DOI 10.4467/21995923GP.18.010.9640 GEOINFORMATICA POLONICA
17: 2018

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KRAKUS AND WANDA MOUNDS AND THE DIVISION OF A YEAR INTO EIGHT PARTS

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Keywords: Krakus Mound, Wanda Mound, Archaeoastronomy, solar calendar

Abstract

The arguments that positions of Krakus and Wanda mounds are not random, but are strictly connected with particular directions of sunrise (sunset) are presented. It has been proved that direction given by Krakus and Wanda mounds determines two dates of sunrise and two dates of sunset. The above dates divide a year into four parts and they may be connected with Celtic holidays. It turns out that the above described astronomical knowledge was also encoded inside of Krakus Mound, where in 1934–1937 archaeological excavations were carried out.

One of the most interesting artefacts was the trace of a wooden pole, located just next to the mound's axis and a system of wooden stakes (or traces of them), arranged in 13 rows radially running from the axis of the mound. In this paper a detailed description is given of the method identifying decoded astronomical knowledge hidden inside the mound based on those traces radiating from the central pole.

KOPIEC KRAKUSA I KOPIEC WANDY A PODZIAŁ ROKU NA OSIEM CZĘŚCI

Słowa kluczowe: kopiec Kraka, kopiec Wandy, archeoastronomia, kalendarz solarny

Abstrakt

W artykule podaje się argumenty uzasadniające tezę, że położenie kopców Krakusa i Wandy nie jest przypadkowe, lecz ściśle związane z wyróżnionym kierunkiem wschodu i zachodu Słońca. Linia wyznaczona przez kopiec Krakusa i kopiec Wandy wyznacza dwie daty wschodu Słońca i dwie daty jego zachodu. Daty te dzielą rok na cztery – w przybliżeniu – równe części. Wypadają one w połowie okresu między przesileniami i momentami równonocy oraz są zgodne z datami świąt celtyckich. Okazuje się, że przedstawiona wyżej wiedza astronomiczna została zakodowana we wnętrzu kopca Kraka. W latach 1934–1937 przeprowadzono na kopcu Krakusa wykopaliska archeologiczne. Jednym z najbardziej interesujących odkryć w aspekcie astronomicznym było znalezienie i udokumentowanie śladów drewnianego słupa centralnego znajdującego się w pobliżu osi kopca oraz śladów linii kołków (płotów) biegnących promieniście od osi kopca. W pracy opisano zastosowaną metodę umożliwiającą odczytanie znacznego zakresu wiedzy astronomicznej zakodowanej we wnętrzu kopca Krakusa.

INTRODUCTION

Two prehistoric mounds are located within the administrative borders of Cracow. Krakus Mound (KM) located at the top of Krzemionki Hill and on the right bank of the Vistula River in the Podgórze district and Wanda Mound (WM) on the left bank of the Vistula River in the district of Nowa Huta. Both mounds are associated with a legend of a family of the mythical Cracow founder Prince Krak and they were probably built around 1200 years ago or are even more.

The listed mounds define several interesting lines in the astronomical calendar. Krakus Mound occupies a special place in the panorama of Cracow. From its top, there is a fully exposed visible horizon (the line of apparent contact of the sky with the surface of the

Earth) and is a convenient, easily accessible place for observing sunrises and sunsets.

Krakus Mound is the largest prehistoric mound in Poland and with Wanda Mound define precisely interesting astronomical alignment. The observer standing on the top of Krakus Mound observes the sunrise over Wanda Mound twice a year, around 1th May and 12th August, when declination angle of the Sun reaches approx. 14°50′. In turn, the observer standing on the top of Wanda Mound can see the sunset over Krakus Mound around 6th February and 4th November, when the Sun declination reaches the value of about – 15°40′. Between the phenomenon of the sunrise observed from Krakus Mound over Wanda Mound and of the sunset over Krakus Mound observed from Wanda Mound is about six months. During that time, the Sun shifts through the ecliptic movement by 180°. The four dates mentioned above split the calendar year into four equal parts. They fall in the middle of the four seasons which coincide with important Celtic celebrations. Celtic tribes inhabited Krakow for a few hundred years around 2000 years ago, therefore both places where the mounds were built must have been well known by them. The May date of the sunrise over Wanda Mound and the November date of the sunset over Krakus Mound and their coinciding with Celtic celebrations was first noted by (Kotlarczyk 1979). It turns out that the astronomical-calendar knowledge presented above had also been encoded inside Krakus Mound in the form of 13 rows of fence posts radiating from the central post. The lines were discovered during archaeological excavations carried out on the mound of Krakus in the years 1934–1937 and described by (Jamka 1965). The course of these lines has been documented on three horizontal cross-sections related to a depth of 10 m, 12 m and 15 m, calculated from the top of the mound (Plan V, VI, VII, Jamka1965). The language of geometry enabled reconstruction of cardinal directions of the horizontal system and the directions of sunrise and sunset during summer and winter solstice. In addition, at the level of plan V, (Jamka 1965) direction between Krakus and Wanda mounds was encoded. The results of the research are described in the second part of the article.

WHERE IS WANDA MOUND LOCATED?

Tourists gathered on Krakus Mound have great difficulty locating Wanda Mound on the horizon. For many years, the "Podgórze" Society has been organizing meetings on the top of Krakus Mound to welcome the rising Sun on the first day of astronomical summer on 21th (22nd) of June. These meetings are becoming increasingly popular. Initially the legend was repeated that on this day observer on Krakus Mound can see the rising sun over Wanda Mound. This false information can also be found in some publications about the mounds of Cracow. This legend however is difficult to be tested because Wanda Mound is now virtually invisible. For an observer on Krakus Mound the top of Wanda Mound is below the visible horizon. The height of the Krakus peak is 271 m above the sea level, while the Wanda mound is 238 m. In addition, on the line KM – WM the area behind Wanda Mound rises and is built-up by steelworks buildings. From here the visible horizon line is above the top of Wanda Mound and approximately coincides with the horizon line of the observer located on Krakus Mound. Therefore, the observer on Krakus Mound will be able to watch the sunrise over Wanda Mound but not on its background. Nowadays Wanda Mound from the north and east is surrounded by trees, so in summer its green lump covered with grass blends with the surroundings. With good air clarity, Krakus Mound is visible from Wanda Mound on the horizon (Fig. 1a). However, with very good transparency of the air, we can also see the hills behind Krakus Mound (Fig. 1b). A person standing on top of Wanda Mound can observe the sunset above Krakus Mound. In winter, in good visibility, when Wanda Mound is covered with snow, it can be seen quite easily from Krakus Mound. But such conditions are rare (Fig. 2).

The shorter chimney of the "Łęg" thermal power plant, visible from Wanda Mound on the right side (Fig. 1a,1b), and from Krakus Mound on the left (Fig. 2) was removed from Cracow landscape in the first half of 2017 (Fig. 4).

THE ASTRONOMICAL ASPECTS OF KRAKUS AND WANDA MOUNDS

On the basis of GPS observations precise geodetic coordinates of Krakus and Wanda mounds have been calculated. The distance between their summits (the geodetic marks) is 8630 m, and the geodetic azimuth of direction Krakus – Wanda mounds is 65°29′38″ (Góral 2006a, 2006b). By applying the formulae of spherical trigonometry to the parallactic triangle, we can find the horizontal coordinates *A* and z

$$\sin \delta = \sin\varphi \operatorname{coz} z + \cos\varphi \sin z \cos A, \qquad (1)$$

where z and δ are, respectively, the zenith distance and declination of the Sun and φ is the latitude of the observation site. When calculating the sunrise and sunset azimuth A we take into account the standard value of the atmospheric refraction horizon (35′), and the observed value of the angular radius of the solar disk (16′). When the moment of sunrise is related to the contact of the upper edge of the solar disk with the horizon line, then the zenith distance of the Sun is z = 90°51′. In fact, the phenomenon of rising and setting of a particular celestial body is observed on the visible horizon (the boundary line of the earth and sky). For the observer standing on Krakus Mound, the visible horizontal line on its western side is at a horizontal height of about 20′ or more.

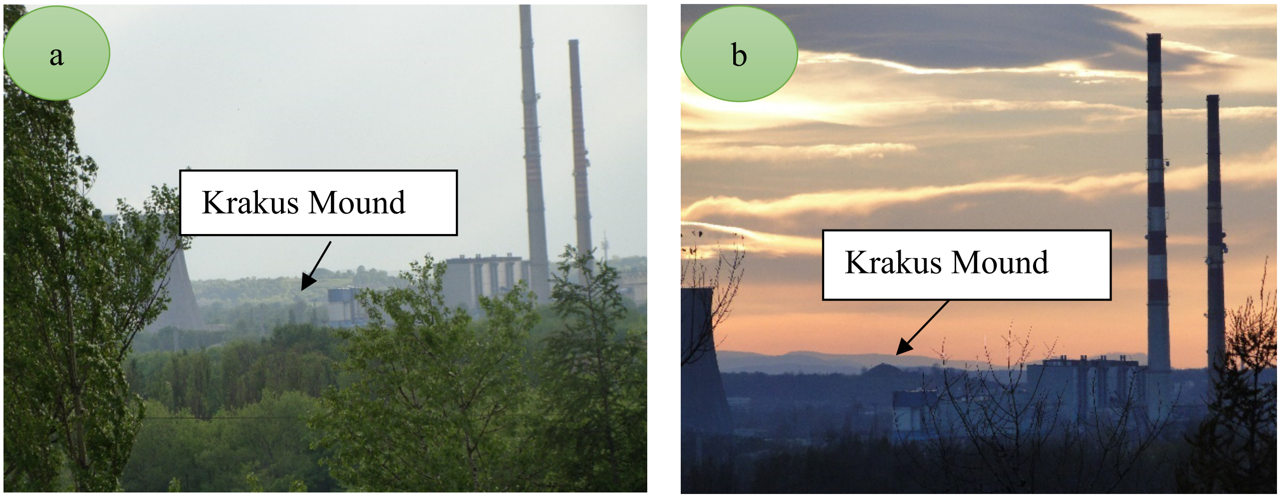

Fig. 1a, b. View of Krakus Mound from Wanda Mound. Photo W. Góral
Ryc. 1a, b. Widok z kopca Wandy w kierunku kopca Kraka. Fot. W. Góral

Fig. 2. View of Wanda Mound from Krakus Mound. Photo W. Góral
Ryc. 2. Widok z kopca Krakusa w kierunku kopca Wandy. Fot. W. Góral

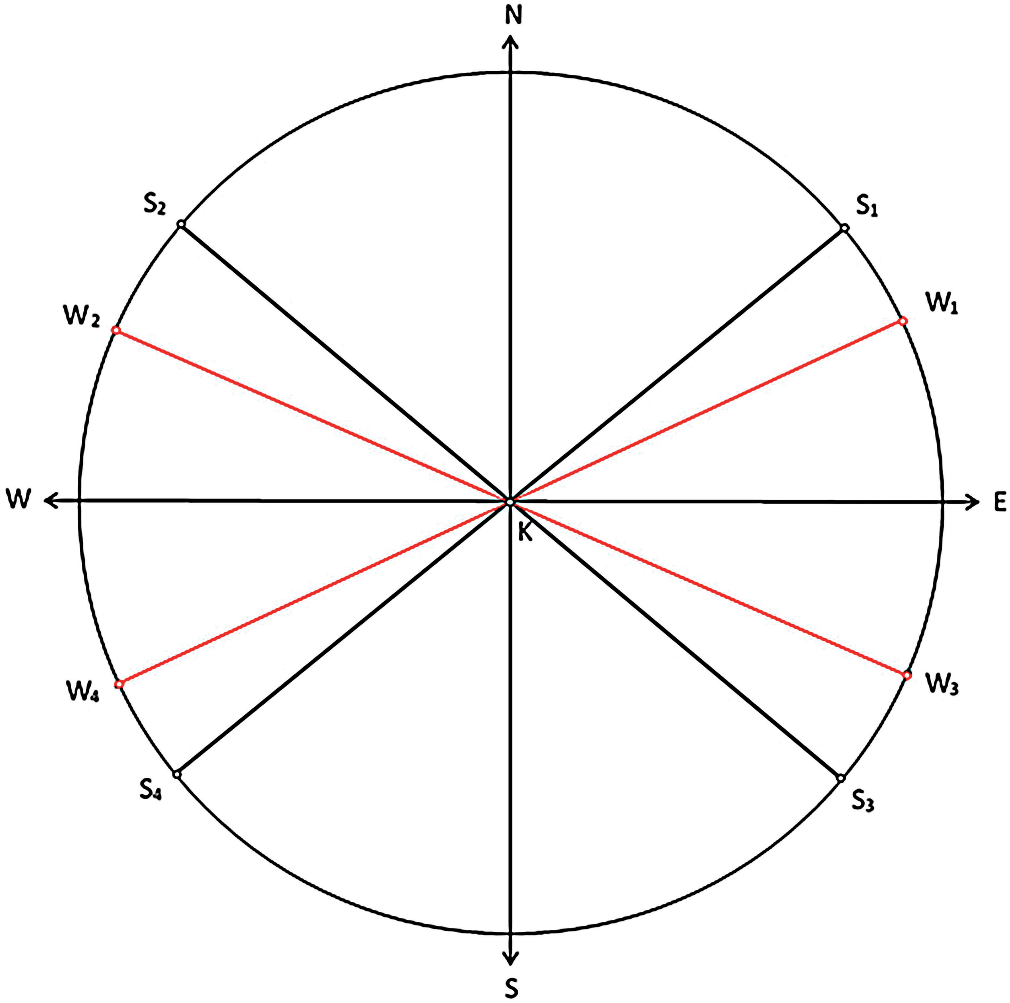

Fig. 3. Scheme of four directions of sunrises and four directions of sunsets. Own source
Ryc. 3. Szkic czterech kierunków wschodu i czterech kierunków zachodu Słońca, opracowanie własne

In further considerations, we assume that at the time of sunrise or sunset the zenith distance of the center of the solar disk is z = 90°, which corresponds to the angular altitude (horizontal height) h = 0°. In this case, the lower edge of the solar disk is in contact with the visible horizon line and the formula for the calculation of the azimuth A of the sunrise and sunset is simplified to the form (Banasik, Góral 2016).

$$\cos A = \sin\delta / \cos\varphi. \quad (2)$$

A person standing on the top of Krakus Mound can observe the sunrise above Wanda Mound around the 1th May and 12th August. The place where the rising sun appears over Wanda Mound depends on the value of its declination angle at the time of sunrise and on the value of astronomical refraction at this moment. The value of the Sun declination angle given in the astronomical almanac and for a given date slightly changes in the four-year cycle due to the leap year. The 1th May in the regular year is the 120th day of the year and in the leap year the 121st day of the year. Moreover the refraction value in the horizon is variable and its value may significantly differ from the standard value of 35′. On 1th May a person on Krakus Mound observes the sunrise in the direction KW_1 above Wanda Mound, Fig. 3. In the following days, the observer standing on Krakus Mound will notice that the sunrise's point continues to shift northwards towards the horizon until

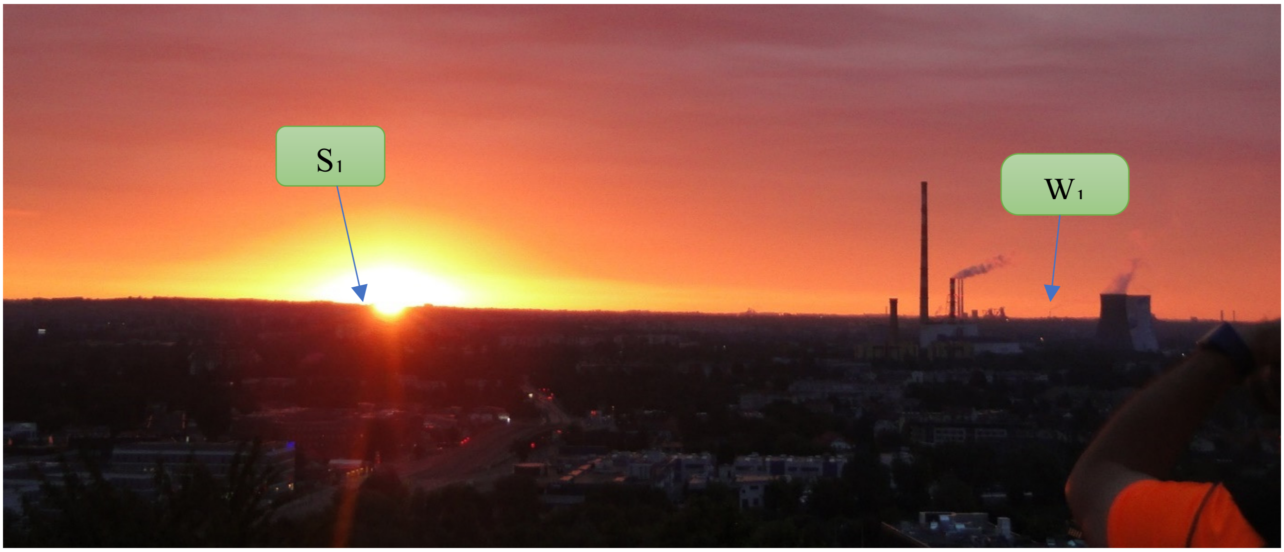

Fig. 4. View from Krakus Mound. Sunrise 21st of June 2017. Photo W. Góral
Ryc. 4. Wschód Słońca obserwowany z kopca Krakusa w dniu 21 czerwca 2017 r. Fot. W. Góral

Fig. 5. Sunrise above Wanda Mound observed from Krakus Mound on 12th August 2016. Photo W. Góral
Ryc. 5. Wschód Słońca nad kopcem Wandy obserwowany z kopca Krakusa w dniu 12 sierpnia 2016 r. Fot. W. Góral

the summer solstice, the beginning of the astronomical summer – 21th (22nd) of June, Fig4. On the day of the summer solstice declination angle of the sun reaches the maximum value equal to the obliquity of the ecliptic, which is currently $\varepsilon = 23°26'$. For $\delta = \varepsilon$, the azimuth of the eastward direction from Krakus Mound takes the value of $KS_1 = 51°46'$, (Fig. 3), Fig. 4. As the direction of the sunset of KS_2 is symmetrical with respect to the local meridian defined by the NS line, the azimuth of the sunset direction KS_2 is expressed by the formula $KS_2 = 360° – KS_1 = 308°14'$. From summer solstice the value of the declination of the Sun begins to decrease. The sunrise begins to shift on the horizon towards the south and on about 12th August it will again be on a line KW_1. Initial phases of sunrise over Wanda Mound are shown on 12th August 2013, Fig. 5. The observer standing on the Krakus Mound on the 1th May, not only observes the sunrise above the Wanda Mound, but also the sunset in a well-defined location on the visible horizon in the direction of KW_2 (294°30′), Fig. 3. We observe the sunset on this day near the point where the visible horizon of Zrąb Sowińca (ZS) adjoins the ridge of

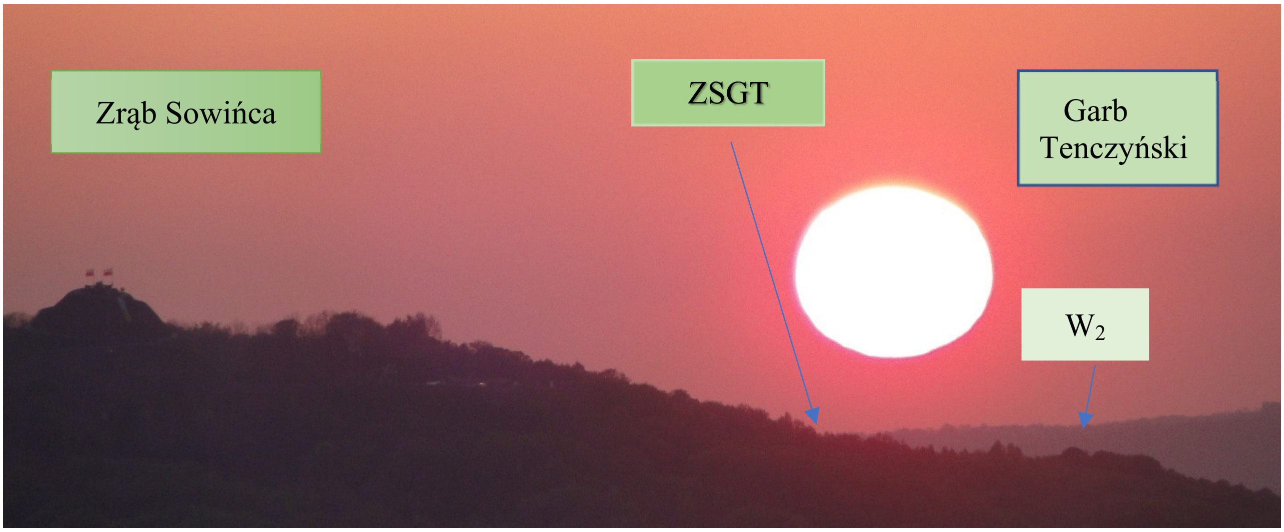

Fig. 6. Sunset observed from Krakus Mound on 1th May, 2009. Photo W. Góral,
Ryc. 6. Zachód Słońca obserwowany z kopca Krakusa w dniu 1 maja 2009 roku. Fot. W. Góral

Fig. 7. Panoramic view of the western horizon as seen from Krakus Mound showing the summer solstice sunset on 25th June, 2011. Photo W. Góral
Ryc. 7. Panorama z kopca Krakusa w kierunku zachodnim. Zachód Słońca obserwowany z kopca Krakusa w dniu 25 czerwca 2011 r. Fot. W. Góral

GarbTenczyński (GT), Fig. 6. On 1th May (12th August) we observe from Krakus Mound the phenomenon of the sunset on the horizon on the background of GT in the vicinity of the direction KW_2 (294°30′).

A fragment of the visible horizon observed from Krakus Mound in the vicinity of the ZSGT point is documented by Fig. 6. The azimuth value of direction KM – ZSGT is 293°55′. This value is close to the azimuth of the sunset KW_2. To the author's surprise, the value of the angle measured from the north (N) direction to the left towards the point ZSGT (360° – 293° 55′ = 66°05′) proved to be close to the azimuth of the direction KW_1 of 65°30'. Azimuth difference amounting to 35′ is only about 3′ greater than the value observed across the horizontal angular diameter of the solar disc, (which is approx. 32′. Fig. 6). In the period

Fig. 8. Summer solstice sunset observed from Krakus Mound on 25th June, 2011. Photo W. Góral
Ryc. 8. Zachód Słońca obserwowany z kopca Krakusa w dniu 25 czerwca 2011 r. Fot. W. Góral

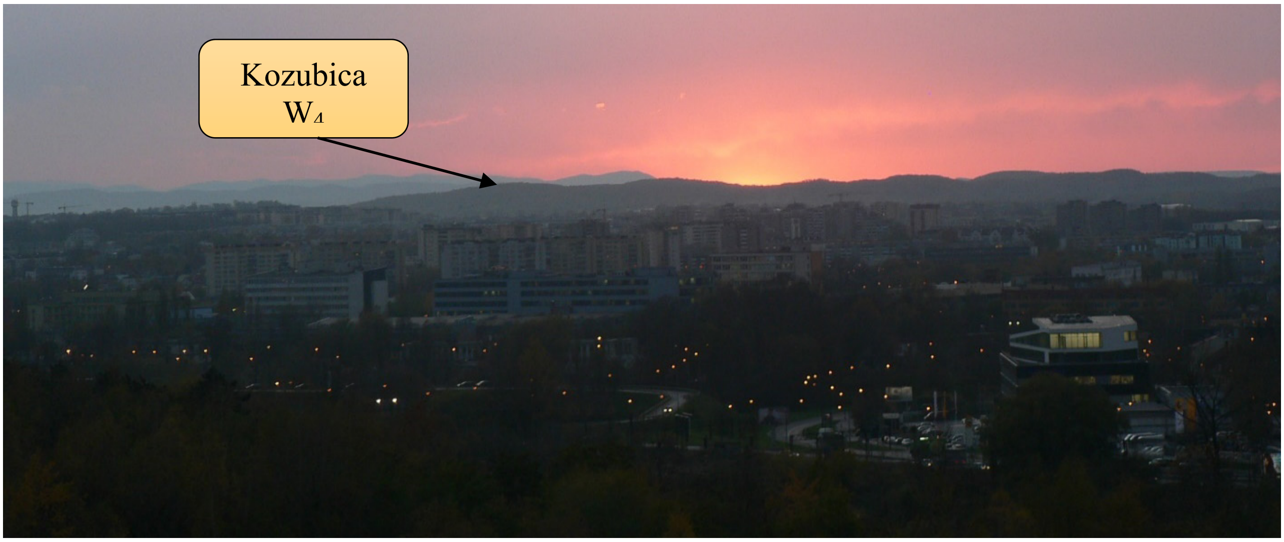

Fig. 9. View from Krakus Mound in the direction of Podgórki Tynieckie after sunset 30th October 2008. Photo W. Góral
Ryc. 9. Widok z kopca Kraka na Podgórki Tynieckie po zachodzie Słońca 30 października 2008 r. Fot. W. Góral

from 1th May to 12th August the point of sunset will move on the horizon between W_2– S_2 – W_2, Fig. 7. The observer standing on Krakus Mound and observing the sunset on the summer solstice (21st June) or around this date will notice that it takes place on the horizon near a characteristic elevation, separated by two hollows (Fig. 7, Fig. 8). These hills are located in the "Dolinki krakowskie" Landscape Park, more than 24 km from Krakus Mound. This observation suggests that Krakus Mound or the hill on which this mound was built was also suitable in the ancient times for precise determination of the sunset during summer solstice. Nowadays the slope of the ecliptic plane relative to the plane of the celestial equator decreases. Therefore, the sunset point on the summer solstice is slowly moving towards the south. Two thousand years ago, the Sun was behind

Fig. 10. Sunset observed from Wanda Mound on 1th November 2009. Photo W. Góral
Ryc. 10. Zachód Słońca obserwowany z kopca Wandy na prawo od kopca Krakusa w dniu 1 listopada 2009 r. Fot. W. Góral

Fig. 11. Sunset above Krakus Mound observed from Wanda Mound on 6th February 2016. Photo W. Góral
Ryc. 11. Zachód Słońca obserwowany z kopca Wandy nad kopcem Krakusa w dniu 6 lutego 2016 r. Fot. W. Góral

the hill visible on the right, Fig. 8. Detail of this matter is shown in (Banasik, Góral 2016). This article is available on the Internet at the Archaeological Museum in Cracow. Also the direction of sunset line KW_4 (Fig. 3) is well defined on the visible horizon by hill Kozubica in the area of Podgórki Tynieckie, Fig. 9. In that direction the observer on Krakus Mound will be able to watch the sunset on around 4th November and 6th February. At the same time, the observer on Wanda Mound will be able to watch the sunset over Krakus Mound, Fig. 10, Fig. 11.

Table 1. Azimuth values of the directions of sunrises and sunsets. Own elaboration
Tabela 1. Azymuty kierunków wschodu i zachodu Słońca. Opracowanie własne

item	KS_1	KS_2	KS_3	KS_4
1	50°57′	309°04′	127°29′	232°31′
2	51°46′	308°14′	128°14′	231°46′
3	52°00′	308°00′	128°00′	232°00′
4	52°30′	307°30′	127°30′	232°30′

Similarly, on the first day of astronomical winter, when the declination of the Sun reaches the minimum value $\delta = -\varepsilon$, the azimuth of the east direction KS_3, according to Fig. 3, will be expressed by the formula $KS_3 = 180° - KS_1 = 128°14′$, and the azimuth of the sunset direction KS_4 is given by the formula $KS_4 = KS_1 + 180° = 231°46′$. For the purpose of comparative analysis the above azimuth values are given in Table1, item 2.

ASTRONOMICAL KNOWLEDGE ENCODED INSIDE THE KRAKUS MOUND

In 1934–1937 archaeological excavations were carried out in Krakus Mound. Extensive description of those excavations can be found in (Jamka 1965), which is the main source for this article. At the initial stage of the study, the root system of the cut down oak was found, which indicates the cult character of the mound. These roots were located within 4 m of the mound's axis, at a depth of 2–6 m from its apex. The oak age was estimated for about 300 years [Szafer 1936]. In the next stage, started in March 1935, excavations were continued, deepening the excavation a few meters further down to the limestone base of the mound. The excavation was made in the form of a cone, with a narrowing diameter which at the base of the mound was about 12 m. One of the most interesting finds was the trace of a wooden pole, located just next to the mound's axis and a system of wooden stakes (or traces of them), arranged in several rows radially running from the axis of the mound. Traces of the above wooden elements were found between levels 10 m – 15 m counted from the top of the mound. In the paper documenting the excavations in Krakus Mound there are three horizontal cross-sections related to the depths of 10 m, 12 m and 15 m, calculated from its apex (Plan V, VI, VII: Jamka 1965). Our attention is drawn to the traces of the wooden central post and the traces of oak pegs running radially from this pole. In the layer at a depth of 10 m (Plan V), Fig. 12, seven such lines were found, defining the following directions with the most probable value of azimuths: A_{10} = 15°, B_{10} = 60°, C_{10} = 118°, D_{10} = 215°, E_{10} = 250°, F_{10} = 290° and G_{10} = 337°, Fig. 12. In the layer at a depth of 12 m (Plan VI) there are 5 lines with the most probable values of azimuths: A_{12}=135°, B_{12} = 157°, C_{12} = 212°, D_{12} = 252°, E_{12} = 288° (Fig. 13). These lines converge in the close vicinity of the central pole trace. At the base of the mound, that is at a depth of 15 m, only one line with (approximate) azimuth A_{15} = 127° is documented (Plan VII, (Jamka 1965). When the mound was erected, which was probably done in stages (Banasik, Góral 2016), the scope of coded knowledge in the form of a peg line increases. Fig. 12 and Fig. 13 show that the stakes have divided the mound into several sectors. The construction of a pole and thirteen rows of stakes was interpreted as facilitating the construction of a mound and preventing the slipping of the mound (stakes, fences). We also note that the extension of 11 lines compatible with plan V, VI and VII, (Jamka 1965) focuses on the central pole or its close surroundings. A closer analysis shows that only the extensions of lines B_{12} and G_{10} are of a different nature. Measurements of the azimuths of individual lines were made with the help of circular protraktor at the points of intersection of individual lines with SN axis. Than these lines were hooked at the beginning of horizontal system with the preservation of

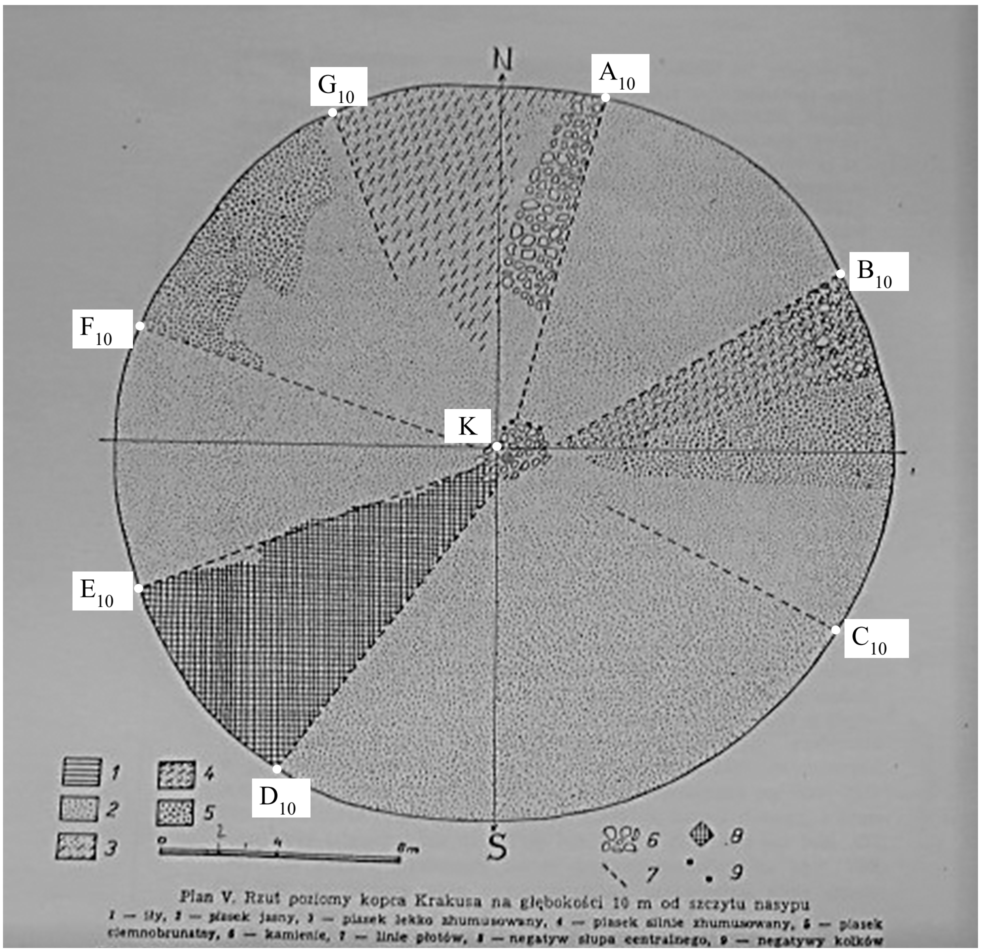

Fig. 12. The lines of wooden stakes on the depth of 10 m from the top of the mound. Own elaboration

Rys. 12. Linie śladów kołków na głębokości 10 m od wierzchołka kopca. Opracowanie własne na podstawie [Jamka 1965, plan V]

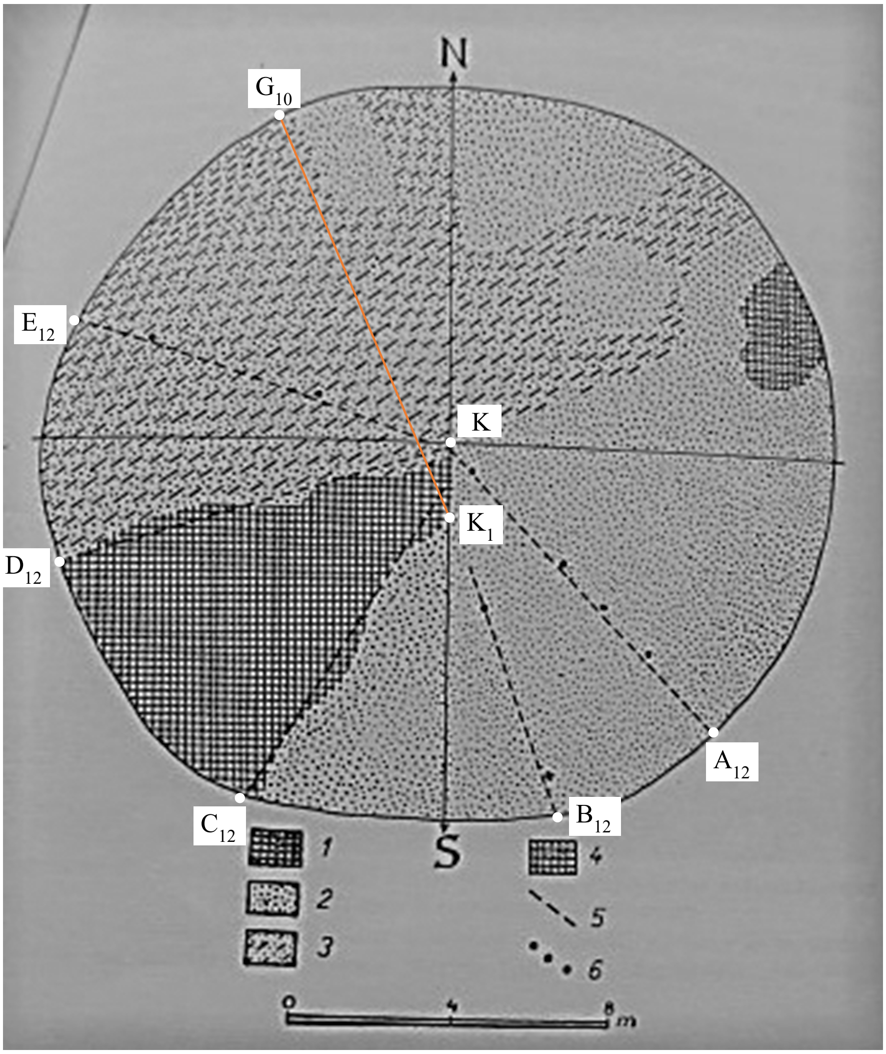

Fig. 13. The lines of wooden stakes on the depth of 12 m from the top of the mound. Own elaboration
Rys. 13. Linie śladów kołków na głębokości 12 m od wierzchołka kopca. Opracowanie własne na podstawie [Jamka 1965, plan VI]

the determined values of the azimuth (Fig. 14, Fig. 15). The result of this preliminary study was a uniform measurement material that significantly facilitated further computational work. The azimuth values were determined using a semi-graduated circular protractor. Measured values of azimuths are the most probable values burdened with an average error of about half a degree. Detailed analysis of the azimuths of the directions of individual lines begins at the base of the mound. This section documents a small fragment of the surface area of the base, amounting to approx. 4% of the area of the entire base of the mound (Jamka 1965). One can have great admiration for the accuracy of the central pole location, whose wooden trace was found at the base of the mound, at a depth of 15 m from its apex. It was located near the axis of the mound, designated by surveyors by means of precise methods at its top. This axis is for individual horizontal cross-sections the beginning of a local horizontal reference system consistent with the cardinal directions. This system was used to locate various artifacts found at a given level. On the lower level there is an interesting and highly documented line defined by the trace of two pegs and the central pole (plan VII, Jamka 1965). The direction of this line with an azimuth of about 127 is consistent with the approximate direction of the sunrise, observed from Krakus Mound, on

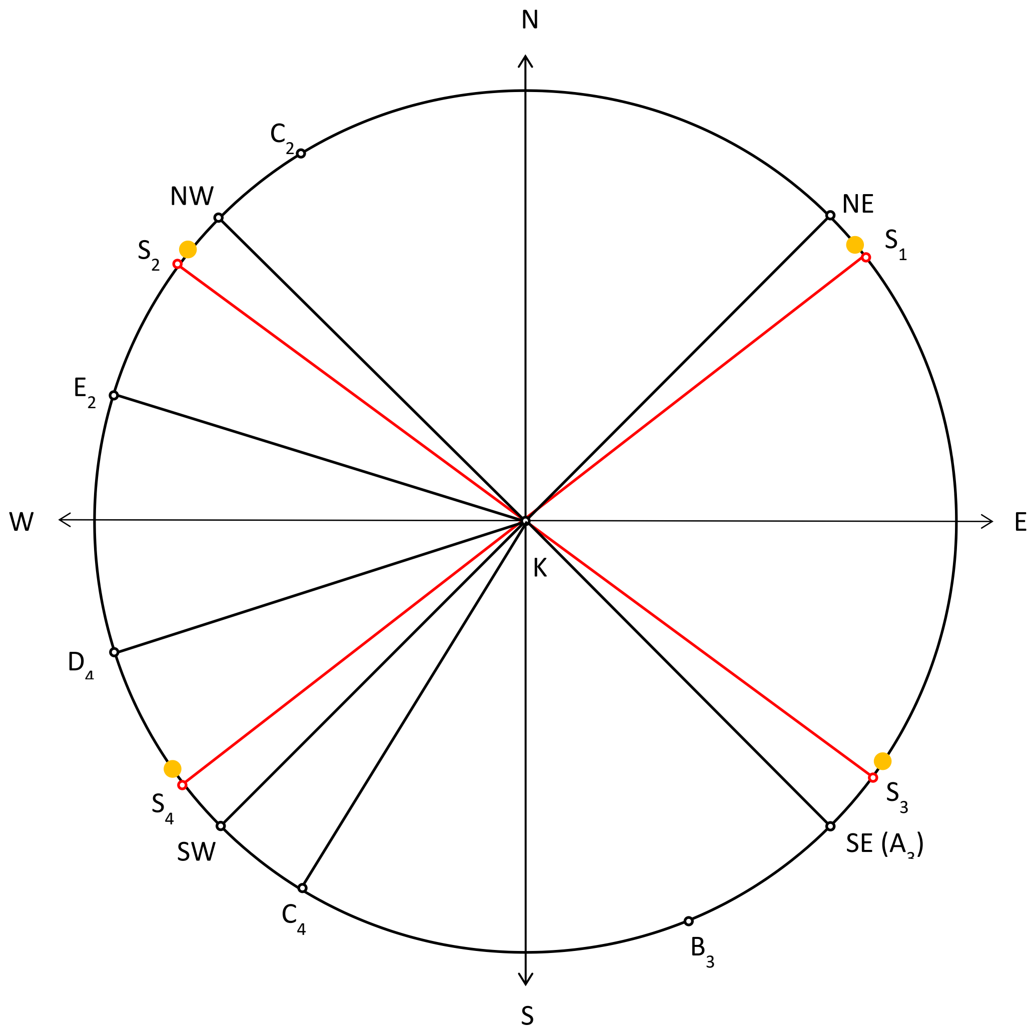

Fig. 14. The lines of sunrises and sunsets in summer and winter solstice based on the traces of stakes running radially on the layer at the depth of 12 m. Own elaboration

Ryc. 14. Linie wschodu i zachodu Słońca w dniu przesilenia letniego i zimowego na podstawie śladów kołków na głębokości 12 m. Opracowanie własne

the day of winter solstice. This line is probably a small fragment of the structure documenting the direction of sunrise and sunset on the winter and summer solstice. A lot of interesting information of a key nature (in the astronomical and calendar aspect) is provided by documentation at the level 3 m higher, Fig. 13, (Plan VI, Jamka 1965). At this level there are five lines located in the south-western part of the horizon and at first glance, it is difficult to say anything about their purpose. In order to further clarify their usage, the lines from Fig. 13 were marked as: A_{12}, B_{12}, C_{12}, D_{12}, E_{12} and described in sequence in Fig. 14 as: KA_3(135°), KB_3(157), KC_4(212°), KD_4(252°), KE_2(288°). In brackets, the azimuth values of the subsequent lines are given and the lower indices "1" and "2" are marked on the horizon line with sunrise and sunset points in spring and summer in the northern hemisphere. While indices "3" and "4" refer to the points of sunrise and sunset in autumn and winter in southern hemisphere. The above-mentioned indices are in accordance with the directions in Fig. 3. At the beginning it is worth noting that the average azimuth value of the KD_4 and KE_2 lines is 270°. This is the direction of the bisector angle D_4 KE_2 determining the west direction of KW. Its extension in the reverse direction determines the direction with the azimuth of 90°, that is the direction of the east of the KE. The perpendicular

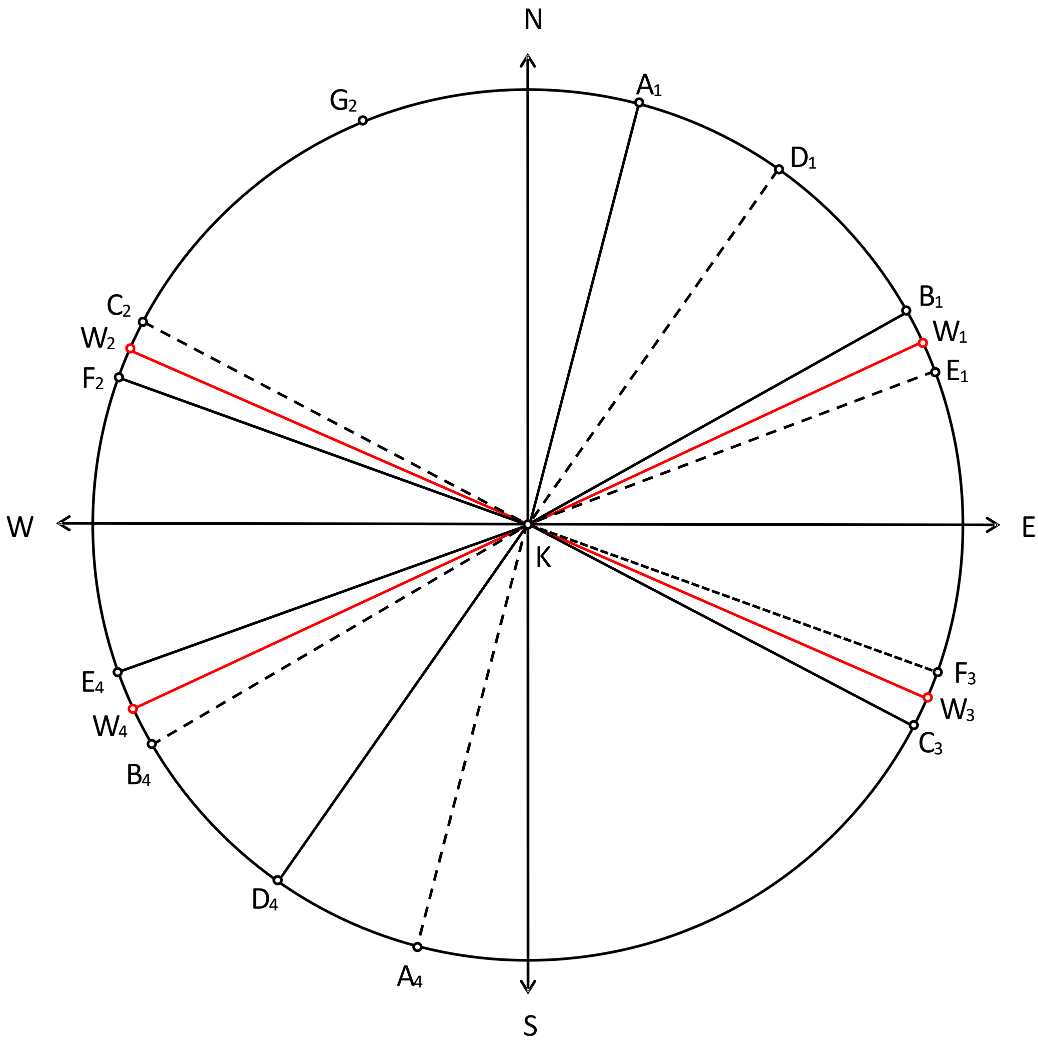

Fig. 15. Lines of sunrises and sunsets in accordance with the direction Krakus Mound - Wanda Mound (KW_1) based on the traces of stakes running radially on the layer at the depth of 10 m. (Jamka 1965, Plan V). Own elaboration

Rys. 15. Linie wschodu i zachodu Słońca zgodnie z kierunkiem Kopiec Krakusa - kopiec Wandy (KW_1) na podstawie śladów kołków na głębokości 10 m (Jamka 1965, Plan V). Opracowanie własne

exposed in point K to the EW axis is determined by the south-north axis SN. This is a surprising result, proving that Krakus Mound builders, at a distance of 3 m from its base, very precisely determined and documented a local horizontal geodetic network fully compliant with the system constructed by surveyors using precision instruments before the excavation works. Another interesting information claims KA_3 line of azimuth 135°, which means that it forms an angle of 45° with line KS. This line determines the south-east direction SE and makes it possible to determine three additional directions coupled with it, because the symmetry axes are: the EW axis and the SN axis. They are therefore lines indicating directions with the following azimuths: south-west SW (225°), north-west NW (315°) and north-east NE (45°). In this way, along with the four cardinal directions: N, E, S, W, we obtain the division of the horizon circle into eight equal parts. In turn, the bisector of the angle, whose arms are lines KC_4 and KD_4, defines line KS_4 with azimuth (232°). Along with the lines connected to it there are three additional lines marked in Fig. 14 as KS_3(128°), KS_1 (52°), KS_2 (308°). The KS_3 and KS_4 lines indicate the direction of sunrise and sunset in the vicinity of the winter solstice. And the

KS_1 and KS_2 lines indicate the direction of sunrise and sunset in the vicinity of the summer solstice. The above data is also included in Table 1, item 3.

The line hooked to point B_3 remains to be discussed (Fig. 13). Its trace differs significantly from the four lines described above, hooked at the beginning of the system at point K (Fig. 13). On the basis of two distinct pin marks, this line is well defined. Its extension to the intersection with the SN axis determines the point K_1 (Fig. 13), located approximately 1.9 m from point K. The value of angle $B_{12}K_1S$ is approx. 23°. This line is significant, because its extension in the north-west direction was also documented on the V plan (Fig. 13) by the location of point G_{10}. The azimuth value of this line can be associated with the value of the angle between the pole of the world and the ecliptic pole, which are located in the plane of the local meridian at the peak of the upper Sun at the summer solstice. The value of this angle was well known to astronomers in antiquity.

Knowledge contained at the level of 3 m (counted from the base of the mound) refers to the initial stage of its construction and brings many valuable observations of an astronomical and calendar nature. When analyzing the course of seven lines on the V plan, Fig. 12, (Jamka 1965). we use two obtained keys to help decode knowledge contained in radially running lines from the central pole. We learn that important astronomical-calendar knowledge has been encoded in the directions of the bisector angles of the considered directions of the line, and that the courses of such lines are symmetrical in relation to the SN axis and the EW axis. Plan V (Jamka 1965) showing a horizontal cross-section of the mound at a height of 5 m from its base (10 m from its apex) contains seven lines marked by stakes and the trace of the central pole surrounded by stones. It is the cross-section with the largest diameter (over 27 m counted along the EW line). This allows to determine the azimuth value of individual lines with the highest accuracy. First the lines marked in Fig. 12 as: A_{10}, B_{10}, C_{10}, D_{12}, E_{10}, F_{10} are described in Fig. 15 successively as: KA_1(15°), KB_1 (60°), KC_3(118°), KD_4(215), KE_4(250°), KF_2 (290°). When analyzing the course of these lines, we note that the bisector E_4KF_2 with an azimuth value of 270° precisely determines the direction of the west KW, and its extension in the reverse direction is determined by the KE line (Fig. 15). And perpendicular to it at point K determines the direction of the SN. This is, therefore, another proof that the builders of the mound were well oriented in the main directions of horizontal system of coordinates and consciously used this knowledge during the construction of the mound. It was also previously documented on the basis of the course of the line on plan VI (Jamka 1965). Having the local horizontal system precisely defined by the mound's builders, we easily determine the azimuths of the remaining lines. The best-fixed line is the KA_1 line. On its considerable length (approx. 10 m) it runs between a layer of stones and a layer of sand. This line of azimuth 15° in conjunction with associated lines defines further lines with azimuths 165°, 195°, 345°. It is also worth noting that the azimuth of the KB_1 line is 60°. This allows the division of the horizon circle into 6 equal parts. The value of the B_1KE angle is 30°, which in turn allows the division of the circle into 12 equal parts. Also bisector of angle A_1KNE, whose one arm is the KNE line with azimuth of 45°, determines the line with the azimuth of 30° and additional three lines with azimuths: 150°, 210°, 330°. Thus the mound's builders obtained precise angle measures allowing the division of the horizon circle into 6 parts with 60°, 12 parts with 30° and 24 sections with 15°. This knowledge could have been used to build a simple solar clock.

Particularly noteworthy are four lines marked as: KB_1, KC_3, KE_4, KF_2. These lines form two angles. One angle B_1KC_3 with the value of 58°, located on the east side and the second angle E_4KF_2 with the value of 40°, located on the western side. Important information is also provided by the extension lines KB_1 (60°), KC_3(118°), KE_4(250°), KF_2(290°), which are marked as: KB_4(240°), KC_2(298°), KE_1(70°), KF_3 (110°), where azimuth values of particular directions are written in parentheses. The above mentioned lines define four angles, which generate the following bisectors marked in red in Fig. 15: KW_1(65°), KW_2(294), KW_3(114°), KW_4 (245°). The azimuth values of the lines defined by the individual bisectors are assigned in parentheses. Considering the accuracy of the designated azimuths with an average error of about 0.5°, we see that the determined azimuth values, to our surprise, correspond to the azimuth of Krakus Mound – Wanda Mound (line KW_1). With reference to the Sun, the first pair of azimuths determines the direction of its east and west on 1th May and 12th August. On those days we observe the sunrise over Wanda Mound from Krakus Mound . The second pair of azimuths is assigned to the direction of the sunset observed on 6th February and 4th November from

Krakus Mound towards Kozubica (also standing on Wanda Mound we see the sunset over Krakus Mound). Bisector of angle D_4 KE_4 with azimuth 232.5° and lines associated with it with azimuths: 52.5°, 307.5°, 127.5°, determine approximate directions of sunrise and sunset in the vicinity of the summer solstice (52.5°, 307.5°) and directions of the sunrise and sunset around the winter solstice (127.5°, 232.5°). For the purpose of comparative analysis, the above results are included in Table 1, item 4. It is worth noting that the above result is consistent with the value of the bisector C_4KD_4, Fig. 13, (Jamka 1965, plan VI). These results testify the importance of these lines for the mound builders. The above given azimuths values of four directions are different about 0.75° from the azimuth values of the sunrise and sunset directions during the winter and summer solstice, given in Table 1, item 2. It should be noted that the old communities did not pay attention to continuous count of time. Therefore, it was important to determine the summer and winter solstice day. For this purpose, observations of sunrises and sunsets were valuable. As the summer or winter solstice approaches, the speed shift of the sunrise (sunset) slowly decreases and stays in the same place for a few days around the day of the summer (winter) solstice. Its position does not noticeably change in this period.

The phenomenon of sunrise lingers on from the appearance of the upper edge of the solar disk on the horizon line until the bottom edge. In Table 1, item 1 azimuths, values are given for the moment of the beginning of the sunrise on the summer solstice and the winter solstice (directions: KS_1 and KS_3), and the sunset (directions: KS_2 and KS_4, Fig. 3). Refraction (35′) and the visible horizontal height above the horizon (20′) are included in the calculation of these azimuths. These items are marked in Fig. 14 with a yellow dot. In Table 1, item 2 the azimuth values of the moment when the lower edge of the Sun touches the horizon line is given. Comparing values of azimuths in item 1 and item 2, Table 1. we notice that during the sunrise and sunset on the summer solstice the solar disc moves along the horizon about 48′, which corresponds to 1.5 angular length of the diameter of the solar disc measured horizontally.

Obtained independently on three levels the correct azimuths of the sunrise and sunset on the summer and winter solstices testify evidence that Krakus Mound or the place where it was later built, in prehistoric times played an important role as a cult place and it was used for astronomical observations.

SUMMARY

In the light of the analysis of artefacts documented by archaeologists on the basis of the excavations carried out on Krakus Mound, the thesis is justified that a considerable range of astronomical and calendar knowledge was deposited inside. Using the radially running lines of fences, the directions of sunrise and sunset were recorded on the summer and winter solstice, including the beginning of spring and astronomical autumn. The east-west line documented inside the mound marked the directions of sunrise and sunset on the spring and autumn equinox, which mark the date of the beginning of astronomical spring and autumn. Additional four dates, falling in the middle of the above seasons, determined two different days of sunrise on the mound of Wanda and two different days of sunset, observed in the opposite direction. Hence Krakus Mound together with Wanda Mound could very well fulfill the function of the solar calendar in ancient times with the division of a year into eight parts. In the light of the sun disc from Nebra found in the area of Saxony – Anhalt (Meller, Garrett 2004) from before 3600 years, the high level of knowledge possessed by the Krakus Mound builders is not surprising. As the astronomical knowledge presented on this disc shows that the inhabitants of Central Europe from the Bronze Age were surprisingly clever observers of the night sky.

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