THEORETICAL POSSIBILITY OF THE ASTRONOMICAL USE OF HAT ROCK IN BOZSOK DURING THE LATE BRONZE AGE PERIOD•

A BOZSOKI KALAPOS-KŐ CSILLAGÁSZATI HASZNÁLATÁNAK ELMÉLETI LEHETŐSÉGE A KÉSŐ BRONZKORBAN

MITRE, Zoltán[1]; ILON, Gábor[2]

[1] Institute of Geography and Earth Sciences, Faculty of Sciences, University of Pécs

[2] Kossuth u. 2., H-9662 Mesterháza

E-mail: mzoltan@gae.hu; ilon.gabor56@gmail.com

In memoriam István Tóth (1944 – 2006)

Abstract

During the Late Bronze (14th-8th century BC) and Iron Age period (7th-1st century BC) on the top of the Szent Vid hill in the in the Kőszeg Mountains, close to the Amber Road along the valley of Gyöngyös river, there was a significant settlement, also a power, industrial and trade center. The Hat Rock is a cliff group of natural origin with a distinctive morphology situated approximately two and a half kilometers from this place, above Bozsok village. Presently Szent Vid hill is still clearly visible from this place. Archaeological research in both places during the last decades presumed the possible astronomical-related use of the Hat Rock, primarily related to the Sun. At the south part of the cliff group, in a leeward place suitable for shelter too, an archaeological excavation found a fire place and potsherds, a clay spoon and a grinding stone from the Late Bronze - Early Iron Ages. In this research we try to reveal such easily available astronomical related functions of the Hat Rock, which are linked to the time, agricultural activities, maybe the productiveness as well. Based on the geodesy data of the territory of Hat Rock, we found its southeast-northwest direction, which coincides with the direction of the sunrise of the winter solstice and the sunset of summer solstice. We found that the times of equinoxes of vernal and autumn can be determined by the position of the Sun correlate with given parts of the Hat Rock, observed from the twin rocks, the possible entrance of the procession route. From this observation point, the apparent positions of Pleiades open cluster also the Orion and Taurus constellations close to the horizon can help to determine the time of vernal equinox. This point is also suitable to forecast the time of winter solstice by the position of Altair star. In the inner place of the area, among the items of cliffs at the highest position, we can mark out an observation point, where the approximate time of the event of summer solstice by the observation of the Sun can be determined. The rising and setting Sun shines into the northern hollow part of the cliff of presumed observatory point during the significant agricultural time period, which is determined by this. The platform shaped cliff item in the highest position from the units of Hat Rock is approachable on a stairway-like path. Its direction coincides with the sunset of the summer solstice also the sunrise of the winter solstice, its feature suitable for ritual purposes. The observers were able to determine the times of annual significant astronomical events of Sun also with the use of skyline and the starry sky from the middle of the area. The significant and other noticeable positions/places we found during our research at the Hat Rock need further archaeological excavations, metal detection works. The complex archaeometrical analysis (like dating, pollen analysis) of possible finds, phenomena cannot be ignored.

Kivonat

A késő bronzkor (Kr.e. 14–8. század) és a vaskor (Kr.e. 7–1. század) idején a Kőszegi-hegységben, a Gyöngyös-völgyében haladó ún. Borostyánkő út közelében, a velemi Szent Vid hegyen jelentős település, hatalmi, ipari- és kereskedelmi központ helyezkedett el. Ettől légvonalban mintegy két és fél kilométerre a mai Bozsok község felett található a Kalapos-kő nevű, sajátos morfológiájú, természetes eredetű sziklatömeg. Innen ma is jól látható a Szent Vid-hegy. A két helyszínen az elmúlt évtizedekben végzett régészeti kutatások felvetették a Kalapos-kő csillagászati vonatkozású használatának lehetőségét, elsősorban a Nappal kapcsolatban. A sziklatömeg déli, szélárnyékos, „menedék” céljára is alkalmas részén végzett régészeti szondázás tűzhely maradványait, a késő bronzkor végére – a kora vaskor elejére datálható edénytöredékeket, agyagkanál darabját és őrlőkő töredéket tárt fel. Jelen kutatásunkban a Kalapos-köveknek olyan könnyen elérhető asztronómiai jellegű funkcióit próbáltuk feltárni, amely az időhöz, a mezőgazdasági tevékenységhez, netán a termékenységhez köthető. A terület geodéziai adatai alapján megállapítottuk annak dél-keleti, észak-nyugati irányultságát, amely egybeesik a

• How to cite this paper: MITRE, Z. & ILON, G. (2019): Theoretical possibility of the astronomical use of Hat Rock in Bozsok during the Late Bronze Age period, *Archeometriai Műhely* **XVI/3** 271–294.

téli napforduló napkeltéje és a nyári napforduló napnyugtája irányával. A feltételezett processziós út bejárati kapujának vélt sziklapárostól a sziklatömeg adott tagjaihoz viszonyítva a napnyugta helyzete alapján megállapítható a tavaszi/őszi napéjegyenlőség ideje. A Fiastyúk (Plejádok) nyílthalmaz, valamint az Orion és Bika csillagképek látszó horizonthoz közeli helyzete a tavaszi napéjegyenlőség időszakára ad információt. Ugyanebből a pontból nézve az Altair csillag a téli napforduló előrejelzésére alkalmas. A terület belső részén, a legmagasabb pozíciójú sziklatömegek egységei között kijelölhető egy megfigyelőhely, ahonnan a Nap megfigyelésével a nyári napforduló időpontja viszonylag jól meghatározható. Az obszervatórium pontjának gondolt homorú sziklatömeg északi oldalára a mezőgazdaságilag jelentősebb időszakban süt be a kelő és nyugvó Nap, amely ezáltal így behatárolható. A Kalapos-kövek sziklatömegei közül a legmagasabb helyzetű sziklaegység egy lépcsőzetes úton megközelíthető teraszos formát alkot, amelynek iránya a nyári napforduló napnyugtája és a téli napforduló napkeltéje irányával is egybeesik, jellege alkalmas lehetett szertartási célokra is. A terület középpontjáról a látható horizontprofil segítségével a Nap nevezetes pozícióinak időpontjai az év során a csillagos égbolt segítségével is hozzávetőlegesen meghatározhatók lehettek. A Kalapos-kő ezen vizsgálata során megállapított fontosabb, valamint más jellegzetes pozíciókban/helyszíneken további régészeti szondázás és fémkereső tevékenység indokolt. A majdani új jelenségek, leletek komplex archeometriai feldolgozása (pl. kormeghatározás, pollen-analízis) nem mellőzhető.

KEYWORDS: ARCHEOASTRONOMY, HAT ROCK, SUMMER SOLSTICE, WINTER SOLSTICE, EQUINOX, SUN, CONSTELLATIONS, BRONZE AGE, IRON AGE, PLEIADES

KULCSSZAVAK: ARCHEOASZTRONÓMIA, KALAPOS-KŐ, NYÁRI NAPFORDULÓ, TÉLI NAPFORDULÓ, NAPÉJEGYENLŐSÉG, NAP, CSILLAGKÉPEK, BRONZKOR, VASKOR, FIASTYÚK (PLEJÁDOK)

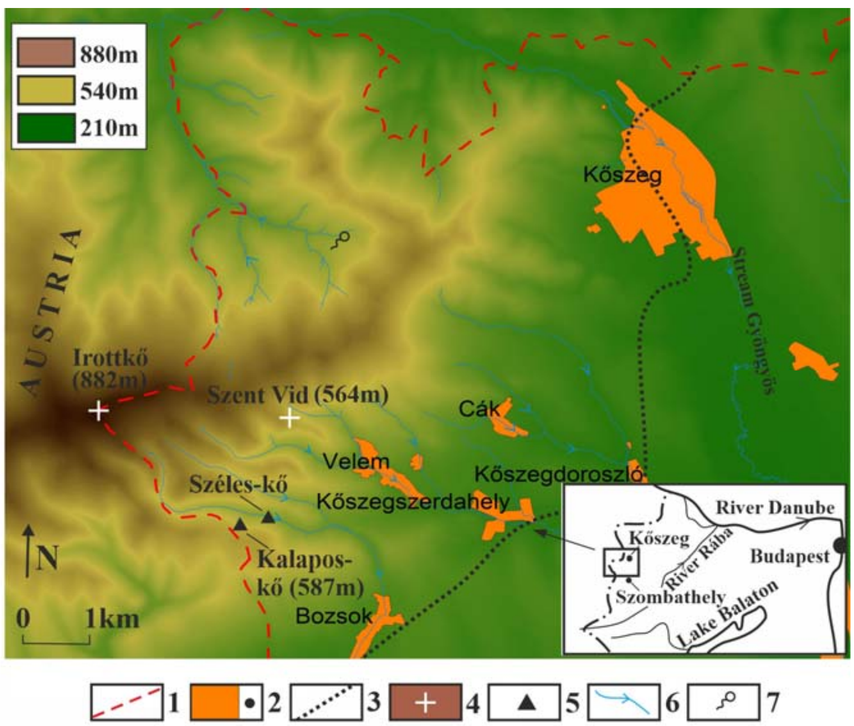

Fig. 1.: Location of examination. Legend: 1. national border; 2. settlement; 3. boundary of the Kőszeg Mountains; 4. peak; 5. rock formation; 6. stream; 7. spring (Veress et al. 2015)

1. ábra: Vizsgált helyszín elhelyezkedése. Jelmagyarázat: 1. országhatár; 2. település; 3. Kőszegi-hegység széle; 4. hegycsúcs; 5. kő formáció; 6. patak; 7. forrás (Veress et al. 2015)

Introduction

In the paper we present a study to reveal the theoretical possibility and resources of the astronomical use of the Hat Rock in Bozsok for a given time period of the late Bronze Age (1200-1000 BC). We were motivated for the examination due to the typical east-west orientation of the site recognized by former examinations, because this is logically linked to the direction of the apparent daily movement of the Sun and sky. Moreover, the artifacts from the area and the excavations in Szent Vid, close to the site, with clear symbolisms are also linked to archaeoastronomy (Ilon 2002, 2012, 2015; Vértes 2002). Research is also reasonable because, in case of favorable environmental conditions (suitable landscape, vegetation), many cultures used natural formations and/or purposely built artificial landmarks to appoint and observe the rising and setting positions of the Sun, Moon, planets, brighter stars, constellations. In case of the Sun, according to the assumptions, observation of solstices and equinoxes had an especially important role (Bartha 2014; Kelley & Milone 2005; Magli 2016; Pásztor & Barna 2015; Ruggles 2015).

Geological and morphological review

Hat Rock is a greenschist cliff group with unusual morphology stretches 100x30 meters, and rises 5-10 meters above its environment. It is located in the western Hungarian outskirts, Pre-Alps middle land, Kőszeg Mountains minor land, on the periphery of Bozsok village in Vas county, northwest from this settlement, approximately 600 meters above the sea level. This cliff group is one of the heights of the greenschist ridge along the direction of east-west, which ends with a steep forehead close to the village Velem (Dövényi 2010; Veress & Szabó 1996) (**Fig. 1.**). In the present the Szent Vid hill is still clearly observable from the site of Hat Rock.

Two processes formed the present appearance of Hat Rock: rise of the mountain, during this process it tipped and rose compared to its surroundings, and a destruction process, which resulted in the morphology we see today. The tilt of the surface in the direction of south-west verifies the tip process, at the same time its surface continuation in the west direction tilts in the east direction. Both north and the south sides of site of Hat Rock are surrounded by plain surfaces with tilt, situated 5-6 meters lower. The tilt of plain surface is larger in the south direction but there are fewer craggy cliff walls with remarkable relief than in the north direction. In the latter direction a long, complex, uniform cliff wall separates the examined cliff group from the surface of the plain in lower position. The line of strike of cliff walls bordered the place is such like that they follow almost exactly one of the well measurable tectonic direction in northwest- southeast. In the place both of tectonic directions in north-east south-west and probably an east-west one is also recognizable. The appearance of chasms is also characterizing the tectonic directions (Veress & Szabó 1996; Veress et al. 1998).

The present form treasure of Hat Rock is a remnant form, the formation of terraces, platforms and typical hat form due to solution processes among other ones (**Fig. 2a**). Although the material of cliff group is basically greenschist, but it also has lime content in various scales as contamination.

Fig. 2a: The highest position cliff item (No. III) of the Hat Rock (Photo by Mitre, Z.)

2a ábra: A Kalapos-kő legmagasabb helyzetű (III-as) sziklatömege (Fotó: Mitre Z.)

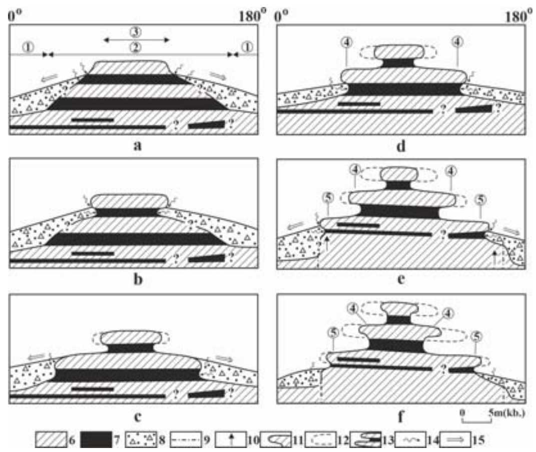

Fig. 2b: Theory of origin of grand features of Hat Rock by Veress & Szabó (1996). Legend: 1. younger surface; 2. remains of younger surface; 3. apical level of Hat Rock, remains of older surface; 4. upper denudation level of Hat Rock; 5. lower denudation level of Hat Rock; 6. greenschist without lime; 7. lime bed and limestone; 8. soil and loose ground; 9. possible fault; 10. uplift; 11. hat; 12. ruined part of hat; 13. platform; 14. percolation of water in detritus in the direction of solution places; 15. denudation of detritus

2b ábra: A Kalapos-kő nagyformáinak kialakulási elmélete Veress-Szabó (1996) alapján. Jelmagyarázat: 1. fiatalabb felszín; 2. fiatalabb felszín maradványa; 3. Kalapos-kő tetőszintje, idősebb felszín maradványa; 4. Kalapos-kő felső lepusztulási szintje; 5. Kalapos-kő alsó lepusztulási szintje; 6. mészmentes zöldpala; 7. meszes összlet és mészkő; 8. talaj és kőzettörmelék; 9. valószínűsíthető vető; 10. emelkedés; 11. kalap; 12. kalap elpusztult része; 13. szinlő; 14. vízszivárgás a törmelékben, oldódási helyek irányába; 15. törmelék lepusztulása

HU ISSN 1786-271X; urn: nbn: hu-4106 © by the author(s)

When debris with soil cover is situated up to the height of lime beds in greenschist material, then a solution-type destruction begins which results large platform formations while the debris cover is exist and the ratio of supply and dispatch are equals. When the uncovering process of this layer becomes more intense and dispatch also increases the development process stops or rather begins in a lower location, creating a new level. Frost effect may also play a role in the development of platforms (**Fig. 2b**) (Veress & Szabó 1996; Veress et al. 2015).

Both the morphological analysis and the character of the cliff group preclude that they were put in this site artificially or their forms were manually constructed.

There were not any noticeable changes in the form treasure of Hat Rock between the examined time period and the present state. According to our lights regarding the dissolution of rocks with lime content we suppose the dissolution negligible considering the elapsed time and environment of the site (Dreybrodt 1988).

Archaeological research of the area

The presume of Hat Rock as a sacral place originate from Mária Fekete archaeologist and her husband István Tóth ancient historian. Not incidental moment of the birth of this hypothesis is a bronze statuette, perhaps a votive early Iron Age object which was published by Kálmán Miske (1908). The 66 mm tall statuette represents a bare woman, which originally had a vessel in her hand (**Fig. 3.**). In the "B" inventory book of the Museum of the Cultural Association of Vasvár County, on the page of 93 under the number of 2988 can be read the following: "Bronze woman statuette. Outskirts of Velem Szt. Vid."

Furthermore, in the Prehistoric inventory book of the Antiquity Storage of Museum of Vasvár County (1925-1937) under the number of 480. on the page 123, the following is written: "Velem, Hat Rock – Woman with vessel in its hand." Unfortunately, the vessel already broke down and disappeared but in addition to the descriptions above in the photo pictures of Miske's publication it is still visible in three points of views (Miske 1908). This statuette may be referring to a public ritual that the community collectively performed in this place (Kalla et al. 2013).

The first step in verifying this hypothesis was an archaeological probe. We executed it in 1997 as a part of the archaeologist technician training of History Department of Berzsenyi Daniel College.

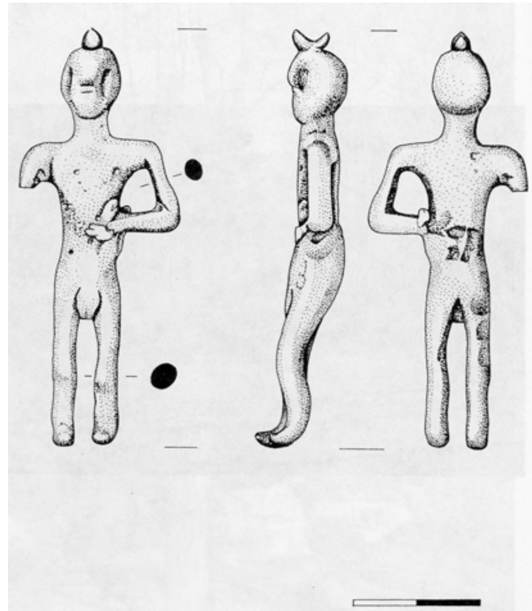

Fig. 3.: Bronze sculpture from the Hat Rock in Bozsok (after Ilon 2002)

3. ábra: Bronz szobrocska a bozsoki Kalapos-kőről (Ilon 2002 nyomán)

We worked one weekend at three selected locations of the Hat Rock (**Fig. 4.**). In the thin humus layer above the bedrock at the workplace 1. (cliff *item I*), we found only tangible findings from the modern history. We worked at the workplace 3, which is a small sized rock cavity (Holler-cave) at the west side of the Hat Rock, in a research pit to the level of greenschist bedrock. In the fill we found only a small number of ceramics from the medieval and modern ages. The research probe 2. (cliff *item IV*) was the interesting place regarding the subject of our examination. At the leg of the south-east side, in wind shade we found the remains of a fire place with a pounder stone and fragments of pots, clay spoon, dated to the transition of late Bronze Age and Iron Age (?) (**Fig. 5a-b**; Ilon 2002a, b). Maybe we entitled to think that, it is remains of a ritual ceremony attached to repast and also presumable, that we maybe consider the above-mentioned bronze statuette at an early Iron Age occasion as a votive present linked to one individual from the community.

In the second step, years later, in the re-publication of gold treasure from Velem we touched also the archaeoastronomy-related adaptation of diadem and spherical slices (Ilon 2015). In Velem, on the top of the Szent Vid hill in the Hungarian Kőszeg-mountain, next to the Amber Road edge along the valley of Gyöngyös river, during the Late Bronze

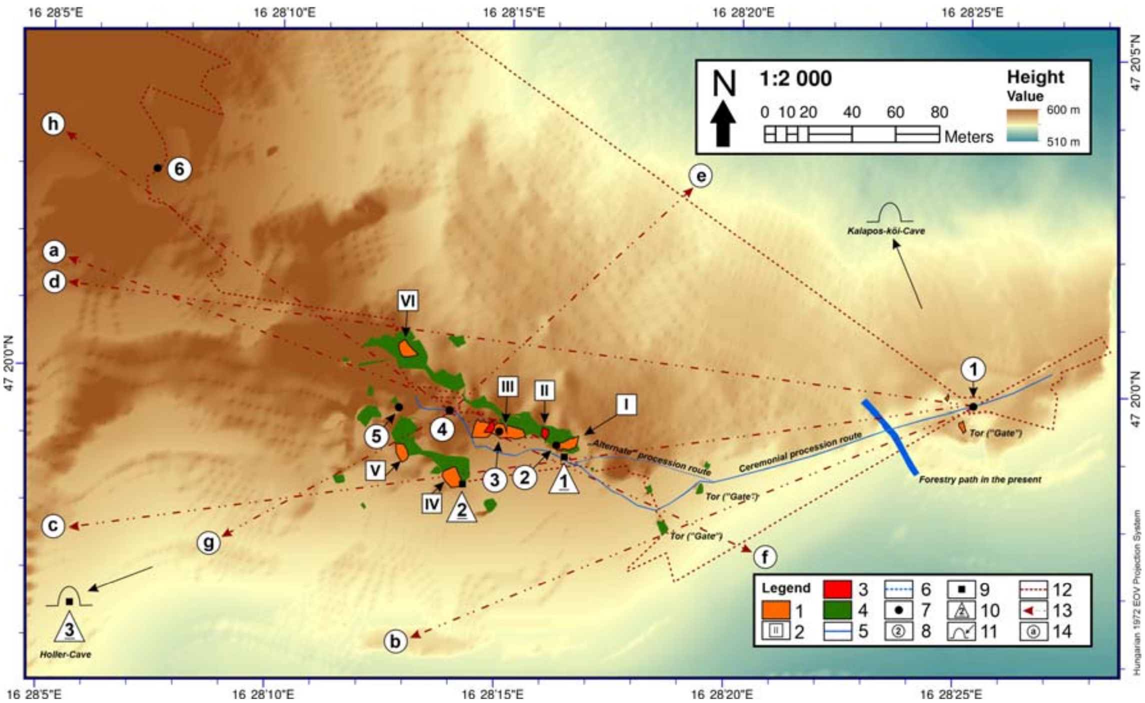

Fig. 4.: Review map of the area and examination. Legend: 1. significant cliffs regarding the examination; 2. numbering of significant cliffs regarding the examination (I-VI); 3. important hat form; 4. other cliffs; 5. present paths (possible procession route separately signed); 6. possible alternate procession route; 7. astronomical examination places (also panorama shooting places); 8. numbering of astronomical examination places (1-6); 9. sites of archaeological examinations; 10. numbering of sites of archaeological examinations (1-3); 11. important caves outside the represented area of map, and their directions; 12. horizon skyline influenced by the landmarks from the site 1.; 13. examined directions of given astronomical objects; 14. data of specific directions of given astronomical objects, for detailed data of the signs of (a-h) see **Table 1.** (Edited by Mitre, Z., based on data of Veress – Szabó 1996; Ilon 2002 and geodesy survey of Isztin, Gy.)

4. ábra: A terület és a vizsgálat áttekintő térképe. Jelmagyarázat: 1. vizsgálat szempontjából jelentős sziklák; 2. vizsgálat szempontjából jelentős sziklák számozása (I-VI); 3. fontosabb kalapforma; 4. egyéb sziklák; 5. mai ösvények (feltételezett felvonulási útvonal külön jelölve); 6. lehetséges alternatív felvonulásiútvonal; 7. asztronómiai vizsgálati helyszínek (egyben panorámafelvételezés helyei); 8. asztronómiai vizsgálati helyszínek számozása (1-6); 9. régészeti vizsgálatok helyszínei; 10. régészeti vizsgálatok helyszíneinek számozása (1-3); 11. térkép ábrázolt területén kívülre eső fontosabb barlang és iránya; 12. tereptárgyak által befolyásolt horizont profil az 1-es helyszínről; 13. adott égitestek vizsgált irányai; 14. adott égitestek jellegzetes irányainak adatai, az (a-h) jelölésekhez tartozó részletes adatokért lásd az **1. táblázatot** (Veress – Szabó 1996; Ilon 2002 adatai és Isztin Gy. geodéziai felmérése alapján szerkesztette Mitre Z.)

(14th-8th century BC) and Iron Age periods (7th-1st century BC) there was a significant settlement, also a power, industrial and trade center. The site of Hat Rock is situated approximately two and a half kilometers from this place.

Archaeoastronomical background

It is presumed that the observation and representation of the Sun and the starry sky already appeared in the culture of the people living in the Pleistocene. In France, several caves were examined and found that several cave drawings were made such places where the sunlight appeared around solstices. In the cave drawings of Lascaux Cave researchers feel as if they identify constellations or the Pleiades open cluster (Messier 45, M45), but many others cautiously and doubtfully accept this theory (Jégues-Wolkiewiez 2011; Pásztor & Priskin 2010; Rappenglück 2004).

In Eurasian and American cultures, the east-west orientation of late Stone Age tombs appears independently of each other. The east-west symbols related to the Sun in Egyptian culture were a symbol of rebirth and death. The orientation not only followed the daily movement, but also tried to appoint the places of highlighted solstices and equinoxes (Bartha 2014).

Fig. 5a: The archaeological probe No. 2., 1997. (Photo by Ilon, G.)

5a ábra: A 2. számú régészeti szonda, 1997. (Fotó: Ilon G.)

The correlation with Sun also recognizable in orientation of late Neolithic round ditches in the Carpathian Basin at the Transdanubia region. Many examinations refer to that the eastern gates of round ditches were orientated to the current sunrise of the time of their position measurement. The relationship with the Sun can also be linked to the death culture and burial (Pásztor & P. Barna 2009; P. Barna et al. 2015).

The Sun veneration appears from Egypt through Central Europe to Scandinavia till the Bronze Age (Ilon 2015). By this time, the idea of the annual decline and renewal of the Sun could have evolved, which was dominant mainly in cultures far from the equator. The difference between winter short daylight and long nights, as well as summer long daylight and short nights is more decisive at higher latitudes (Bartha 2014).

It is perceptible in many cultures, that their artificial build-ups were configured, oriented in such a way that the Sun illuminates a certain point of the structure on special occasions (such as solstice or equinox) or its rise or set position considered from a certain part of the structure coincident with the direction of a given part of building or landmark of natural origin. A part of researchers assume an astronomical orientation associated with the Sun in the case of the well-known Stonehenge as well, but many other artificial and natural observation sites are also proper examples. Orientations and observation points associated with the Moon and brighter stars in the starry sky are also recognizable in case of installations that have astronomical purposes as well (Bartha 2014; Kelley & Milone 2005; Magli 2016; Ruggles 2015). For example, in Siberia there are some locations from the late Bronze Age where Larichev et al. (2015) assumed that important positions of the Sun or Arcturus star could be observed and used often natural landmarks as point of reference, but they also assumed observation point for the position of the Betelgeuse star (in constellation Orion).

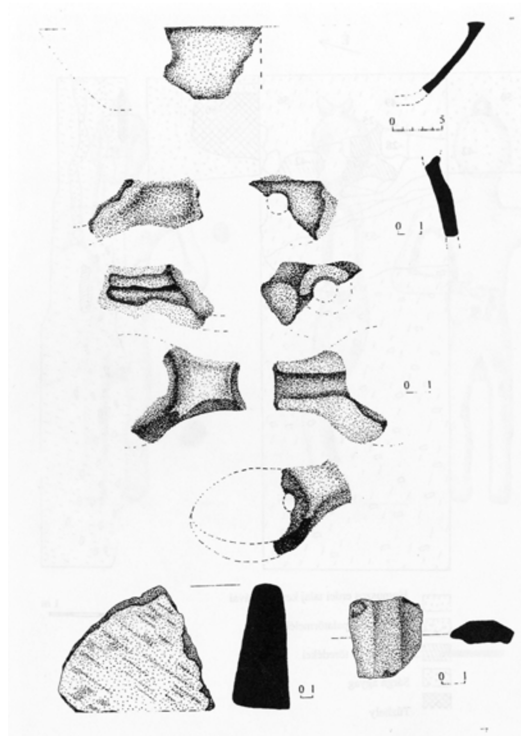

Fig. 5b: Drawings about finds from the archaeological excavation in 1997 (after Ilon 2002)

5b ábra: Az 1997. évi régészeti szondázás során előkerült leletek rajza (Ilon 2002 nyomán)

Observation of stars also helped to predict the times of significant positions of the Sun (for example winter solstice) (Larichev et al. 2015).

Direction of the east-west orientation is also typical in later eras and cultures, for example it is recognizable in the orientation of a part of medieval Hungarian churches (Guzsik 2002; Keszthelyi 2012) and the effect were built on the movement of sunlight within the space (Pásztor – P. Barna 2017). In addition to orientation in the direction of the Sun, Moon, stars, other astronomical related solutions may occur. Near Magdalenenberg in Germany, for example, Mees (2007) assumed that the Hallstatt-age tombs were placed in the vast heap grave in such a way that they represented an exact replica of the observable constellations in the night sky during the summer solstice of the 7th century BC. At the same place, the extreme positions of the rise and set of the Moon (due to the lunar standstill phenomena) were also employed for orientation (Mees 2007).

In addition to precisely oriented burials and buildings, symbols depicting the sky, Sun, Moon, stars appear in many cultures on articles of personal use and symbols of power. Astronomical symbols can also be assumed in the objects of the golden treasure turned up in Szent Vid (**Fig. 6a-c**).

Fig. 6a: Gold treasure from the Szent Vid hill at Velem, with presumed astronomical symbol decorations: sphere slices and diadem (after Ilon 2015)

6a ábra: A velemi Szent Vid feltételezhetően asztronómiai szimbólumokkal díszített aranykincsének tárgyai: gömbszeletek és diadém (Ilon 2015 nyomán)

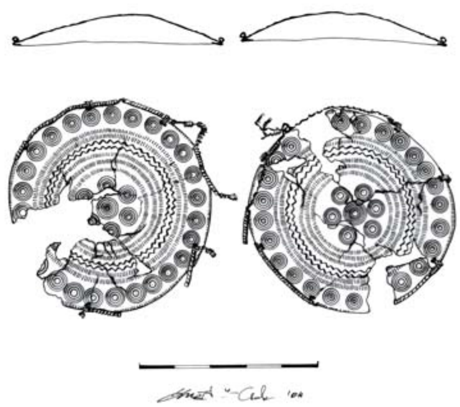

Fig. 6b: Drawings of the pair of sphere slices no. II. (after Ilon 2015)

6b ábra: A II. gömbszeletpár rajza (Ilon 2015 nyomán)

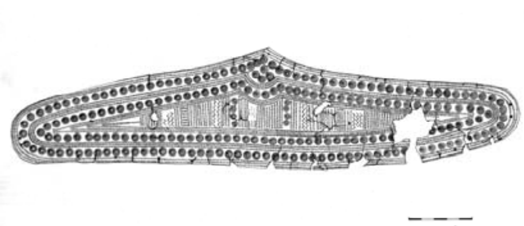

Fig. 6c: Drawing about the diadem before conservation (after Ilon 2015).

6c ábra: A diadém restaurálás előtt készített rajza (Ilon 2015 nyomán)

The number of the concentric circle symbols on the edge of the diadem is 221, which may indicate the length of the Pleiadic year in days. The Pleiadic year consist of 7 synodic (an average of 29.53 days) of lunar months and 14.3 days. The record of length of this time can be recognized in other cultures as well (Ilon 2015; Schlosser 2010). The recognized 27-28 symbolic numbers attached to the Moon may indicate the Moon's sidereal (27.3 days) orbital period. The number 7 also can be recognized which refer to the phases of the Moon (Ilon 2015). But this number can represent the stars of the Pleiades too (Ilon 2015; Schlosser 2010), or the seven bright stars of the Orion constellation, perhaps the stars of the Big Dipper, but also may symbolize the 7 astronomical objects of the solar system visible with naked eye.

The symbolism of the golden treasure is also concordant with the symbolism system of other European finds of the Late Bronze Age, which is linked to the passage of time, fertility, the cycle of nature (Ilon 2015). The solar symbols found in the diadem and other artifacts from the examined period not definitely refer to the solar culture, it may be just decorative elements referring to the Sun (Pásztor 2009, 2015). The representation (hence its observation) of stars in the Bronze Age got an important role in societies. The observation of characteristic stars can be related to time, over and above ritual significance can also be attributed to this fact (Bartha 2014; Pásztor 2010).

Former surveys of the Hat Rock used for research

Over the last two decades geomorphological and archaeological researches were also made in the area of Hat Rock. In case of both of these occasions accurate maps were made, suitable for orientation with right directions. In the mid-1990s, to recognize the accurate geomorphology of the place a very detailed, large-scale geomorphological map was created for research purposes, using a traditional method (Veress & Szabó 1996). In 2005-2006 at the request of Gábor Ilon for archaeoastronomy purposes the surveyor Gyula Isztrin in collaboration with college students of archaeology technician made an accurate digital survey.

The first sketchy astronomical survey of Hat Rock in relation to the position of main astronomical directions was carried out for the researches of G. Ilon (2002). Based on the position measurements of Ernő Vértes (2002) a sketch map was made from the field with right scales and directions about important major cliff items. Position measurements showed that the location of some rock units of the Hat Rock coincides with the main (astronomical) points of the compass. Furthermore, the path through the ceremonial procession gates supposed by István Tóth historian of antiquity (**Fig. 4.** and

10.) is in the direction of east-west has only a few degrees in bias, at the end point of it there is a large cliff item (*no. III*), a part of it may be a venue of some kind of ceremony (Ilon 2002; Vértes 2002). This assumption, so the use of the Hat Rock as a ceremonial place, the Early Iron Age bronze figurine in the **Fig. 3.** also may confirm.

Data about the climate of Bronze- and Iron Age, also status of landscape and vegetation – condition of the sky observation

The examined archaeological period is situated in the Sub-boreal section of the Holocene epoch of Quaternary period. In general, the climate of the Late Bronze- and Early Iron Age are characterized by one of the wet temperature minimums in the Hallstatt-cycle. The system approached research of the approximately 2300-year-old Hallstatt-cycle presumes an astronomical background to the engine of the cycle, the last minimum of the cycle coincided with the medieval Little Ice Age (Scafetta et al. 2016).

Evidence could be found at several places to the cool climate of the examined time period. Due to the drop in temperature, Greek settlements in Bronze Age have depopulated (some data refer to low solar activity as well), in Turkey, Lebanon, the Arabian-peninsula and the Middle East pollen data and the change in Dead Sea water level refers to a drier and cooler climate (Drake 2012; Falkenstein 2013; Finné et al. 2011).

In the Carpathian Basin, the climate was also cooler, but wetter. The general reconstruction with high resolution of climate and humidity was made by László Kordos (1977) with the use of the spread of sensitive vole species to these. With the help of further data retrieved from environmental archaeological research, small changes in the climate become recognizable. The time of Hungarian Late Bronze Age is characterized by a continental climate section with somewhat more moderate humidity which rises again in the Iron Age (Horváth 2002; Sümegi 1998; Sümegi et al. 2003, 2011). The wet cool climate favorable for richer vegetation, but the considerable anthropogenic effect can influence this. Landscape formation by anthropogenic origin also causes a significant change in the nature and morphology of vegetation and landscapes (Pécsi 1991). Hungarian stratigraphic examinations indicate significant logging which led to the spread of species prefer open space, it may result sparse, highly visible areas (**Fig. 7.**) (Sümegi et al. 2003; Willis et al. 1997).

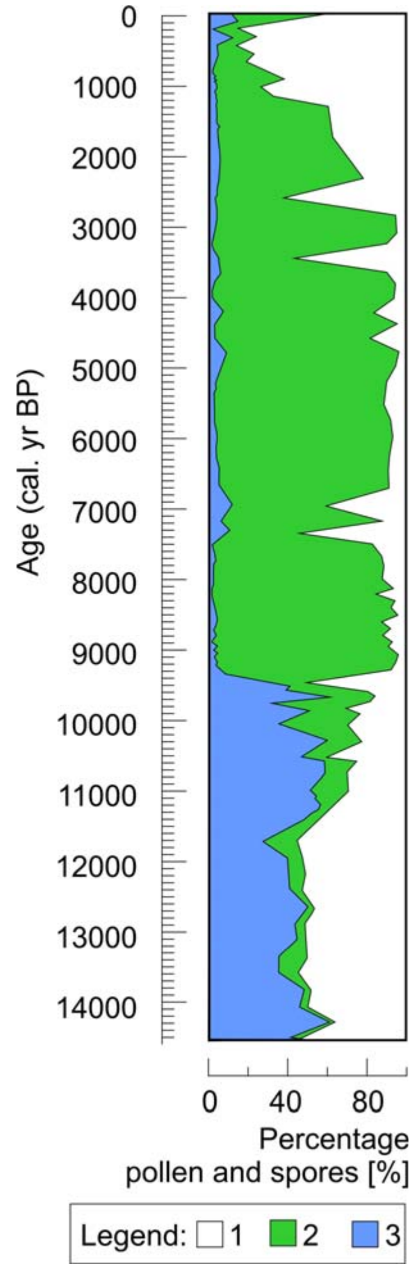

Fig. 7.: Change of nature of vegetation in the last 14 thousand years based on pollen and spore data (Kelemér, Kis-Mohos). During the Late Bronze period the ratio of herbs preferring open space significantly rose. Legend: 1. sum herbs; 2. sum broad-leaved; 3. sum needle-leaved (Sümegi et al. 2003; Willis et al. 1997)

7. ábra: A növényzet jellegének alakulása pollen és spóra adatok alapján az elmúlt 14 ezer évben (Kelemér, Kis-Mohos). A késő bronzkorban jelentősen megnövekedett a nyílt területeket kedvelő fajok aránya. Jelmagyarázat: 1. nyílt területet kedvelő fajok; 2. lombos fák; 3. tűlevelűek (Sümegi et al. 2003; Willis et al. 1997 nyomán)

In connection with archaeological research, detailed geological, pollen and macro-plant particle examinations were made close to the place of the Hat Rock in and around the Cemetery of Szombathely-Zanat dated to the younger phase of Urnfield culture in Late Bronze Age (about 20 km) and much closer, at the turf bog at the foot of Szent Vid (about 5 km). Thus, we have a lot of information about the condition of vegetation in the close area. Data of pollen, macrobotanic and scale refer to in the examined area forest extraction and very active agriculture, grazing livestock, i.e. significant anthropogenic activity and landscape-transforming work. At the border of the Bronze and Iron Ages, the transformation of vegetation decreased and then became significant again during the Iron Age, maybe due to the increase in population (Juhász 2007; Jakab & Sümegi 2007; Sümegi 2007; Sümegi & Törőcsik 2011).

The change in the nature of the vegetation at the place of examination was typical of recent past as well, since there are references to extensive mountain pastures and meadows. Surroundings of villages Velem and Bozsok are mainly characterized by offset forests (Dövényi 2010). Multiple changes in vegetation may also lead to changes in the degree of transport of soil and material from greenschist cliff masses. We estimate that soil thickness in the area was maybe 10-20 cm above than the present status, but cycles of short-term soil accumulation and transfer periods are assumed by changes in vegetation and climate, result soil thickness is not changed significantly compared to present status. Sparse vegetation and open areas are significantly preferable for archaeoastronomy use.

Examination methods

Before the astronomical examination, we analyzed the astronomical capabilities of the site based on map information. We processed the Isztrin's geodesic survey using geoinformatics solution, developed the 3D model of the area and compared, refined this digital survey with the map of Veress & Szabó (1996), which helped accurately identify given landmarks. Archaeological excavations and significant sites were localized by the sketch map of Ilon (2002) oriented to the points of compass.

Astronomical survey is limited from some selected points for examination by the present vegetation of the site. We were able to capture accurate field panorama shoot about nearby landmarks during winter minimal vegetation, but already had to digitally produce the horizon profile from the geodesic survey data in case of landmarks in medium distance. We examined the horizon profile composed by far relief landmarks with the help of geoinformatics data about the wider area (e.g. SRTM). The production of horizon models helped to determine from the examination points in the Hat Rock the visible position in which the covering of Sun, Moon, planets, stars are start by a given topography element, landmark and rock. We made further examination of panorama shoots and horizon profiles in digital planetarium software after computer procession.

To determine the visible position of the astronomical objects, we use classic spherical astronomy calculations in topocentric horizontal coordinate system. In case both of celestial bodies and visible landmarks we worked with the angles of altitude (*h*) and azimuth (*Az*) – due to the work with geodesy data – the latter we measured from the beginning north point to the direction of east.

To the calculation of these essential visible positions, the

$$\begin{aligned} \cos h \sin Az &= \cos D \sin t \\ \sin h &= \sin D \, sin\varphi + cosD \cos\varphi \cos t \\ \cos h \cos Az &= -\sin D \cos\varphi + \cos D \sin\varphi \cos t \end{aligned} \quad (1)$$

equations can be used, where *h* altitude above horizon, *Az* is azimuth (take into consideration, that in astronomy calculations its starting direction is south), *D* is declination, *t* is hour angle, φ is geographical latitude of observer (Kelley & Milone 2005; Marik 1989). To value *t*, we need to know the *RA* right ascension of the astronomical object and the hour angle of the point of vernal equinox at the observation place. The required values *Az* and *h* for the examination could be determined by the combination of equations (1). The value of *h* must be corrected by the refraction of the atmosphere (Marik 1989).

Many solutions and perturbation calculations could be used to determine the ephemerides *RA* and *D* of planets, the Sun and the Moon to a given time (Érdi 2001; Marik 1989). These calculations are not required in case of examining stars; only their coordinates need to be corrected. We took into consideration stars brighter than 2 magnitudes visible in the sky of 11-13th centuries BC during our work. Regarding the corrections for the practical part of the examination of astronomical objects we mention two important long-term movements of the Earth. The ε obliquity of the Earth's axis is change as the function of time; we applied the sufficiently precise solution of Laskar (1986) covering 20 000 years to calculate the change (**Fig. 8.**). In addition, lunisolar precession has to also take into consideration; its effect causes significant change in the coordinates of astronomical objects over thousands of years. We do not detail the theories and methods of each mentioned individual calculations (Érdi 2001; Gábris 1998; Kelley & Milone 2005; Marik 1989; Meeus 1991).

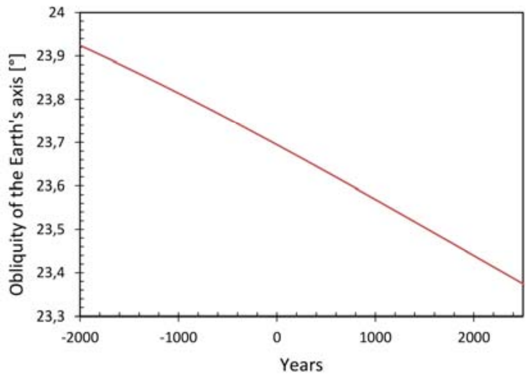

Fig. 8.: Graph of change of obliquity of Earth's axis between 2000 BC and 2500 AD based on the calculations of Laskar (1986)

8. ábra: Laskar (1986) számításai alapján készült grafikon a Föld dőlésszögének változásáról Kr.e. 2000 és Kr.u. 2500 között

However, more – also free, like Stellarium – planetarium software and online calculators give quick and adequately accurate outcome from archaeoastronomy point of view. Digital planetarium software is widely used in archaeoastronomy research (Conolly 2016; Zotti 2016).

Despite of the difficult celestial mechanics background, many positions of the Moon and the planets – such as transits, conjunctions – are repeated with more or less accuracy, so we summarized them from the examined period. For example, in case of planets, the planet Venus returns to almost the same position in every 8 years (we dispense with small angular deviations). In the case of the Moon, the lunar phases – with a relatively larger error – are repeated in every 8 years (octaeteris). Lunar phases occur in every 19 years on the same day of the year, the latter is the Metonic cycle. Eclipses are repeat in an 18 years 11 days cycle – so-called Saros cycle (Meeus 1991; Marik 1989). Archaeoastronomy also highly examine the extreme positions of Moon, the lunar – minor or major – standstills, that are the result of the rotation of its orbit plane with an 18.6-year-old cycle due to perturbation. As a result of this phenomenon, the *Az* values of rising and setting positions of the Moon get into extreme positions, these are recognizable e.g. in case of Iron Age artifacts as well (Mees 2007).

Even the subject of archaeoastronomy examinations is searching for signs of periodic phenomena. Episodic phenomena can be comets, meteor showers, solar and lunar eclipses, Moon covers stars or planets, supernova explosions, interesting conjunctions. Due to the small amount of the artifacts, we did not pan out about examination of them, but only even checked the positions of zodiac light.

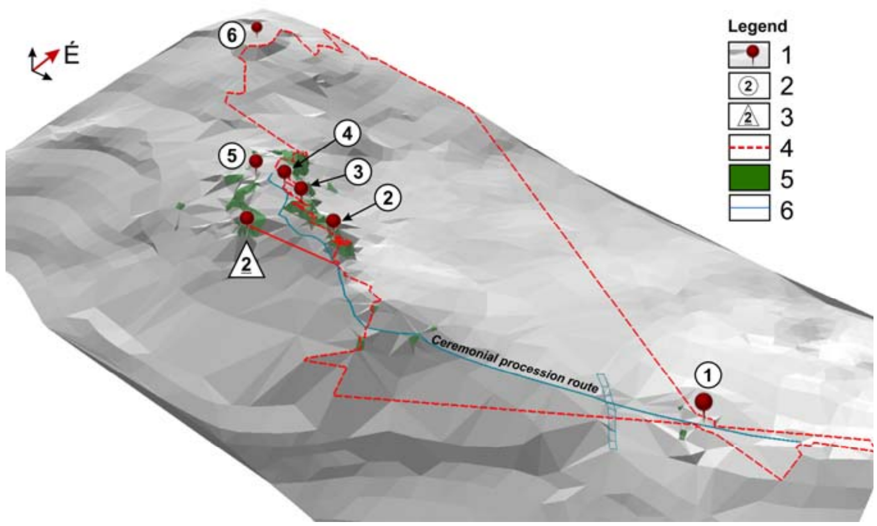

Fig. 9.: Digital model of terrain surface based on the geodesy survey with signs of some important examination sites and the skyline from the site 1. Legend: 1. astronomical examination places (also panorama shooting places); 2. numbering of astronomical examination places (1-6); 3. numbering of sites of archaeological examinations (2); 4. horizon skyline influenced by the landmarks from the site 1.; 5. other cliffs; 6. present paths (possible procession route separately signed) (Edited by Mitre, Z. based on the geodesy survey of Isztin, Gy.)

9. ábra: Geodéziai felmérés alapján készült digitális domborzatmodell a fontosabb vizsgálati helyszínek jelölésével és az 1-es helyszínről látott horizontprofillal. Jelmagyarázat: 1. asztronómiai vizsgálati helyszínek (egyben panorámafelvételezés helye); 2. asztronómiai vizsgálati helyszínek számozása (1-6); 3. régészeti vizsgálatok helyszíneinek számozása (2); 4. tereptárgyak által befolyásolt látott horizont profil az 1-es helyszínről; 5. egyéb sziklák; 6. mai ösvények (feltételezett felvonulási útvonal külön jelölve) (Isztin Gy. geodéziai felmérése alapján szerkesztette Mitre Z.)

Results

The stated approximate east-west orientation carried out by Vértes (2002) was confirmed by high-precision data from the geodetic and mapping survey, but this orientation is not accurately east-west rather southeast-northwest, which also coincides with one of the tectonic directions founded by Veress & Szabó (1996). This direction - within acceptable margin of error - is the same as the horizontal direction of the setting Sun during the period around the summer solstice and also the rising around the winter solstice.

During the executed fieldwork we identified four places that, or rather combinations of these could be interesting in archaeoastronomy point of view. One place from these allows approximately accurate astronomical observation too. We do not consider the astronomical use feasible of the further two examined places. In **Fig. 4.,** the data of former examinations and also the geodetic and astronomic surveys are summarized. **Fig. 9.** gives a spatial review from the area. The locations of interest for examinations are numbered in these latter figures, which we refer in the later parts of the paper.

According to the executed astronomical calculations for the examination, during the BC 1200-1000 period due to the precession movement of the Earth, the notable astronomical events during a year are occurred in the following constellations: vernal equinox in Aries, summer solstice in Cancer, autumn equinox in Libra, and winter solstice in Capricornus. That is why – based on the present time – on average, in the examined time period the vernal equinox occurred on 31 March, the summer solstice on 3 July, the autumn equinox on 3 October and the winter solstice on 31 December. The direction of the Earth's rotational axis did not point to any bright star at that time. In the examined period obliquity of this axes was greater than the presently known value of 23° 26’, approximately 23° 50’ (**Fig. 8.**), it has to take into account in case of rising and setting astronomical objects. This amount in obliquity difference results in excess of 30% plus in the *Az* value near the horizon than the angular appear diameter of the Sun.

Using of east gate to determine the equinoxes

For the observation of the spring and autumn equinoxes, we regard principally *site 1* and, under certain conditions, *site 2* suitable. *Site 1* lies on the path edge along the greenschist back from the direction of the Wide Rocks (Széles-kövek), its place appointed by two cliff formations apiece of them containing more platforms, diameter between 2-3 meters with a height of 1.5 meters (**Fig. 4.** and **10.**).

Fig. 10.: Two greenschist rocks, which mark the entrance of procession route (present path) (Photo by Mitre, Z.)

10. ábra: A felvonulási út (mai ösvény) bejáratát jelző két zöldpala szikla (Fotó: Mitre Z.)

As we have described before, these two cliff items are could be interpreted as a kind of gate by their type, the track is connected as a procession path to them. The cliff mass of the Hat Rock is located west from here at a distance of 200 meters, its highest visible altitude point reaches $h \approx 8°$ altitude. Looking west from observation *site 1* during the vernal and autumn equinoxes, when the Sun reached h≈7° altitude, it appeared in the direction of the leg of cliff *item I* of the Hat Rock, lowering till its coverage. We also mention, that the direction of cliff height (cliff *item IV*) above the archaeological probing place *number 2* falls exactly the same direction, but it is covered by the relief.

Looking in the west direction the observer could see the Hat Rocks in the highest position as a group at a relief section in a range of about $Az \approx 248°-277°$. The south part of this range is bounded by the rise of large south cliff item of the assumed third “*tor*” gate and at the north the edge of the steep rock wall, which separates the examined rock mass from the flat surface in the lower position. Within this interval, the Sun appeared about 1-1 months before and after the vernal equinox, so the time of the equinox could therefore be approximately determined. Regarding of forecast, it is obvious that, approaching to the autumn equinox the north part of the interval, in case of the vernal one the south part of the interval was first touched by the Sun (**Fig. 11.**). To control the time, use of the full moon could also be used, as in the period around the equinoxes, just before sunrise, it set with slightly deflection behind the Hat Rocks in the same direction of sunset.

HU ISSN 1786-271X; urn: nbn: hu-4106 © by the author(s)

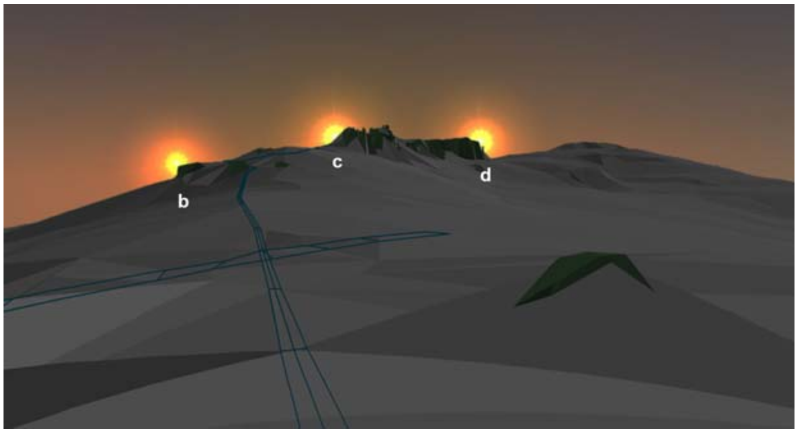

Fig. 11.: Simulation of b, c, d, Sun-positions as seen without vegetation in the direction of western horizon from the examinationsite 1. in 1100 BC. See **Table 1.** for more details in this figure.

11. ábra.: A b, c, d Nap-pozíciók szimulációja az 1. vizsgálati pontból növényzet nélkül látható nyugati horizont irányában Kr.e. 1100-ban. A jelölésekhez tartozó részletes adatok a **1. táblázatban** láthatók.

Looking east from *site 1*, there is no significant landmark for our examination, the altitude of area rises about 3 meters, which covers the background topography. It is seen in **Fig. 10.**, which is a photo taken in the direction of east. During the summer solstice, in the morning, when the Sun reached an altitude *h≈10°* above the horizon, it was seen in the direction of *site 1* in case of receding in the direction of east from the Hat Rock cliff mass, leaving the second gate on the ceremonial procession path.

Table 1.: Data for the astronomical positions represented in **Fig. 4.**

1. táblázat: A 4. ábrán szereplő csillagászati pozíciókhoz tartozó adatok

Mark	Observation site	Date, time period of observation	Astronomical object	Azimuth (*Az*)	Altitude (*h*)	Fig. of reference	Remark
a	2	07.03.1100. BC summer solstice	Sun	291.1°	13.1°	-	-
-	2	06.22. 2018. BC summer solstice	Sun	290.5°	13.1°	**Fig 16b**	Control observation
b	1	03.01.1100. BC	Sun	247.9°	4.4°	**Fig. 11.**	Approxiamtely at 11.01.1100. BC Sun was in the same position
c	1	03.31.1100. BC spring equinox	Sun	262.4°	7.3°	**Fig. 11.**	Approximately at 10.03.1100. BC during the autumn equinox Sun was in the same position
d	1	04.27.1100. BC.	Sun	277.9°	6.9°	**Fig. 11.**	Approxiamtely at 09.06.1100. BC Sun was in the same position
e	4	03.31.1100. BC spring equinox	Vega	43.2°	12.2°	**Fig. 18.**	-
f	4	03.31.1100. BC spring equinox	Antares	114.8°	3.1°	**Fig. 18.**	-
g	4	03.31.1100. BC spring equinox	Sirius	241.3°	2.5°	**Fig. 18.**	-
h	4	03.31.1100. BC spring equinox	Capella	306.2°	16.1°	**Fig. 18.**	-

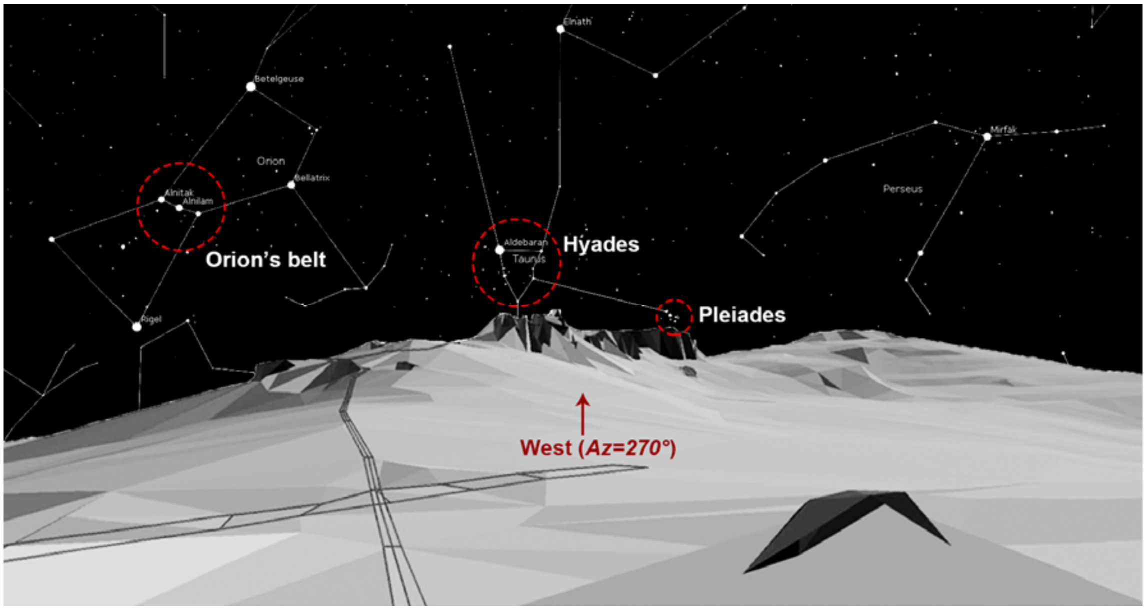

Fig. 12.: The visible starry sky from the examination site 1. in 1100 BC, one week before the spring equinox, at the time of the Sun's height h=-12° (start of astronomical twilight)

12. ábra: A csillagos égbolt látványa az 1. pontból a Kr.e. 1100. évi tavaszi napéjegyenlőség előtti héten, a Nap h=-12°-os magasságának időpontjában (csillagászati szürkület kezdete)

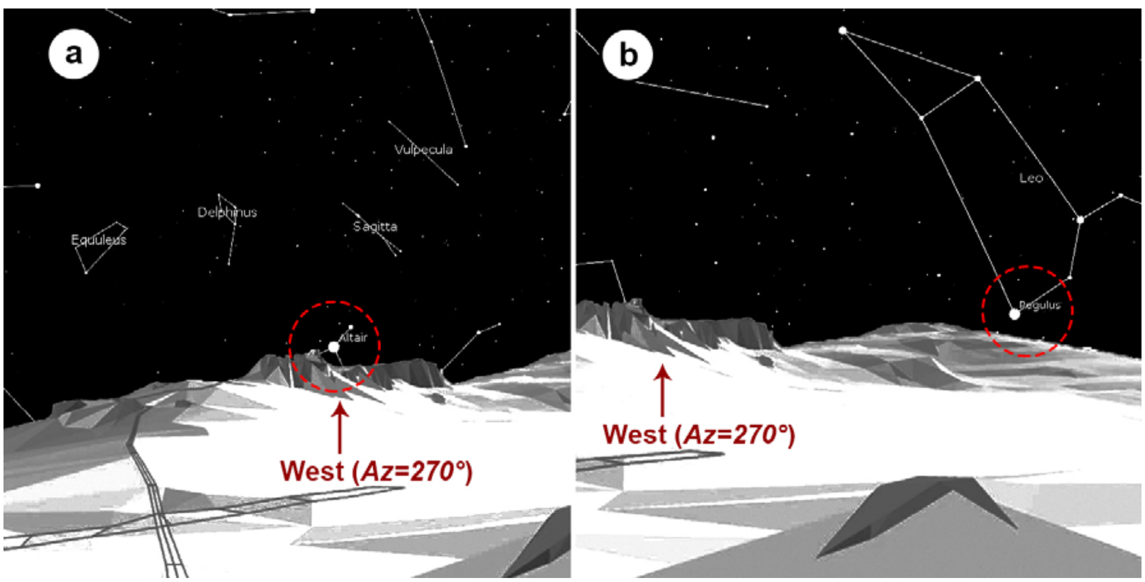

Fig. 13.: a) The heliacal setting of Altair star at the winter solstice on the 12.31.1100 BC. b) The heliacal setting of Regulus before the summer solstice on the 06.20.1100 BC. Both of the simulations were made from the examination site 1.

13. ábra: a) A téli napforduló idején az Altair nevű csillag heliákus nyugvása Kr.e. 1100.12.31-én. b) A Regulus heliákus nyugvása a nyári napforduló előtt Kr.e. 1100.06.20-án. Mindkét égboltkép szimuláció az 1. vizsgálati pontból készült.

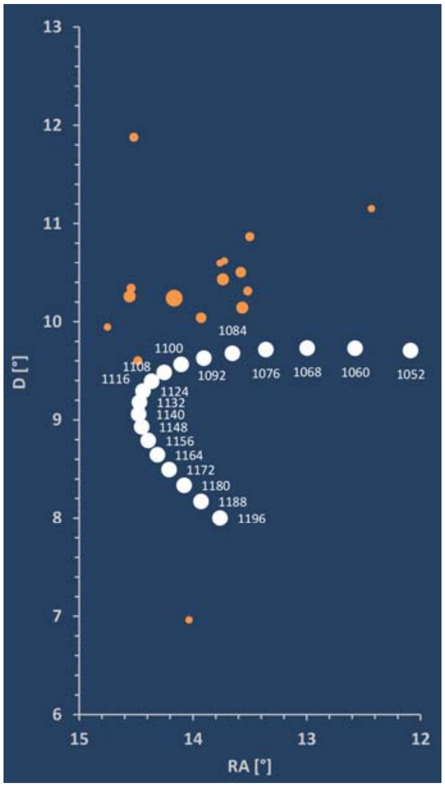

Fig. 14.: Spring conjunctions of Venus and Pleiades on every 1st of March in the highlighted years BC at 18.5 hours UT, in the western sky. We use the epoch of equinox point in 1100 BC to represent the positions.

14. ábra: A Vénusz és a Plejádok tavaszi együttállásai a jelölt Kr.e. években március 1-én 18,5 óra UT-kor a nyugati égbolton. Az ábrázolt pozíciók a tavaszpont Kr.e. 1100. évi epochára vonatkoznak.

The time of the vernal equinox could also be estimated by examining the visible starry sky close to the horizon in the direction of the Hat Rock. During this notable time, after sunset, the direction of setting constellation Orion (and the three stars that form its belt) coincided with the direction of the greater part of the supposed procession route goes from *site 1* (observer on the path essentially moves in the direction of the constellation). Before the equinox, the Pleiades open cluster approached the visible horizon in the northern part (*Az≈277°*) of the relief containing the cliff items of Hat Rock and did a heliacal setting. The cosmical setting of the cluster before sunrise was possible to observed in the middle of October, and possible to linked to the autumn equinox. Interesting phenomenon that clusters of Hyades and Pleiades observed from the examination point almost clasped the Hat Rock in *Az≈263°–277°* section *(***Fig. 12.***)*. The Big Dipper, compiled from 7 spectacular stars, had a characteristic position without any comparison with landmarks during the vernal equinox, when it reached its highest position in altitude in the sky and was in the same position in dawn during the autumn equinox.

In addition, with the help of positions of brighter stars close to the horizon and their heliacal settings, prediction of the winter and summer solstice was also possible. In the former case from the examination point in the middle of December, the Altair star of the constellation Aquila in the direction of *Az≈270°* was seen close to the horizon profile of the Hat Rock. In the latter case, the Regulus star approached the visible distant horizon in the weeks before the summer solstice in the direction of *Az≈298°* after sunset (**Fig. 13.**). The Spica star of the constellation Virgo in the direction of *Az≈270°* was seen after sunset in mid-end of July close to the horizon of Hat Rock, the same place where the Altair star was seen in winter.

We highlight the bright planet Venus as an example in our examination, because this astronomical object did a repeating conjunction in every 8 years with the Pleiades cluster close to the vernal equinox. There were such years, when observer saw this astronomical object situated inside the open cluster. Venus's recurring positions, however, shift over time due to various celestial mechanical effects, although recurrence was relatively regular at a longer examination time period, there is a good example for this in **Fig. 14.**

In relation with the setting extreme positions of Moon regarding the lunar standstill phenomenon such position cannot be assigned where these extreme positions would have associated with an outstanding landmark or topography element.

The possibility of the use of "observatory site"

The place of *site 2* can essentially be attributed to an "observatory" function. In this location the observer had to stand on the north side of the cliff block *item I* (**Fig. 4.**), where the shape of this cliff is concave (**Fig. 15.**). The wall of the cliff item has a line of strike in the east-west direction with a slight difference (in the direction of linked *Az≈75°* and *255°* positions).

When the observer standing on the mentioned side of the cliff item, at the western end of that, looking at the direction of *item II* and *item III* cliff blocks, between them in the direction of *Az≈290° (± 2°)* can see a gap (**Fig. 16.**). The area is rising in this direction, it follows that the surface is seen at an altitude of *h≈10°*, the visible highest point of the two cliff items are approximately *h≈20–25°*, the bottom of the gap between the two cliff items ends at an altitude of *h≈12°*. Around the position of the summer solstice, in the late afternoon, the Sun becomes visible through the gap, partly lowering along its tilt in the direction of the horizon.

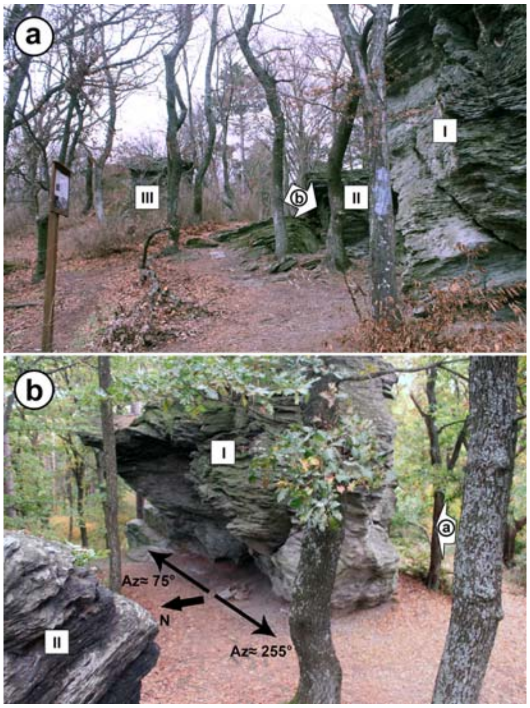

Fig. 15.: Important cliffs and the observatory point. In the pictures we marked the numbers of cliffs according to the **Fig. 4.**, place and direction of photoshoots by arrows, in these with a) and b) the appropriate picture.

15. ábra: Lényeges sziklatömegek és az obszervatórium pontja. A képen jelöltük a **4. ábra** szerint a sziklák számozását, nyíllal a fényképezés helyét és irányát, a nyílban szereplő a) és b) betűvel a megfelelő fényképet.

This assumption was confirmed by the field examination on the 22 June 2018 (**Fig. 16.**). We remark, that the time of summer solstice was on the 10 hours 07 minutes UT on 21 June 2018. Our field work delayed due to weather circumstances, but this time difference meant negligible shift in the Sun's position (Nautical Almanac of The Stars 2018). We also found that based on the change in the angle of obliquity of the ecliptic the position of the Sun was slightly more favorable for its observation through the gap during the 1200-1000 BC time period.

During the solstice the Sun reaches the most favorable extreme position for observation through the gap between cliffs for the observer, and in the days before/after the solstice, the observation possibility is becoming less and less favorable. Despite of the large parallactic displacement of the close cliff items, the ideal observation point can be clearly marked standing at the wall of cliff *item I*. The Regulus star described earlier could be suitable for forecasting the summer solstice, which position during the examined time period permitted its observation before heliacal setting too through the observation gap.

From this point, assignment of positions of vernal and autumn equinoxes is heavier. In case of sparse vegetation, it was possible to observe, that the Sun set behind the visible horizon in approximately halfway between the cliff *item IV* with lowered position and the cliff *item III*, but this point is not adequately suitable for accurate observations.

Also, in case of the Moon we cannot sign out notable points. When its digression in the northern sky is positive from the ecliptic as plain of reference, then during its stay in constellation Cancer it could be observable in the observation gap while moved towards the horizon. In case of negative digression, it was covered by the cliff *item III*. In winter, the light of full moon close to its rising and setting position could have reached the north concave part of cliff *item I*, in case of major standstill its duration could have been slightly longer.

Worthy of note, that after the sunset during vernal equinox the zodiac light may visible from the observatory point in the direction of cliff *item III*. Ideally, during the ages of examination, the top of the zodiac light may approach the Regulus star, which appeared in high altitude this time. Through the gap of examination assigned by cliff *items II and III* from the *site 2*, moving both of the – naked eye visible as misty spot – M44 Beehive cluster and the M31 Andromeda galaxy to the direction of the horizon could be observable. However, the observation possibility of these latter objects cannot be linked to a notable time of astronomical event.

The heliacal setting of Antares star in Scorpion constellation could be observed above the cliff *item IV* in the direction of *Az≈245°* in the middle of September, which could prognose the autumn equinox a few weeks before. The cosmical setting of Antares in the same position occurred after the vernal equinox. It is obvious, based on the data shown in **Table 1.,** that the "b" Sun position in the **Fig. 11.** coincident with the above-mentioned position of the Antares close to the horizon.

Therefore, the star could be used as a control star from observation *site 1* to detect the time period of these notable astronomical dates, because before its set it was visible very close to the south point of the relief.

Fig. 16.: a) From the examination site 2. in the direction of Az≈290° we can see a gap between the cliffs of II. and III. b) position of the Sun close to the summer solstice on the 22nd June 2018, at 17:26 UT from the same point (Photo by Mitre, Z.)

16. ábra: a) A 2-es jelzésű vizsgálati helyszínről Az≈290° irányban tekintve látható a II-es és III-as sziklatömb által közrefogott rés. b) A Nap pozíciója ugyanebből a pozícióból a nyári napforduló környékén, 2018. június 22-én 17:26 perc UT időpontban (Fotó: Mitre Z.)

Orientation of the highest point

Connected to the summer solstice, cliff *item III* (**Fig. 4.**) can be attributed to an additional role. We appointed the *site 3* next to the highest point of the cliff item. The highest point (587 m) of it (and simultaneously the area) is a "hat cliff" about an elliptical shape with approximately a semi-major axis 3 meters and a semi-minor axis 2 meters, separated by a remarkable platform from the level below it (**Fig. 2a** and **17.**).

This cliff item can be approached via a small terrace, both of orientations the longitudinal direction of terrace and semi-minor axes of the cliff item are approximately *Az≈300°*. Next to the hat cliff item, when the observer stands on this small terrace faces opposite the Sun approach its sunset during the time of the summer solstice, sees its setting in the direction of the examination *site 6*. The examination *site 6* is currently not visible due to trees, but it is well detected in the simulation based on geodesy survey data. The observation *site 3* is well accessible, essentially without much effort, used by the stair-like positions of platforms of the cliff mass. The natural shape and approach of the cliff mass has an individual aspect, it may seem ideal for a sacral site associated with the Sun (**Fig. 17.**).

The orientation of southern side of the cliff *item III* is east-west, between spring and autumn the light of the Sun was limited or could not be reached it in the morning or late afternoon when this was in low altitude. In all cases, the light of the Sun between its position *Az=90°-270°* illuminates the southern wall. During the equinoxes sunrises and sunsets can be assigned along the southern wall of the cliff item. In the east direction, the cliff *item I* also coincides with the direction of this assignment, which is essentially surrounded by the light of the Sun when rising.

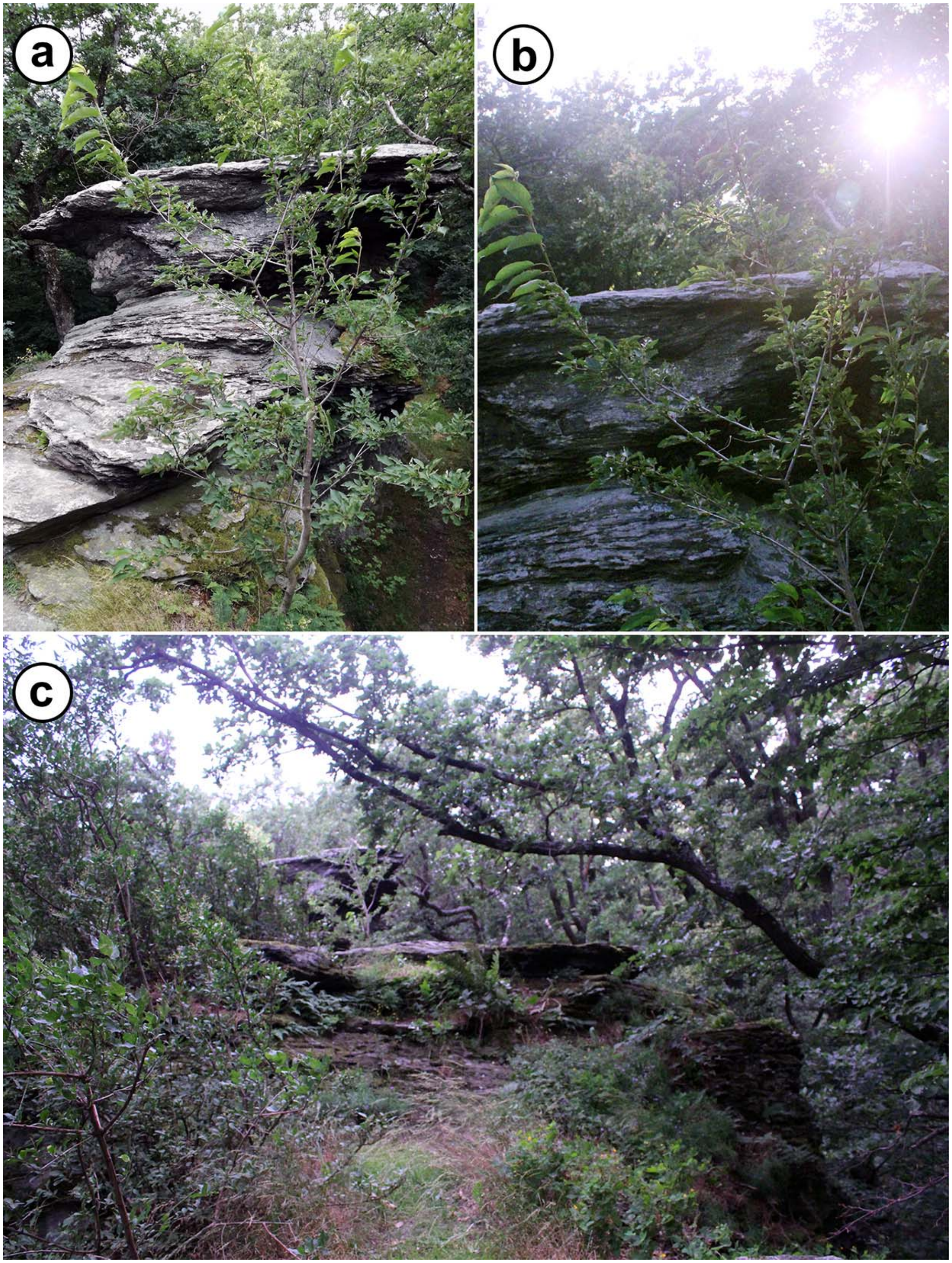

Fig. 17.: a) Specific hat-formed peak of the examination site 3. (also the highest point of the area); b) position of the Sun during the afternoon of summer solstice; c) this place is approachable on a stairway-like path (Photo by Mitre, Z.)

17. ábra: a) 3-as helyszín különleges kalapos sziklacsúcsa (egyben a helyszín legmagasabb pontja); b) Nap helyzete a nyári napforduló délutánján; c) a helyszín lépcsőzetes teraszokon keresztül közelíthető meg (Fotó: Mitre Z.)

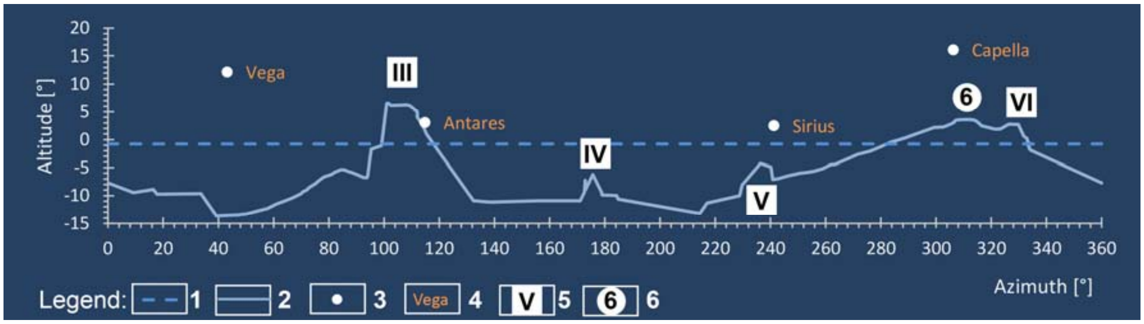

Fig. 18.: Simplified horizon skyline and some important stars from the examination site 4. at 03.31.1100 BC, in the night of vernal equinox at 20h UT based on the data of geodesy survey. We use the epoch of equinox point in 1100 BC to represent the positions. Legend: 1. position of calculated sea level horizon; 2. profile of relief based on the data of geodesy survey; 3. important stars; 4. name of important stars; 5. numbering of significant cliffs regarding the examination (see **Fig. 4.**); 6. astronomical examination places (also panorama shooting places, see **Fig. 4.**)

18. ábra: A horizont egyszerűsített profilja és néhány fontosabb csillag Kr.e. 1100.03.31.-én, a tavaszi napéjegyenlőség estéjén, 20 óra UT-kor, a geodéziai felmérés alapján a 4. vizsgálati pontból, a tavaszpont Kr.e. 1100 szerinti epocha szerint. Jelmagyarázat: 1. tengerszintre számított horizont helyzete; 2. domborzat profil a geodéziai felmérés adatai alapján; 3. fontosabb csillagok; 4. fontosabb csillagok neve; 5. vizsgálat szempontjából jelentősebb sziklák számozása (ld. **4. ábra**); 6. asztronómiai vizsgálati helyszínek (egyben panorámafelvételezés helye, ld.. **4. ábra**).

Centre of the area

The examination *site 4* essentially the center of the area, which is a remnant of a lower terrace on the greenschist rock. We examined it because we assumed that it could be used primarily to observe the sunrise of the vernal and autumn equinoxes, but we did not find clear possibility to it. It is obvious, that viewed from this examination site only a few close cliff items rise above the horizon, only the *item III* is the one, that raised more significantly in the direction of *Az≈110°* reach up to the altitude of *h=6–7°* (see the photo of the cliff block from the examination site in the **Fig. 2a**). The cliff *item IV* essentially visible in the direction of south (*Az≈180°*) and the *item V* in the direction of *Az≈235°*, but height of these are below the position of horizon, otherwise these might be suitable for mark out directions. Two bulges are visible as low-rise height on the one hand the distant one in the position of *Az≈310°* and *h≈3,5°* where we mark out the examination *site 6* and on the other hand the cliff *item VI* in the position of *Az≈330°* and *h≈3°*.

Several bright stars were possible to observe from this location used the landmarks mentioned above as points of references. As it is seen in **Fig. 18.**, in the turn of the centuries $12^{th}/11^{th}$ BC, the set of Sirius star during the evening of vernal equinox was visible in the direction of hat cliff *item V* at the same time, when the rise of the Antares star was observable in the direction of cliff *item III*. The Capella star was situated with relatively higher altitude in the direction of examination site 6 (also the direction of sunset of the summer solstice). The Vega star appeared in the direction of north-east in similar altitude like Capella (approximately opposite the Sirius) (**Fig. 18.**). In the dawns right after this equinox the observer could observe the Antares star in the direction of hat cliff *item V*.

The observer could also observe during the dawns around of the summer solstice the cosmical setting of Arcturus star in the direction of northwest (*Az≈325°*) which approximately coincides with the direction of cliff *item VI*. To the east, in the direction of cliff *item III* the Pleiades cluster and Taurus constellation located in high altitude and both of them disappeared in the light of the rising Sun. Regarding the Regulus star, we already described about its heliacal setting during the evening of summer solstice.

At the dawn, during the autumn equinox we cannot appoint distinctive positions, only Sirius could be seen close to its culmination and the zodiac light could be observed in the direction of east, however its direction did not coincide with the cliff *item III*. In the evening sky it was not possible to appoint distinctive positions, a few hours after the sunset the appropriate positions of former mentioned summer solstice dawn sky appeared.

We already described the heliacal setting of Altair star during the winter solstice, but at the same time in dawn it was possible to observe its heliacal rising as well. During its dawn position it was visible in the direction of cliff *item III* relatively high before disappeared in the light of the rising Sun, at the same time the Antares star reached its culmination, high in the direction of cliff *item IV*.

HU ISSN 1786-271X; urn: nbn: hu-4106

Fig. 19.: The sunlight shines into the northern hollow part of the cliff item I. during the late afternoon of summer solstice in 2018. The edge at western part of the cliff partly covers the sunlight (Photo by Mitre, Z.)

19. ábra: A I-es számú szikla északi, homorú oldalára bejutó napfény a 2018-as nyári napforduló késő délutánján. A sziklatömeg nyugati pereme a napfény egy részét kitakarja (Fotó: Mitre Z.)

In the evening of the winter solstice the sunset happened in the direction of cliff *item V*. After sunset, the constellation Orion was seen in the direction of cliff *item III*, and after the darkness arrived the Sirius star appeared next to the same cliff item. While the Regulus star rose in the direction of north-east, at the same time the Vega star lowered close to the horizon in the direction of cliff *item VI*.

Possible agriculturally active period indicator cliff item

The Sun shone during the examined period into the northern concave side of the cliff *item I*, when it was north from *Az≈75°* during its rise or *Az≈255°* during its set (**Fig. 15.**). The topography conditions are somewhat reducing the length of this time period.

During the time period of 13-11. century BC the Sun's light touched the examined part of the cliff item approximately between the first part of April and October (approximately the time between the vernal and autumn equinoxes), which could be indicative taking into also account agricultural and production aspects. Within this, between early May and September are the time section when rising Sun close to the horizon from east may illuminated the north side of the cliff item, not just only the setting one. We should add that there are edges on both of the eastern and western parts of the concave side of the cliff *item I*. These reduce the amount of the sunlight reach both of the area and the concave side behind them (**Fig. 19.**).

We already wrote before about the cosmical setting of Antares star, which is also observable from this point. We add that at the beginning part of September, when the Sun touched the northern part of the relief section visible from the *site 1* (marked "d" in the **Fig. 11.**), the Sun touched the visible horizon at *h≈11°* altitude from the observation *site 2* at the left root side of the cliff *item III*.

It is interesting that the direction of the center of the Milky Way (where it is the densest, most spectacular) from *site 2* was seen during the autumn equinox at the end of the astronomical dusk in the direction of cliff *item IV*.

We notice, that the formerly described south wall of the cliff *item III* may also be suitable for assign the boundary of the active-passive period separated by the equinoxes.

The "shelter" and fireplace

The *site 2* was appointed by the former archaeological probe in 1997, where artifacts and trace of a fireplace were successfully excavated from Late Bronze-Early Iron Age. The place is located at the leg of the hat rock *item IV*, in the root under a cliff platform in the direction of south and south-east (**Fig. 4.** and **5a**). Its altitude is 574 meters above the sea level, which is 10-15 meters lower than the height of the cliff items of Hat Rocks in the highest position. This point provided relatively tolerable protection against the northern down-wind and precipitation due to its concave shape (a larger platform covers it) at the leg of the cliff form.

The Sun by moving along in low altitude could light well the examined archaeological *site 2* between the autumn and vernal equinoxes until the early afternoon. Between the vernal and autumn equinoxes, however, the light of the Sun close to the horizon was covered on the one hand in the direction of east by the relief of the area on the other hand in the direction of south-west by the wall of cliff *item IV*. The line of strike of the cliff wall, which gives place to this *site 2* has a coincident direction with the sunset of winter solstice, so the light of the setting Sun can only reach this place only during winter solstice. This hypothesis was checked on field during the winter solstice.

A few meters from the above-mentioned site, at the south-west part of the cliff *item IV*, the cliff wall leading towards the Limax Cave roughly coincident with the direction of the sunrise during the winter solstice, so the light of the rising Sun that time could graze it. However, the light of the rising Sun is covered outside this solstice, it can only reach the place later from a higher altitude, so the Sun between the positions of *Az≈125°* and *Az≈270°* could surely shine on it. The light of the setting Sun could reach the cliff wall and the surroundings of the cave between the autumn and vernal equinoxes.

The shelter-like use of the Holler Cave close to the examined area, southwest from it, would seem logical, but the archaeological probing (*site 3*) in 1997 – regarding the now examined time period – was unprofitable. We do not know whether the artifacts of the examined period were "cleaned" from there or whether the cave was not used at all.

Regarding the whole area it is a priori problem that the small amount soil on the greenschist rock affects rather unfavorably the possibility of successful archaeological probing. We add that the Hat Rock Cave and its environment may also be interesting for archaeological examinations, its total length is approximately 30 meters, situated north from the examined area (**Fig. 4.**).

Uncertain sites

In the previous sections we examined such locations, which astronomical resources are easily recognizable. However, we cannot exclude that there were other sites that may suitable for observation, so our examination is far from complete. There were also sites that astronomical use we considered possible, but during our examination we did not find easily accessible astronomical resources for them.

The *site 5* is located on the slope of the greenschist cliff mass oriented to south, at the center of a semi-circular evolved edge, on a cliff item whence several cliff masses with hats can be seen in the directions of east, south, west including also a possibility to assign appropriate positions. However, in the simulation tests following the panorama survey we did not find convincing points to assign directions.

At the same time, *site 6* may be interesting for further examinations. From here as well, due to the vegetation currently not possible to see the location of the Hat Rock cliff group (the same as from the *site 1*), but the examination of the geodesy survey data showed that the winter solstice is able to observe from the site. In case of sparse vegetation due to its high position the observer could have a full view to the highest cliff items of the Hat Rock, so at the previous mentioned time the Sun could be visible to rise in exactly that direction.

During the examinations the question also arose whether the supposed procession path followed another track and missed the third "*tor*" gate, because edge along on the uplift seems the most ideal trail. Based on the geodesy examinations the site is easier accessible on a path along on the back of the cliffs than on the less favorable trail path currently used (**Fig. 4.**).

Conclusions

The location of the Hat Rock which is coincident with the direction of the movement of the Sun and the sky in correlation with both of the archaeological finds of Szent Vid and the examination place, propose the possibility of the astronomical related sacral use linked to productivity, agricultural, perhaps mountain culture. The people of the cultures living here "found" this formation with distinctive morphology "ready to use" which could strengthen its sacral character.

Astronomical use – i.e. observing the rising and setting of the Sun and other astronomical objects close to the horizon – is the most efficient in case of an environment with sparse vegetation, rich in open spaces, with good view to landmarks. According to the climate model created, based on the previous researches of this time period, there was a cooler, wet climate, which was favorable to the rich vegetation. However, environment history data confirming mosaicity refer to significant forest extraction in the Carpathian Basin and the examination site as well. This and the increase in the number of species that prefer open spaces refer to favorable observational conditions.

The astronomical resources and capabilities of the area could use as an indicator of a kind of agricultural activity. The observation made from the *site 1*, which is able to determine and predict the vernal and autumn equinoxes, may have already set out the beginning and the end of the productivity-active period. For example, the observation *site 4* in the middle of the area is suitable to check the time of vernal equinox where this time after sunset, in the early evening in the direction of cliff *items III-V-VI* a brighter star could be seen. We notice, that equinoxes could not compose a subject of typically accurate observations due to their brief nature and difficult detection of these moments. We consider the nature of illumination rather as a time marker in case both of cliff *items I and III*. The south wall with its east-west orientation of cliff *item III* and its inclusive nature regarding vernal and autumn equinoxes could clearly help to separate the spring-summer (productivity) and autumn-winter (decline, rejuvenation) time periods.

Within the area, cliff *item I* and examination *site 2* may also was suitable for observation of active agricultural time period. On the one hand, the section between the vernal and autumn equinoxes as the late afternoon Sun close to the horizon lit the northern side of this cliff block during this period, on the other hand the section between early May and early September, when the light both of the rising and the setting Sun close to the horizon may touched that. The time of the summer solstice could be clearly determined by observing the lowering Sun in the direction of western horizon through the cliff gap from observatory *site 2*. The heliacal setting of Regulus star was also suitable to prognose the time. The time of the autumn equinox can be estimated from *sites 1 and 2* as well. The time of the winter solstice can be well determined from the *sites 1 and 4* by the position of the Altair star both of its heliacal setting and at the same time rising at dawn.

The small number of archaeological finds in the Hat Rock complicates the reality of the theoretical results of our examination. The decorations of the artifacts found on Szent Vid Hill may refer to mainly to solar symbols as well as to the Moon month and the Pleiades cluster. However, it is difficult to find a vestige regarding how much the Hat Rock were used for astronomical observation in relation to these symbols. Presumably it could have also a limited observatory role in respect of observations regarding it is not an artificial creation. The further possible functions of the cliff items regarding the shadow effect will have to be a subject of a separate examination.

The raised astronomical thinking and resource exploration in this paper was intended to denote a theoretical possibility of use. New targeted archaeological excavations and comparative researches would be essential for further examinations in the practice and confirmation of archaeological theory. In the area the very thin soil layer on the greenschist rock makes the research with archaeological probe difficult, so only small number of finds of artifacts can be expected. As a result of climatic and vegetation effects, the thickness of the soil layer may have changed, but in general we assume transport from the area. Based on field examinations we find that further archaeological research everyhow must be carried out in places where artifacts fell down or transported with soil by rainwater and these can gather due to pluvial processes in area with lower altitude due to the relief circumstances around the environment of Hat Rock. Metal search activity is an urgent task too. Complex archaeometry processing (e.g. dating, pollen analysis) of subsequent new archaeological phenomena cannot be ignored. The results of the new archaeological researches would greatly contribute to the clarification of the theoretical approach in this paper and the planning of further steps of archaeoastronomy research.

References

BARTHA, L. (2014): Archeoastronómia (Csillagászat a régészetben és történelemben). *Egyesületi Híradó – a Gothard Amatőrcsillagászati Egyesület Tájékoztatója* **25/3** 22–38.

CONOLLY, D. (2016): *Archaeoastronomy for archaeologists*. BAJR Series Guide **43** 19 p.

DÖVÉNYI, Z. (2010): Kőszegi-hegység. In: DÖVÉNYI, Z. ed., *Magyarország kistájainak katasztere*. Magyar Tudományos Akadémia Földrajztudományi Kutatóintézet, Budapest 354–357.

DRAKE, B. L. (2012): The influence of climatic change on the Late Bronze Age Collapse and the Greek Dark Ages. *Journal of Archaeological Science* **38** 1862–1870.

DREYBRODT, W. (1988): *Processes in Karst Systems. Physics, Chemistry, and Geology*. Springer-Verlag Berlin Heidelberg, 288 p.

ÉRDI, B. (2001): Az ekliptika és az egyenlítő dőlésszögének szekuláris változása. In: ÉRDI, B. *A Naprendszer dinamikája*. ELTE Eötvös Kiadó, Budapest 228–234.

FALKENSTEIN, F. (2013): Kulturwandel und Klima im 12. Jahrhundert v. Chr. Das Beispiel Kastanas in Nordgriechenland. *Offa*. Berichte und Mitteilungen zur Urgesichte, Frühgeschichte und Mittelalterarchäologie. **69/70** 2012/2013, 505–526.

FINNÉ, M., HOLMGREN, K., SUNDQVIST, H.S., WEIBERG, E. & LINDBLOM, M. (2011): Climate in the eastern Mediterranean, and adjacent regions, during the past 6000 years - A review. *Journal of Archaeological Science* **38** 3153–3173.

GÁBRIS, GY. (1998): A Föld mint égitest. In: GÁBRIS, GY., MARIK, M. & SZABÓ, J. (Szerk.) *Csillagászati földrajz*. Nemzeti Tankönyvkiadó, Budapest 54–107.

GUZSIK, T. (2002): *Keresztény liturgiák építészete*. Budapesti Műszaki Egyetem, Építészmérnöki Kar Építészettörténeti és Műemléki Tanszék. http://www.eptort.bme.hu/doc/szakral/szakral2.html Last accessed: 2019.07.18.

HORVÁTH, A. (2002): Újholocén klíma- és folyóvízi környezetváltozások vizsgálata hazai régészeti adatok segítségével. *Földrajzos Doktoranduszok VII. Országos Konferenciája - A Természetföldrajzi Szekció előadásai*, ELTE Földrajzi Tanszékcsoport, Budapest 11 p.

ILON, G. (2002): Früheisenzeitliches rituelles zentrum auf dem Kalapos-kő (Hutstein) in Bozsok bei Velem-Szent Vid? *Specimina Nova Universitatis Quinqueecclesiensis* **XVI** 19–30.

ILON, G. (2012): Das Rad, die Sonne, der Wasservogel und die Vogelbarken auf spätbronzezeitlichen Schwertern ... mögliche Ausdrucks-formen des Handels oder anderer Beziehungen? *Studii şi Comunicări* **XXVIII/1** 169–209.

ILON, G. (2015): *Aranykincs a velemi Szent Vidről.* Archaeolingua, Budapest 248 p.

JÉGUES-WOLKIEWIEZ, C. (2011): The Relationship between Solstice light and the entrances of Paleolithic Painted Caves. In:

GHEORGHIU, D. ed., *Archaeology Experiences Spirituality?* Cambridge Scholars Publishing, 11–50.

JAKAB, G. & SÜMEGI, P. (2007): The macrobotanical remains from Velem–Szent Vid. In: ZATYKÓ, CS., JUHÁSZ, I. & SÜMEGI, P. eds., *Environmental Archaeology in Transdanubia*. Archaeological Institute of the Hungarian Academy of Sciences, Budapest 277–280.

JUHÁSZ, I. (2007): The pollen sequence from Velem–Szent Vid. In: ZATYKÓ, CS., JUHÁSZ, I. & SÜMEGI, P., eds., *Environmental Archaeology in Transdanubia*. Archaeological Institute of the Hungarian Academy of Sciences, Budapest 273–277.

KALLA G. — RACZKY P. — V. SZABÓ G. (2013): Ünnep és lakoma a régészetben és az írásos forrásokban. Az őskori Európa és Mezopotámia példái alapján. In. DÉRI, B. Szerk., *Convivium. Az Eötvös Loránd Tudományegyetem Bölcsészet-tudományi Karán 2012. november 6–7-én tartott vallástudományi konferencia előadásai.* Budapest 11–46.

KESZTHELYI, S. (2012): Magyarországi középkori templomok tájolása. *Egyesületi Híradó – a Gothard Amatőrcsillagászati Egyesület Tájékoztatója* **23/4** 17–26.

KELLEY, D.H. & MILONE, E.F. (2005): *Exploring Ancient Skies. An Encyclopedic Survey of Archaeoastronomy*. Springer Science+Business Media Inc., 612 p.

KORDOS, L. (1977): Changes in the holocene climate of hungary reflected by the " vole - thermometer" method. *Földrajzi Közlemények* **25/1-3** 222–229.

LASKAR, J. (1986): Secular terms of classical planetary theories using the results of general theory. *Astronomy and Astrophysics* **157** 59–70.

LARICHEV, V.E.; GIENKO, E.G. & PARSHIKOV, S.A. (2015): Stellar Astronomy of the Bronze Age Sanctuaries in North Khakassia. *Archaeoastronomy and Ancient Technologies* **3/1** 42–64.

MAGLI, G. (2016): *Archaeoastronomy. Intro-duction to the Science of Stars and Stones*. Springer International Publishing Switzerland 246 p.

MARIK, M. (1989): Szférikus csillagászat. In: MARIK, M. *Csillagászat*. Akadémiai Kiadó, Budapest 15–110.

MEES, A (2007) Der Sternenhimmel vom Magdalenenberg. *Jahrbuch des Römisch-Germanischen Zentralmuseums* **54** 217–264.

MEEUS, J. (1991): *Astronomical algorithms*. Willmann-Bell, Virginia 429 p.

MISKE, K. (1908): Egy őskori bronzszobrocskáról. *Archaeológiai Értesítő* **28** 266–268.

NAUTICAL ALMANAC OF THE STARS (2018) *Internet: nauticalalmanac.it* 385 p.

P. BARNA, J., TOKAI, Z.M., EKE, I. & PÁSZTOR, E. (2015): A késő neolitikus körárkok kutatásának helyzete Zala megyében. *Archeometriai Műhely / Archaeometry Workshop* **XII/2** 75–88.

PÁSZTOR, E. (2009) A szakrális kincsleletek szerepe a bronzkori ember világképének tanulmányozásában. *Tisicum* **XIX** 197–208.

PÁSZTOR, E. (2015): Magyar archaeoasztronómiai kutatások II. Légköri jelenségek szimbólumai bronzkori ábrázolásokon. *Magyar régészet online magazin* – 2015 tavasz 1–8.
http://files.archaeolingua.hu/2015TA/Pasztor_H15TA.pdf
http://files.archaeolingua.hu/2015TA/Pasztor_E15TA.pdf
Last accessed:2019. 08. 05.

PÁSZTOR, E. & P. BARNA, J. (2009): A késő neolit Lengyeli-kultúra körárkai. Lehetséges csillagászati ismeretek a Kárpát-medencében. In: BENGE, E. & LŐRINCZY, G. Szerk., *Medinától Etéig*. Szentes 205–213.

PÁSZTOR, E. & P. BARNA, J. (2015): Neolithic Longhouses and Bronze Age House sin Central Europe. In. RUGGLES, L. N. C. ed., *Handbook of Archaeoastronomy and Ethnoastronomy*. Springer Science+Business Media New York 1307

PÁSZTOR, E. & P. BARNA, J. (2017): A fény régészete. A természetes fény szerepe az őskori ember életében és hitvilágában. In. Z. KARVALICS L. & FÁBIÁN, B. szerk., *A fény információtörténetéhez* 9. Gondolat, Budapest 29–60.

PÁSZTOR, E. & PRISKIN, A. (2010): Történelem előtti csillagászok? *Természettudományi Közlöny* **141/12** 555–558

PÉCSI, M. (1991): *Geomorfológia és domborzatminősítés*. Magyar Tudományos Akadémia Földrajztudományi Kutató Intézet, Budapest 296 p.

RAPPENGLÜCK, M. A. (2004): A palaeolithic planetarium underground the cave of Lascaux (part 1). *Migration & Diffusion* vol. **5**, Issue Number **18** 93–119.

RUGGLES, L. N. C. ed. (2015) *Handbook of Archaeoastronomy and Ethnoastronomy*. Springer Science+Business Media New York 2297 p.

SCAFETTA, N., MILANI, F., BIANCHINI, A. & ORTOLANI, S. (2016): On the astronomical origin of the Hallstatt oscillation found in radiocarbon and climate records throughout the Holocene. *Earth-Science Reviews* **162** 24–43.

SCHLOSSER, W (2010): Die Himmelsscheibe von Nebra – Astronomische Untersuchungen. In: MELLER, H. & BERTEMES, F. eds., *Der Griff nach den Sternen*. Internationales Symposium in Halle (Saale) 16. –21. Februar 2005, Band **II** 913–934.

SÜMEGI, P. (1998): Az utolsó 15000 év környezeti változásai és hatásuk az emberi kultúrákra Magyarországon. In: ILON, G. ed. *A régésztechnikus kézikönyve I*. Szombathely, Pannivclvs Régiségtani Egylet - Savaria Múzeum, Pannicvlvs Ser. B. No. 3. Szombathely 367–397.

SÜMEGI, P. (2007): The sediment sequence from Velem–Szent Vid. In: ZATYKÓ, CS., JUHÁSZ, I. & SÜMEGI, P. eds., *Environmental Archaeology in Transdanubia*. Archaeological Institute of the Hungarian Academy of Sciences, Budapest 272–273.

SÜMEGI, P., KERTÉSZ, R. & RUDNER, E. (2003): Magyarország rövid környezettörténete. In: VISI, Zs. szerk., *Magyar régészet az ezredfordulón*. Nemzeti Kulturális Örökség Minisztériuma, Teleki László Alapítvány, Budapest 51–56.

SÜMEGI, P., NÁFRÁDI K., PERSAITS G., PÁLL, D.G., TÖRŐCSIK, T. & ILON G. (2011): A zanati lelőhely és vidéke környezetrégészeti vizsgálatának eredményei. / The results of the environmental archaeological analysis of the Zanat site and its surrounding area. In: KAVASSY, J. ed., ILON G., SÜMEGI, P., TÓTH, G., NÁFRÁDI K., PERSAITS G., PÁLL, D. G., TÖRŐCSIK, T., NYERGES, É., MIHÁLY, J., SÁNDORNÉ KOVÁCS, J., RADICS, A. & UDVARDI, B. *Szombathely–Zanat késő urnamezős korú temetője és a lelőhely más ős- és középkori emlékei természettudományos vizsgálatokkal kiegészített anyagközlés*. / *The Late Urnfield period cemetery from Szombathely–Zanat supplemented by an assessment of Prehistoric and Medieval settlement features and interdisciplinary analyses.* VIA Kulturális örökségvédelmi kismonográfiák / VIA Monographia minor in cultural heritage **2** Magyar Nemzeti Múzeum–Nemzeti Örökségvédelmi Központ / Hungarian National Museum–National Cultural Heritage Protection Centre, Budapest 201–353.

VERESS, M. & SZABÓ, L. (1996): Adatok a velemi Kalapos-kő morfogenetikájához. *Vasi Szemle* **L/2** 211–234.

VERESS, M., SZABÓ, L. & ZENTAI, Z. (1998): Mésztartalomhoz köthető felszínfejlődés a Kőszegi-hegységben. *Földrajzi Értesítő* **XLVII/4** 495–514.

VERESS, M., ZENTAI Z., & UNGER, Z. (2015): Hat Rock: Solution Features in Metamorphic Mountains. In: LÓCZY, D. ed., *Landscapes and Landforms of Hungary*. Springer, Switzerland 47–54.

VÉRTES, E. (2002): Csillagászatilag tájolt ősi kultikus hely a Kőszegi hegységben? *Egyesületi Híradó – a Gothard Amatőrcsillagászati Egyesület Tájékoztatója* **13/2** 29.

WILLIS, K. J., BRAUN, M., SÜMEGI, P. & TÓTH, A. (1997): Does soil change cause vegetation change or vice versa? A temporal perspective from Hungary. *Ecology* **78/3** 740–750.

ZOTTI, G. (2016): Open-Source Virtual Archaeoastronomy. *Mediterranean Archaeology and Archaeometry* **16/4** 17–24.

HU ISSN 1786-271X; urn: nbn: hu-4106