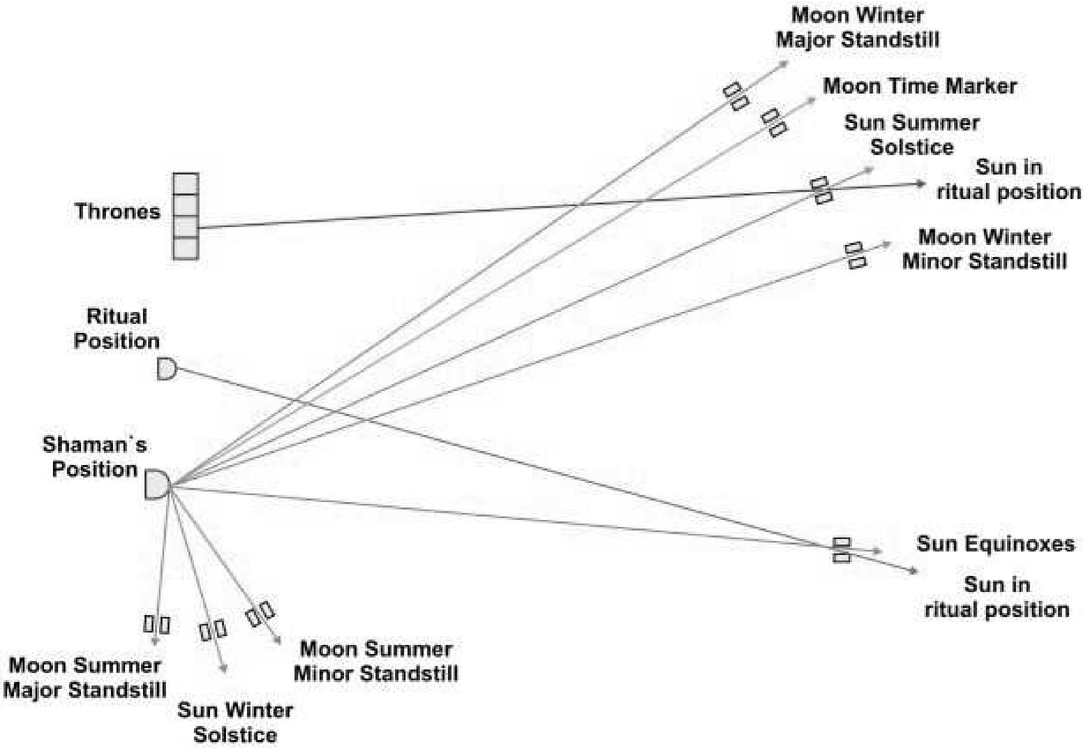
Sun and full Moon rise markers

The main idea of the archaeo-astronomical analysis was to measure the horizontal coordinates of all specially carved East horizon stone markers observed from the central position of the site, then using the formula for the transformation to convert them into the equatorial system, and calculating the declination value to reach a conclusion concerning the nature of the celestial object, whose rise was marked on the East horizon. For that purpose the following formula was used:

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

where δ is the declination of the celestial object, A is the azimuth, measured from the Northern horizon point, h is the elevation over the horizon, and φ is the latitude of the site.

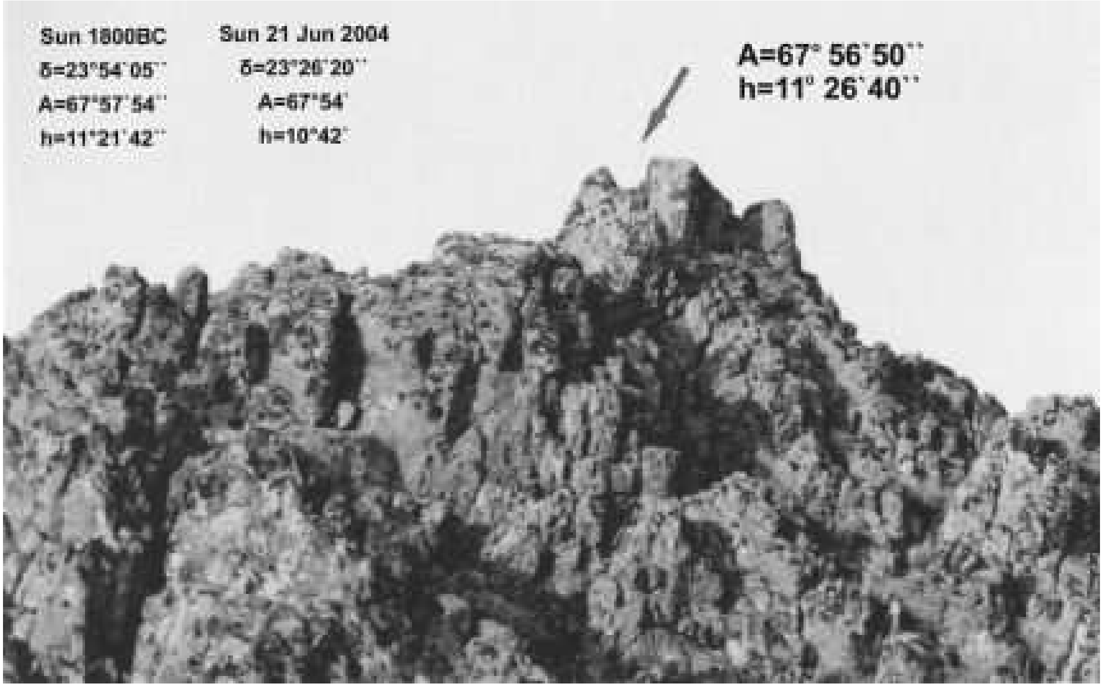
These measurements were performed with assistance of geodesist Chedomir Arsovski, and the instrument used was Total Station Lica 307 with laser, that enables us to obtain results with great precision (Cenev 2002, 2006). As an illustration of the measurements and analysis performed I shall present the following example of the marker



Фиг. 4. Analysis on the markers alignments

used for marking the position of the sunrise on the East horizon on the day of the summer solstice. The measurements of the horizon coordinates of the marker have provided the following values: $A = 67^0 56' 50''$ and elevation $h = 11^0 26' 40''$" (Fig. 5). A calculation mistake due to the refraction impact ($\rho = 3.1'$) can be anticipated. Using the given values in the above mentioned formula, we can calculate that the declination of the celestial objects risen in the past and marked with this stone marker, has value of $\delta = 23.9^0$. This is the declination value of the Sun on the day of the summer solstice in 1800 BC.

Due to the precession impact the current value of the Sun declination on the day of the summer solstice has a different value (Fig. 5). Thus, nowadays on the day of the summer solstice, viewed from the observatory central position, the Sun over the stone marker will rise lower and more on the left than 3800 years ago. That can be nicely seen in the photos of the Sunrise over the stone marker taken on June 21, 2005 or on the day of the summer solstice (Fig. 6). Calculations and documentation of the stone markers, marking the typical Sun and full Moon rise points on the East horizon were performed using the similar methods measurements. It was concluded that there are the following easily recognized stone markers observed from the site central position: three stone markers, marking the places of the East horizon Sun rise on the days of the summer solstice, on the days of the vernal and autumn equinoxes, as well as on the days of winter solstice (Fig. 7). The movement of the Moon on the sky is not so simple, and the places of the East horizon full Moon rise repeat over the longer periods of time. Nevertheless, and of course for our big surprise, the site presented us four stone markers used by the ancient inhabitants for marking places of the full Moon rise above the East horizon, in winter when the Moon has maximum and minimum values



Фиг. 5. Coordinates of the Sunrise stone marker

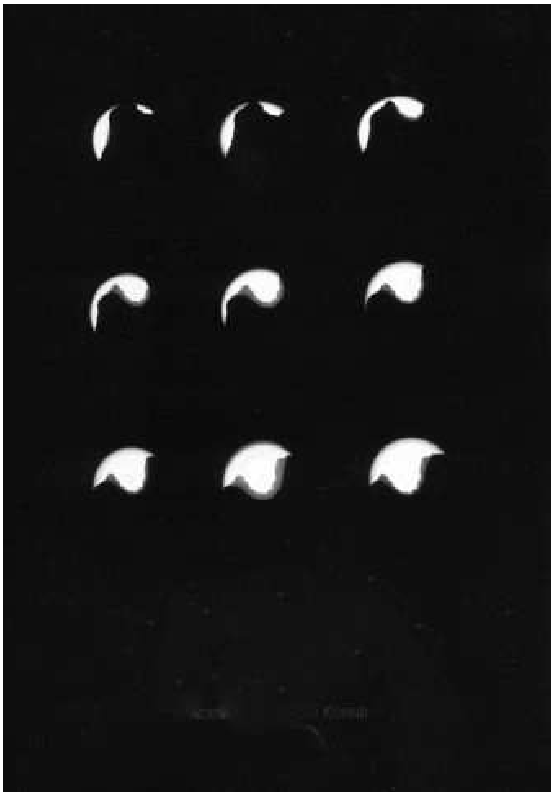
of the declination, as well as in the summer in days when also there are maximum and minimum values of the declination (Fig. 8). These values are given in Table 1, where for comparison the values of the markers of the famous Stonehenge according to the measurements and calculations of G. Hawkins are also provided (Hawkins 1963), as well as the theoretical values of the declination for the objects in 1800 BC.

Таблица 1. Declinations of the Sun solstices ans Moon standstills in epochs of Stonehendge, Kokino and today

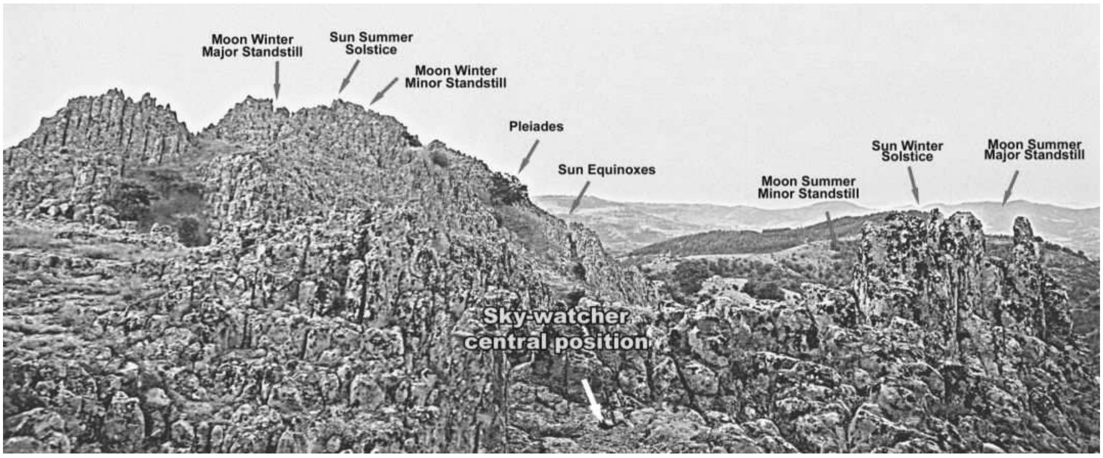
	STONEHENGE	KOKINO	2000 BC
Sun summer solstice	23.9°	23.9°	23.9°
Sun winter solstice	−23.9°	−23.9°	−23.9°
Moon winter major standstill	29.0°	28.2°	28.2°
Moon winter minor standstill	18.7°	20.4°	17.9°
Moon summer major standstill	−29.0°	−30.2°	−30.0°
Moon summer minor standstill	−18.7°	−18.6°	−19.6°

Sunrise over the ritual marker

The archaeo-astronomical analysis presented also an evidence for the existence of one very characteristic stone marker used for marking the sunrise position on a very impor-



Фиг. 6. Sunrise phases on June 21, 2004



Фиг. 7. Central position and visibility of all stone markers

tant ritual day dedicated to the ceremonies performed for the last day of the harvest (Fig. 9). The analysis showed that Sun in the course of one year twice fills the aperture of the marker: first time in the middle of May - period having no special meaning in relation to the agriculture, and second time - at the end of July, when actually it is

Фиг. 8. Full Moon rise seen to the marker direction

the end of the harvest. The archaeo-astronomical analysis demonstrated that having in view the fact that the celebration of the end of the harvest was of a very huge importance for the ancient farmers, the entire site was especially arranged for performance of the rituals on that day. This stone marker is carved into a vertical rock in such a way that on a ritual day it is seen completely in the aperture, providing an effect of sunray. In the past this marker most probably was covered (Fig. 10) intensifying the sunray effect. This sunray moves right along the right margin of the trench and falls only on one of the thrones, where at that time the leader of the tribe was sitting. The trench that is carved in the block of rocks is of great importance for the entire ancient observatory. Viewed from the mountain top in the East-West direction, the left margin of the trench is block of rocks, where a sunrise marker used in the summer solstice day is carved, and the right margin is carved with exact width needed just one sunray from the ritual marker to fall only on one of the thrones (Fig. 11).

Discussion

The archaeo-astronomical analysis proved that the site had the central position where the ancient observer stood and only from that place observed the rise of Sun and full Moon on the East horizon. Only this position offers opportunity to view all seven stone markers used for marking the positions of Sun and full Moon rise on the East horizon. The existence of three stone markers for marking the places of the sunrise on the days of the summer solstice, winter solstice, as well as of the days of the vernal and autumn equinoxes is clear evidence that the ancient sky observers were well familiar with the movement of the Sun in the course of one tropical year. Also, the existence of four stone markers for marking places of the full Moon rise above the horizon, two of which are for the days, when the Moon has maximum and minimum values of the declination in the summer and two are for the days when the Moon has maximum and minimum values of the declination in the winter period speaks clearly that the ancient sky observers were also familiar with the 19-year cycle, when the full Moon rises in the same phase in the same calendar day. Thus, the existence of the markers for the places of the full Moon

Фиг. 9. Ritual stone marker

rise above the East horizon confirmed that this site contains all necessary characteristics of one ancient observatory. The acquaintance with the 19-year lunar cycle leads to the fact that in the past some very careful sky observers followed the East horizon and the rise of the full Moon at least 2 - 3 cycles, and when they discovered that they are dealing with periodical full Moon rise they marked those places with stone markers. In other words, 38-57 years of careful observations of the full Moon movement were dedicated in order to position the full Moon rising places. If we take into the consideration the fact that at that time average life of people was around 40 years of age, it is evident that at least two generations of dedicated sky observers (today we would called them astronomers) stood on the central position of the site and observed the movements of Sun and Moon.

Knowing the declination value of the Sun, when in the past it rose over the stone marker in the day of the solstice, as well as the precession of the Earth rotation axis we can calculate the time, when the stone marker was carved, along with the age of the observatory. The calculations pointed out that this happened in the period of 1800 +/- 50 years BC. The presented difference is due to the small error of the measuring instrument, but in the course of the measuring error analysis and determination of the observatory age we must take into account the fact that people that time carved markers according to the precision of one human eye (about 2 arcmin), as well as the fact that

Фиг. 10. Ritual marker in its possible shape in the past

the change of the declination of the Sun happened relatively slow. Therefore, we can declare with high certainty that during the entire period between 1900 and 1800 BC there were organized and systematically structured observations performed in relation to the sky, and movements of Sun and Moon. In one archaeo- astronomical analysis of one archaeological site beside the measurements and mathematical calculations the archaeological confirmation of the received results is of great importance and relevance. The archaeological excavations performed on the site in the recent years showed that there are artifacts on the site (Fig. 12) dated in the period between 1800 and 2000 BC.

The combination of archaeo-astronomical and archeological evidences illustrates that this site has all characteristics of an ancient observatory used around 18 century BC or that the observatory is at least 3900 years old.

The existence of a stone marker for the sunrise place in the day, when the end of the harvest was celebrated, points out to the fact that this site was not just an ancient observatory, but at the same time secret place, where variety of important rituals and ceremonies were performed. The carving the marker, trench and thrones lead us to the fact that celebration of the end of the harvest was performed with typical solar rituals. The illumination of the leader of the tribe sitting on one of the stone thrones with sunray coming from the stone marker aperture, actually represents ritual unification of the God Sun with the leader of the tribe and strong support of his power to manage the community and also to provide guarantee for huge crop in the agriculture next year. The confirmations that we are really dealing with the ritual linked with the celebration of the end of the harvest are about twenty wheat hand mills discovered on the stone marker pedestal (Fig. 13).

Kokino calendar

The development of a calendar was one of the main tasks, and of course, extraordinary achievement - a proof for the ancient sky observer creativity. The stone markers con-

Фиг. 11. Sunray route

firming that the ancient astronomers were familiar with the apparent movement of the Sun on the sky in the course of one year, as well as with the apparent movement of the full Moon in the course of 19-year cycle at first time impose the dilemma of the type of the calendar that was developed in this ancient observatory (Stoev and Stoeva 2003). Was it solar, lunar, or combination of lunar and solar calendar?

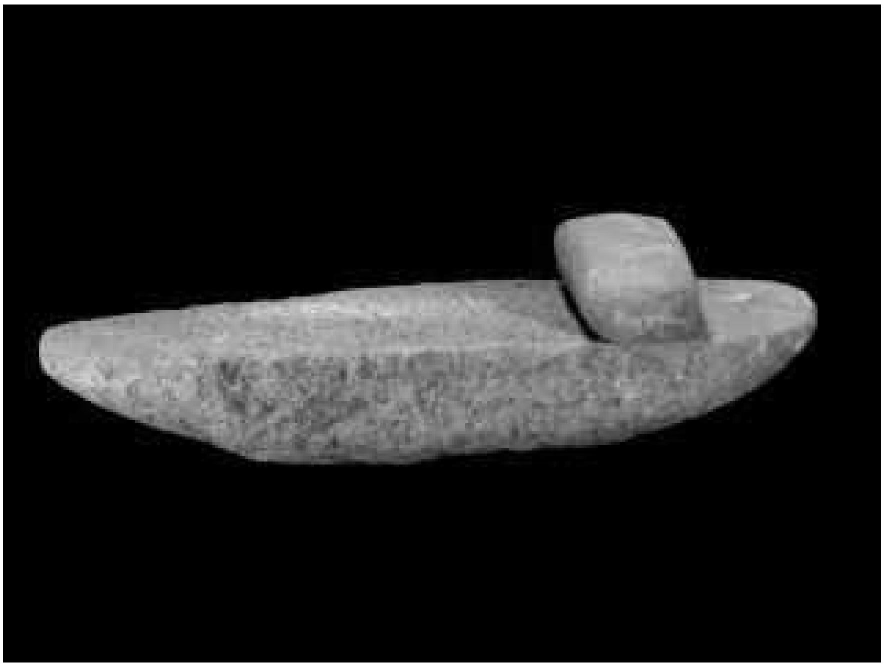
This dilemma was solved at the end of 2006 and at the beginning of 2007 when it was evidenced the existence of stone markers measuring the length of the lunar month with 29 and 30 days (Cenev 2007). On December 5, 2006, the full Moon had its maximum declination in winter period in the 19-year cycle and its rise occurred right above the stone marker aperture. This stone marker was discovered in the previous years (Fig. 14). In the same stone block there is clearly noticeable a stone marker with the same shape, marking the full Moon rise exactly one lunar month later, or on January 3, 2007 (Fig. 15). The full Moon rise seen through this marker on the above mentioned day clearly points that ancient astronomers knew about the 19-year lunar cycle of the full Moon rise, but also knew and literally measured the length of the lunar month with 29 days during the winter period. The existence of two similar markers in the stone block, where full Moon rise places were marked in the days of maximum declination during the summer period also proves that the ancient inhabitants knew and measured lunar month with length of 30 days.

In this manner it become evident that in the megalithic observatory Kokino (this site today is recognized in the world under this name) a lunar calendar was developed, containing 19-year cycle which encompasses certain number of lunar months with length

Фиг. 12. Artifacts from 19 century BC

of 29 days and certain number of lunar months with length of 30 days. The performed analysis showed that in this 19-year cycle, there are 12 years with 12 lunar months that are so-called regular years and 7 years with 13 lunar months, so-called leap years. While conducting the lunar calendar analysis, the ethno-astronomical data of the Macedonian people collected last 25 years of researches (Cenev 2004) was proved to be of great importance. According to these data even nowadays it is evident that in one calendar year there are only two seasons: winter and summer. In the past the people used to believe that winter months were very bad and were shorter, opposite to the summer months that were very good and had more days. Based on these data recorded in the collective memory of the people, we can conclude that Kokino calendar in its regular years had 6 winter months with 29 days of length and 6 summer months with 30 days of length. In the leap years there were 13 lunar months as one extra summer month with 30 days of length was added. In 19-year cycle, leap years had special pattern of occurrence. According to the Kokino calendar and in compliance with the number of full Moons in the years in that time period, in every 2, 5, 8, 10, 13, 16 and 18 years, one lunar month with 30 days of length was added. In this manner in Table 2, we have lunar calendar with 19-year cycle, today known as Kokino calendar.

This calendar is in an excellent agreement with the change of seasons, as well as with the tropical year length. Using these methods the ancient astronomers from the megalithic observatory Kokino developed the lunar calendar. The utilization of the same meant provision of timely instructions related to the start and competition of agricultural and stockbreeding activities and provision of required amounts of food on one hand and on the other hand with the utilization of the calendar the religious life of



Фиг. 13. Hand mill

Фиг. 14. Moon rise on December 5, 2006

Фиг. 15. Moon rise on January 3, 2007

the community was organized in a very qualitative way. Important information related to the calendar, for example, that the day when they need to start the plough of the fields had come, was announced with simply setting a fire on the top of the mountain right behind the thrones. The dominant position of the mountain enabled this signal to be noticed in a circle of at least 30 kilometers. In such way the ancient observatory influenced the qualitative organization of the life of the people in one wider region in the center of the Balkan peninsula.

Defining the type of the calendar that was developed in Kokino, the role of the stone markers for marking the East horizon positions of sunrise was made also clearer. Compatible with the well known experts in religious history (Elijade 2004) in the time when the megalithic observatory was constructed, Sun was very important God that managed life cycle first of all of the vegetation. Its movements were carefully followed on the horizon, we can even say with huge doze of fear. In the case that the Sun in the summer period continues to move toward North after the solstice day, the heat would increase in such measure that will burn out the entire world, and if in winter the Sun continues to move toward South after the day of the solstice, the cold would frost the entire Earth according to the people believes. The rise of the Sun, seen though the markers of the vernal and autumn equinox, actually meant change of the seasons, change of the winter and summer in the Kokino calendar years.

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Таблица 2. Kokino calendar

Year in the Kokino Calendar	Number of the Lunar months	Number of days	Number of days in a tropical year	Difference in days with the tropical	Number of days in the Metonic Cycles	Difference in days with the tropical year
1	12	354	365	-11	354	-11
2	13	384	365	+8	354	-22
3	12	354	365	-3	384	-3
4	12	354	366	-15	354	-15
5	13	384	365	+4	354	-26
6	12	354	365	-7	384	-7
7	12	354	365	-18	354	-18
8	13	384	366	0	354	-30
9	12	354	365	-11	384	-11
10	13	384	365	+8	354	-22
11	12	354	365	-3	384	-3
12	12	354	366	-15	354	-15
13	13	384	365	+4	354	-26
14	12	354	365	-7	384	-7
15	12	354	365	-18	354	-18
16	13	384	366	0	354	-30
17	12	354	365	-11	384	-11
18	13	384	365	+8	354	-22
19	12	354	365	-3	383	-4

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