Revisiting Sevsar: Towards a Possible Gnomon in the Armenian Highlands

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Abstract

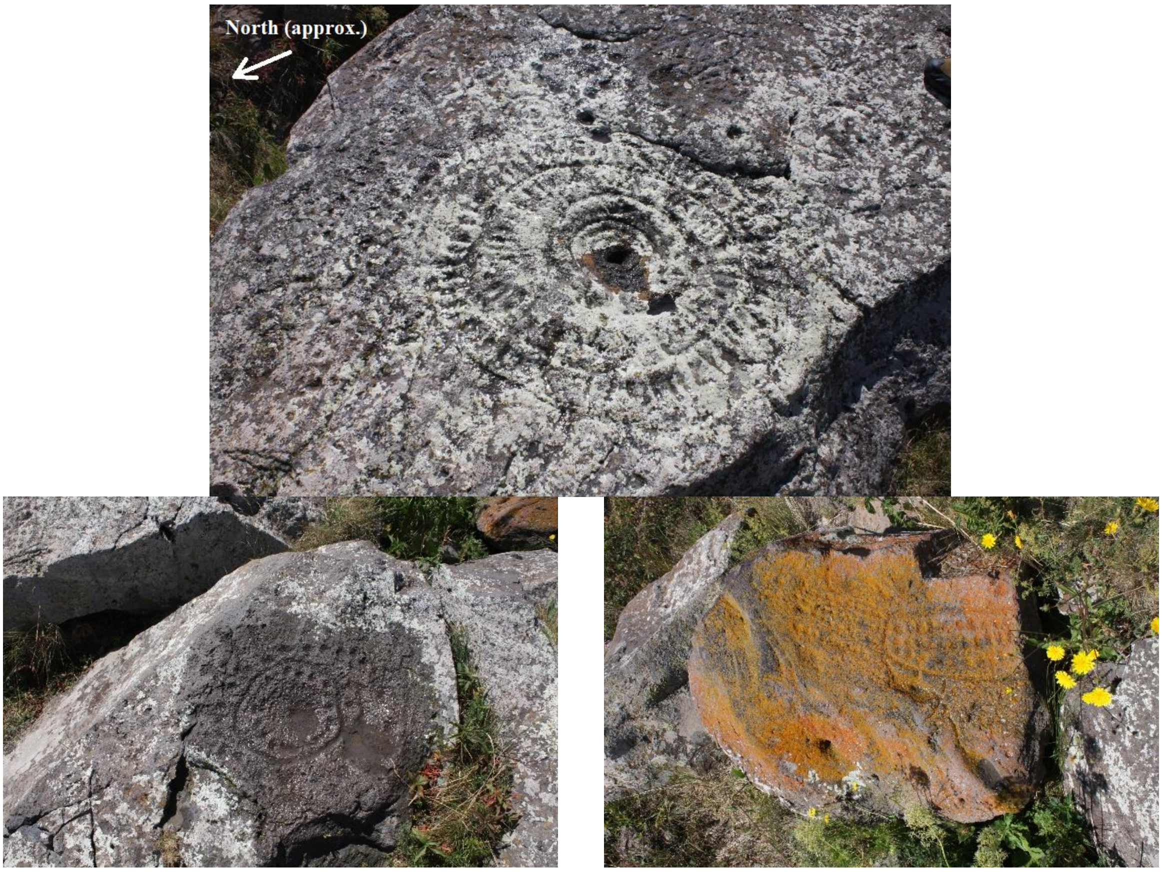
The Armenian highlands contain numerous remote petroglyph sites. While many are pastoral depictions of animals, others are abstract and complex. One example is found on Sevsar mountain at about 2700 m altitude. The site is isolated, and no other nearby sites are known. Archaeologists believe it to date from LBA period. The only existing major theory about the abstract carvings' dates from the 80s when it was believed to represent a lunar and solar calendar. During our two expeditions to the site (2017 and 2019) we noticed the strange cup mark in the large circular petroglyph, deep enough to hold a vertical wooden pole. Its intricate design with a radiating spiral and three concentric circles placed at non-equidistant radii from the centre made us consider its possible use as a sundial with the circles representing the noon shadow lengths on solstices and equinoxes. Our analysis shows that the dimensions of the petroglyph closely matches actual shadow lengths in LBA, and that the petroglyph can be reconstructed with high accuracy from theoretical ellipses. Together with its remote location this indicates that the movement of the Sun was important to the builders and a possible ritualistic as well as initiatic destination for the site.

Context

Mount Sevsar or Sevkar is in Gegharkunik region, on the western part of Vardenis mountain range in Armenia. Vardenis or Vardenyats range is 60 km in length, the highest peak being the Vardenis mountain at 3522 m. There are several volcanic cones at 3200-3300 meters altitude. The northern slopes merge with the southern edge of Lake Sevan. It has a temperate climate; high mountain zones are rich with alpine vegetation (Baghdasaryan et al. 1971, 66). Sevsar is located at 3050 meters above sea level and 10 km south of Geghovit (Lernakert) village (Cadaster Armenia 2007, 110). The name is derived from the volcanic black rocks on the slopes.

The petroglyphs are part of the Sevsar "astrosite" (Figure 1) located on the northern slope of the mountain, at an altitude of 2700 m about 10 km away from the 14-century caravanserai on the Vardenyats Mountain Pass situated at 2410 m. Its geographical coordinates are 40.02756 N 45.25867 E. The rock carvings were initially studied as part of the Geghama mountains petroglyphs which were discovered by the geologist A.P. Deymokhin (Martirosyan and Israelyan 1981, 49-52). Later, based on his notes, archaeologist S. Sardaryan and architect S. Petrosyan studied and copied the rock drawings in 1963-1964. They consisted of 20 elements on a 50 by 20 m area (Tokhatyan 2015). A part of them were studied more comprehensively and later published as a book (Sardaryan 1967). H. Martirosyan called the petroglyphs of Sevsar as the “Vardenis big composition”. He is the only one till nowadays who did a deep research about the rock carvings as an observatory and sky map. He tried to find out the prehistoric meaning of the complex with the seasonal, sun, moon and star-based calculations as well as by comparing it with the similar places all over the world known for that time (Martirosyan and Israelyan 1981, 49-52). Tumanyan also studied the carvings and expressed a different opinion. In his theory the large circular petroglyph depicts a comet impact. He found the possible impact site near Mt. Azhdahak (Tumanyan 1972). The period between 1960-1980 was the only time Sevsar has been surveyed. Therefore, we believe a versatile and comprehensive research is required. Nowadays the rock containing the engravings is split in at least three pieces, one containing the large circular petroglyph, another containing abstract images such as ovals with 30-31 dots and further circular petroglyphs (Figure 1 top and centre – images taken by the authors).

In this paper we analyse it from an archaeoastronomical perspective by looking at rise and set points of the Sun, Moon, and stars and by considering the geometrical properties of the great circular petroglyph (Figure 1). The great circular petroglyph is interesting not merely due to its intricate design of a spiral with 3 outer concentric circles interrupted by dashes, but also due to its inner cup mark which may have been used to support a wooden pole. This has caught the attention of our team in our 2019 expedition and made us infer an alternate destination of the site extending beyond its assumed lunar and solar calendar purpose derived from arithmetic calculations based on the number of dots and dashes.



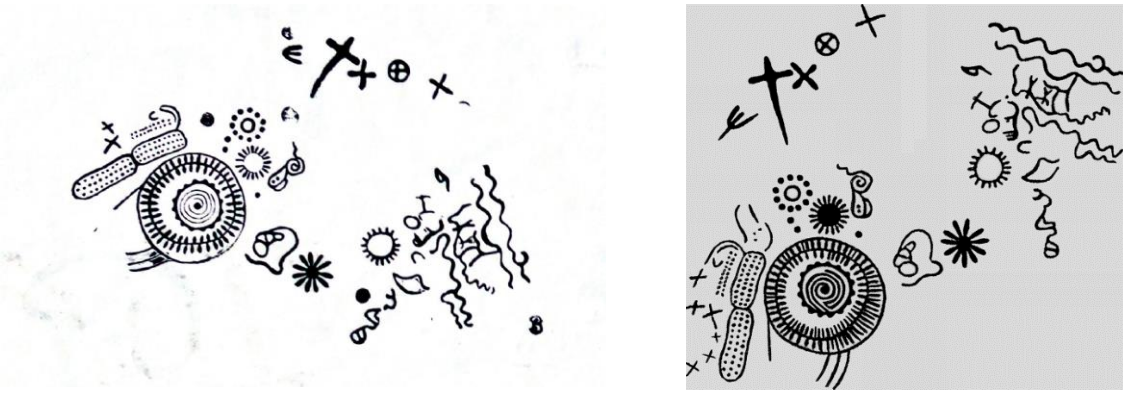


Figure 1. (top) Sevsar great circular petroglyph. (centre left) The circular petroglyph stone fragment to the NW of the large circular petroglyph. (centre right) Groups of 30-31 dots on the stone fragment located eastwards. (bottom right) Depiction of the petroglyph complex according to (Tokhatyan 2015, 15). (bottom left) Depiction of the petroglyph complex according to (Martirosyan and Israelyan 1981, 65).

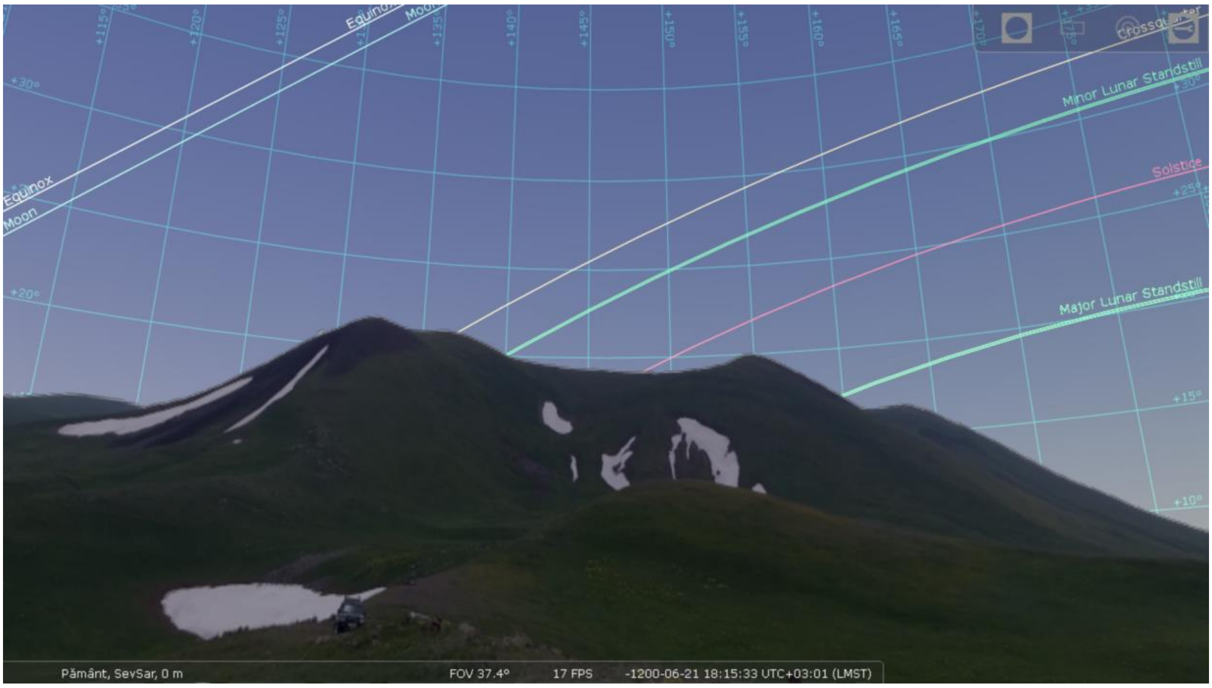
Existing studies

Existing studies outlined what researchers believe to be celestial maps (Martirosyan and Israelyan 1981, 49-52; Tokhatyan 2015, 15). The two studies differ in their interpretation of the large circular petroglyph (Figure 1). On one hand Martirosyan believes it to be a solar calendar which together with the two ovals with 31 dots inside form a bronze age lunisolar calendar. Tumanyan theorizes that the same petroglyph is in fact a depiction of a large impact crater found nearby. The three lines under the circular petroglyph depict based on his assumption the direction of the crater which he found on Mt. Azhdahak. We focus on the solar calendar theory as explained by Martirosyan. The reason is that our study will show in the following sections that the petroglyph may indeed have played a role in determining the solar year. Martirosyan proves mathematically that the number of elements in the group associated with the great circular petroglyph is evidence of a luni-solar calendar of 364 days. The main elements he identifies are the two oval shaped petroglyphs each with 31 dots inside, two lunar crescents, two crosses, and the circular petroglyph itself which he describes as a depiction of the moving Sun based on an interpretation of the inner spiral. The arithmetic behind the calculations is correct, but quite complicated and only works if the bottom left image in Figure 1 is used. The problem is that other studies (see the image in the bottom right of Figure 1) have identified different petroglyphs which following Martirosyan's reasoning lead to a different result. Furthermore, he seems to completely ignore other groups of 30-31 dots found on site (see Figure 1 center right).

Martirosyan describes the great circular petroglyph – from the exterior to the interior – as follows: on the outer circle there are 3 lines pointing south (our team found out that the orientation is in fact SE). The next circle contains several dashes, 34 on one side and 44 on the other. Our team discovered in the 2019 expedition that, considering the 34 dots series, the Sun shadow needs on average 8.5 minutes to move from one dash to another. The third circle contains 16 circular protuberances on it. Finally, the fourth element consists of the spiral. He interprets these four elements of the petroglyph as being connected with the four main positions of the Sun on the ecliptic, the solstices and the equinoxes, and with the four seasons.

Horizon profile study

To better understand the location of the site we analysed its horizon w.r.t. astronomical elements. Our analysis involved a Suunto Tandem 360Pc compass and clinometer. According to the specifications, the device has an error of 0.33º for the compass and 0.25º for the clinometer. The magnetic compass readings were adjusted for magnetic declination, which according to the National Oceanic and Atmospheric Administration website (NCEI NOAA 2020) is 6.29º E. The panoramic image was loaded in Stellarium (Stellarium 2019) and the sky for the Armenian Late Bronze Age was set (1200 BCE). Figure 2 depicts the Summer Solstice Sunset (SSSS) and Winter Solstice Sunrise (WSSR) since these are the only points where significant horizon markers (volcanic cones in our case) exist. There is no precise alignment with the Sun rising between the two peaks at WSSR and on setting on the slope of the volcano at SSSS. While the WSSR with the Sun between the two peaks is interesting the high altitude makes the site impracticable during winter as the whole area is covered in deep snow. Given the above nothing concluding about the choice of the location based on horizon markers can be made. The site itself may have not been used in the practice of the horizon astronomy, but it might have played a different role during the meridian transit of the Sun; i.e., the moment when the Sun reaches the highest point on the horizon.



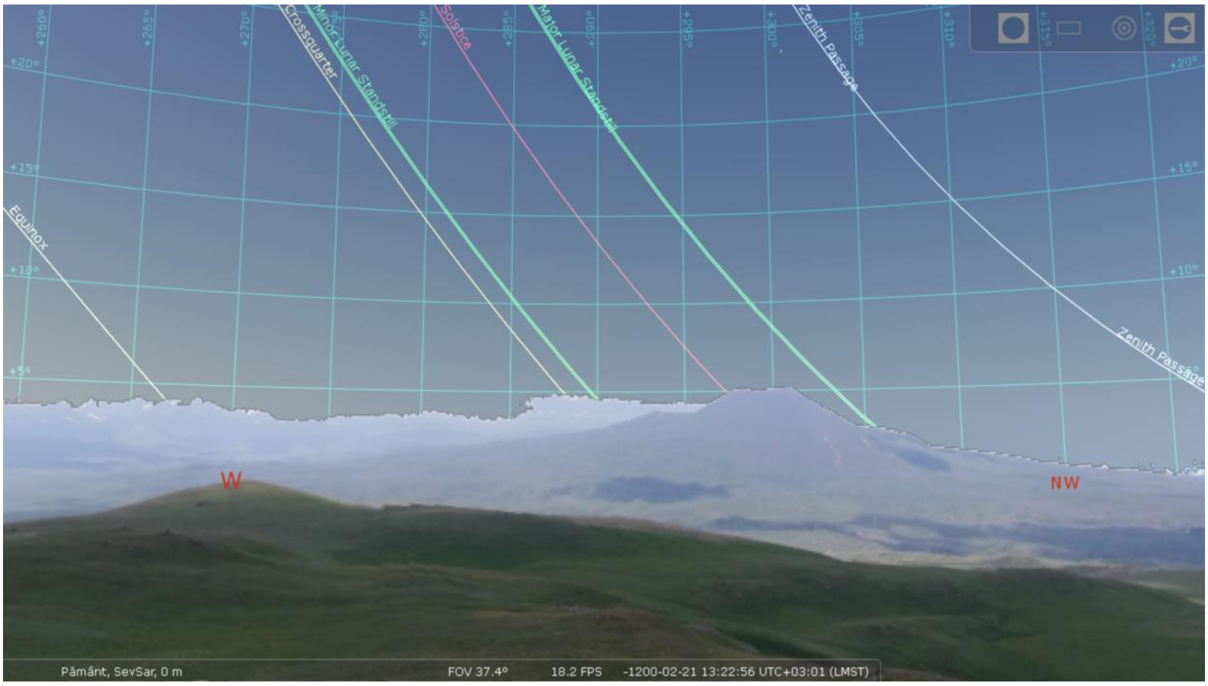


Figure 2. Horizon with markers for the WSSS (top) and SSSS (bottom) for 1200 BCE.

Gnomons and the gnomonic factor

The Sun has played an important role throughout ancient civilizations. Numerous temples were dedicated to it around the globe, and its social significance was strengthened by the reckoning of time as solar calendars were devised. The **gnomon** was probably one of the first instruments to determine solar time. Ancient China used gnomons (Figure 3) as probably as far back as 2300 BCE (Li 2014, 2095; He 2018, 20-32). Egyptians also used sundials by 1500 BCE (Universität Basel 2013) and Anaximander introduced it to the Greeks in the 6th century BCE.

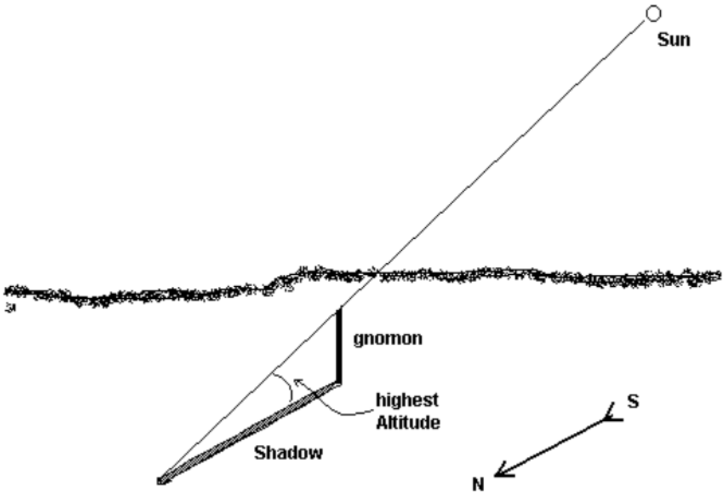


Figure 3. The shadow of a gnomon at noon when the Sun reaches its highest altitude (author 2000, Fig. 1).

The function of a gnomon is based on a natural occurrence as the shadow length varies throughout the day as the Sun crosses the sky moving along the ecliptic (Isler 1991). At the meridian (the imaginary circle passing through the north and south cardinal points) transit the shadow of the Sun is shortest, marking the astronomical noon. Hence its direction at that moment indicates true north. At the same time, at equinoxes, given a flat horizon at sunrise and sunset the shadows cast be the Sun form a straight line indicating the East-West direction. The length of the shadow at equinoxes can also be used to determine the latitude of a particular place given the height of the gnomon. For instance, at equinoxes at 45° N latitude, the height of the gnomon is equal to its shadow, at 26.57° N its shadow is twice its height, and at 63.43° N its shadow is half its height. However, the equinox is a term introduced by ancient Greek astronomers to define the moment the Sun crosses the equator. For prehistoric societies devoid of these geometric concepts the equinox as we see it today would have had no meaning (Ruggles 1997, 44-50) but East-West alignments do however exist and may have been used for time keeping and ritualic purposes as far back as the Maltese temples (Cox 2010, 2217-2231) and Minoan civilization (Henriksson 2011, 59-68). Solstices would have probably played much more important roles due to their relatively easy – although not necessarily precise – observation. Several Neolithic archaeological sites such as Newgrange in Ireland, and Maeshowe in Scotland are aligned with the sunrise and sunset at solstice time. These might indicate a long-lost ritual of fertility and rebirth during those times. The absence of the Moon during the longest night of the year would have certainly increased the effect on prehistoric societies awaiting the warmth of Sun. L. Sims makes an interesting case for Stonehenge where a dualistic Sun-Moon ritual at winter solstice involving the Dark Moon every 19 years might have taken place (Sims 2006, 191-207). The Zuni in North America used a calendar where the winter solstice was correlated with the occurrence of the Full Moon while the summer solstice was correlated with the New Moon (Penprasse 2010, 143; Zeilik 1986, S4). This was achieved by skipping few calendar days to synchronize the lunar and solar calendars. This was done to bring balance between the weak winter solstice Sun and the Full Moon and vice versa at summer solstice. The medicine wheel in the Big Horn Mountains was also built to signal the warm months around summer solstice by marking the heliacal rising of several stars at equal time intervals (Aveni 2003, 149-191). The Chumash tribe from California used a portable sun stick that was inclined precisely towards the winter solstice Sun. This gnomon-like object was used in a ceremony aimed at reversing the southward path of the Sun and to renew the Earth (Penprasse 2010, 145).

As seen, evidence from Neolithic times going as recent as the native American tribes seem the indicate that some knowledge of the Sun path on the sky marked by gnomons existed. We cannot therefore dismiss the possibility that the varying length of the shadow of a gnomon was known to other societies in other parts of the world, especially Bronze Age cultures close to the Fertile Crescent. The earliest Mesopotamian sources for constructing a gnomon come from the MUL.APIN at the end of the second millennium BCE (Rochberg 2010, 184).

The gnomon defines at the extreme points of the Sun (the solstices) two right triangles. In 2000 and later in 2014, the co-author introduced the **gnomonic factor** (Figure 4) to better understand whether given locations were selected by ancient societies based on the Sun, and to corroborate and complement archaeological data in providing a possible date for the construction of various structures (author 2014, 45-53). The gnomonic factor *fg* is defined as the ratio between the difference of the shadow length at solstices over the height of the gnomon. The rationale behind this concept is that ancient cultures probably used exact ratios in their calculations (e.g., 1, 1 ¼, 1 /½, 1 ¾) due to their simplicity, possibly in building gnomons and structures that could be derived from the lengths of the shadows at different dates of the year. For instance, given a gnomon of 1 m in the 14^{th} century BCE located at Sevsar, the difference of the winter and summer solstices' shadows divided by the gnomon length would be of exactly 1 ¾ (1.7500) making it easily reproducible and representable using integer numbers and simple tools. Changing the epoch and moving backwards in time the ratio drifts from an exact value making it harder to be represented and later applied. Since the obliquity of the Earth's axis changes over time due to precession, finding exact ratios in archaeological sites which corroborate the archaeological dating could be evidence of using a gnomon when selecting the site, designing and building the structures themselves. This means that ancient cultures might have observed in certain time periods particular relations between the shadow lengths at solstices that were easy to use and remember and that they may have designed structures to commemorate this aspect.

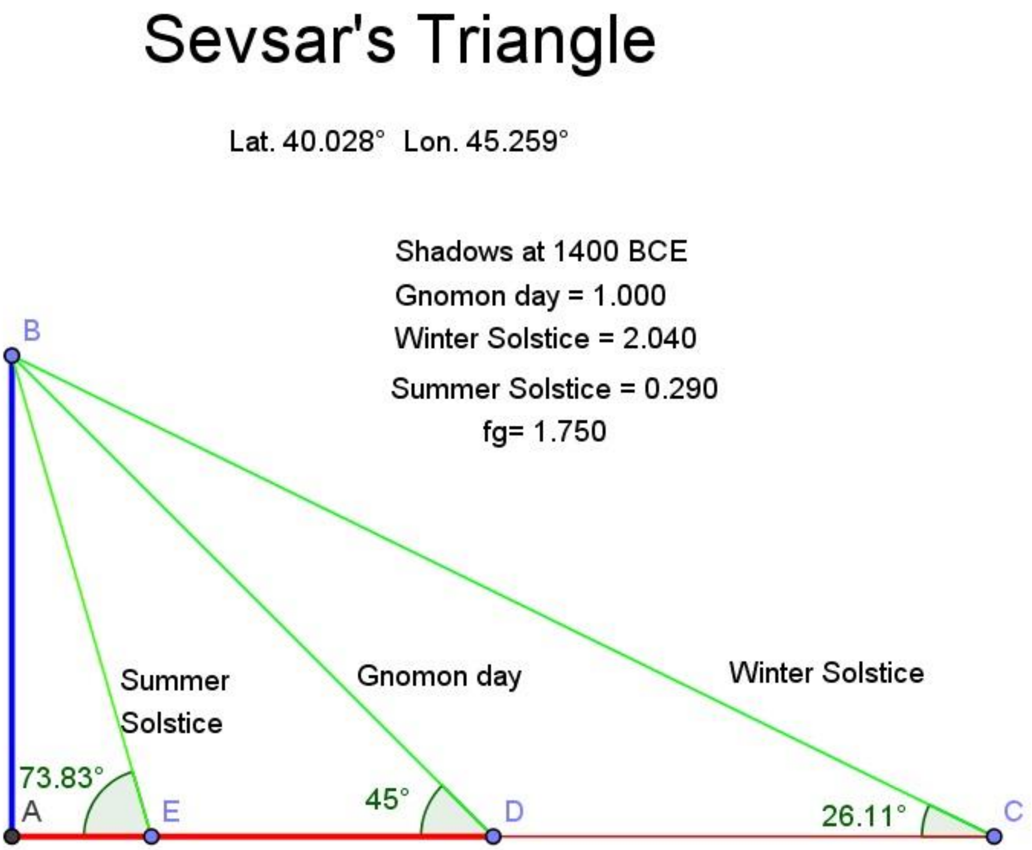


Figure 4. The gnomonic factor *fg* exemplified with solstice angles for the Sevsar site on 1400 BCE. Figure adapted from (author 2014, Fig. 1).

Sevsar analysis

The great circular petroglyph comprises of a central orifice about 5.5 cm deep and 5 cm in diameter, a spiral radiating from it and three concentric circles with dashes in them. In June 2019, an expedition to the site measured the orientation of the monument and size of different elements of the circular engraving found on site. Table 1 summarizes the measurements. It can be immediately be seen that the circular engravings are not exact circles but rather oval shaped. As already mentioned, several theories about the engravings exist, some arguing for a solar and lunar calendar. However, the attention of the team was captured by the strange cup mark in the middle of the engraving and the three concentric circles each marked by several perpendicular lines. The three circles together with the fact that during a solar year we have four important dates: two solstices and two midpoints (i.e., equinoxes) on the Sun's yearly path. Despite the equinox being a relatively modern and abstract concept, it is possible for ancient users of gnomons to have noticed not only the extreme lengths of the shadows at noon (for the two solstices) but also the mid-point (which approximates the modern day equinoxes).

Table 1. Measurements (in cm) of the circular engraving from the centre of the orifice.

Element	SW	Ratio/r2	NE	Ratio/r2
outer spiral (r1)	12	0.6667	9.5	0.63333
inner circle (r2)	18	1.0000	15.0	1.0000
mid circle (r3)	28.5	1.5833	29.0	1.93333
outer circle (r4)	41.5	2.3056	37.0	2.46667

The team then analysed these data and searched using the Laskar algorithm (Meeus 1998, 147) for a period when an exact *fg* ratio using solstices existed at Sevsar (fg=1.750 or 1 ¾). The result corresponds to the period 1385-1384 BCE which falls around the same period indicated by the archaeologists as the possible period (LBA) for the construction of the site. Furthermore, by using an 18.14 cm gnomon placed in the central orifice the measured radiuses towards the north can be derived from the shadow lengths as follows (Table 2)**:** r1 as the difference between the equinox shadow (EQ) and the summer solstice one (SS); r2 as the equinox shadow (EQ); r3 as the difference between the winter solstice shadow (WS) minus summer solstice shadow (SS); and finally, r4 as winter solstice shadow (WS). The length of the gnomon was searched using χ^2 method while comparing the radiuses measured on site (Table 1) to the shadow lengths obtained from using the latitude of Sevsar rock at the epoch given above. The χ^2 value of 0.023298 corresponds to the local minimum indicating a very good fit for the size of the gnomon. This result indicates a high probability that the Sun shadows at solstices and equinoxes played an important role in the design of the engravings. While the measured radiuses seem to reflect the shadow lengths and WS, EQ and differences between EQ and SS, and between WS and SS, there is no apparent representation of the shadow length at SS when its value would have been of 5.26 cm measured from the center of the orifice. The inner spiral exhibits (measured NE) 3 loops and a central orifice (5 cm in diameter and 5.5 cm in depth). The first loop is at 3 cm from the centre of the orifice, the second at 5.5 cm while the fourth is at 9.5 cm (r1 in Table 1). The second loop matches closely the SS noon shadow.

Table 2. Best match eclipses from Figure 5 vs. calculated ones for Sevsar (NS orientation).

Radiuses	Best match eclipse axis (see Figure 5)	Shadows (N-S)	Calculated using 18.14 cm gnomon	χ^2
r1	10.12	EQ-SS	9.98	0.00203667
r2	14.89	EQ	15.24	0.00804665
r3	31.40	WS-SS	31.75	0.00379127
r4	37.60	WS	37.00	0.00942385
				0.02329843

From our measurements we note that the Sevsar great circular petroglyph matches more closely an ellipse rather than a circle (see Table 1 for the data). To reconstruct it we used GeoGebra and its five-point ellipse tool (GeoGebra, 2019). First a line going from NE to SW was drawn. Then, four ellipses were drawn using those points and other three for support; these three additional points were moved until the values of Table 2 data were obtained (second column). Figure 5 depicts the resulted ellipses while Figure 6 shows them overlaid on the Sevsar petroglyph.

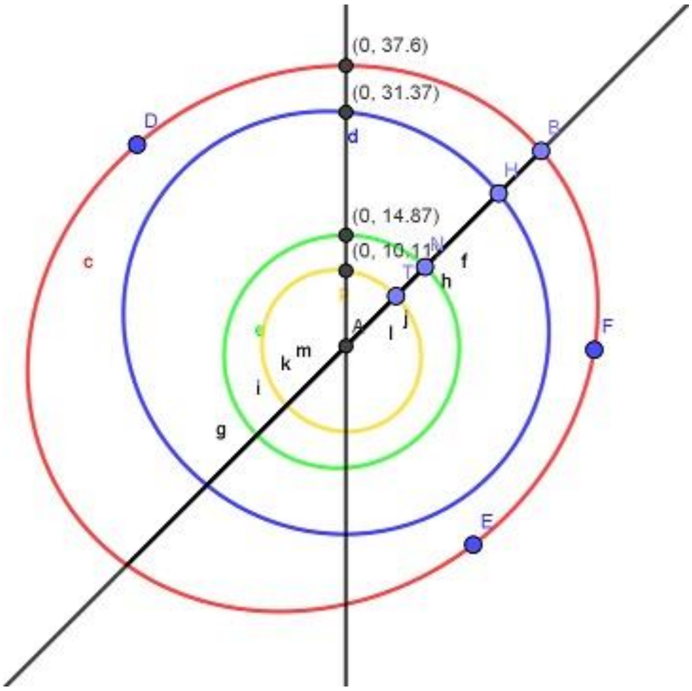


Figure 5. Ellipses calculated from the analysis of Sevsar engraving.

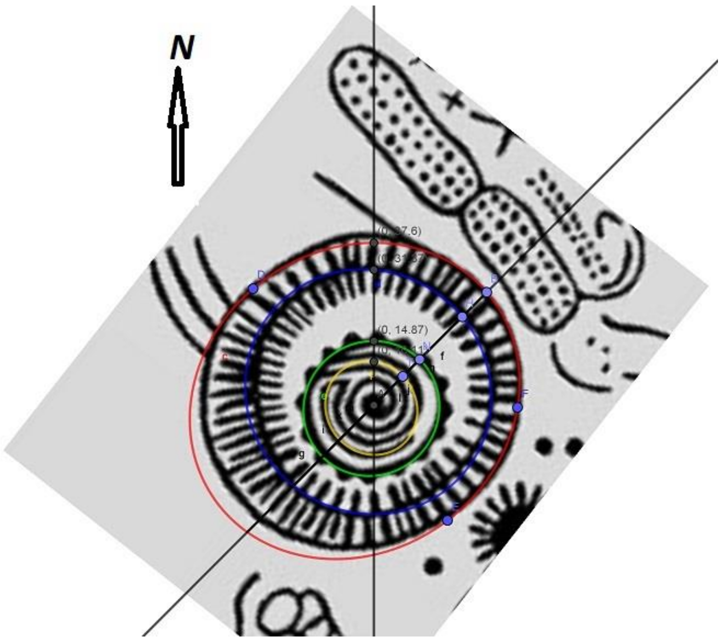


Figure 6. Reconstructed Sevsar engraved structure from the calculated values superimposed over the actual petroglyph.

Conclusion

In this article we propose an alternative theory about the meaning of the Sevsar circular engravings and suggest it to be a gnomon-based diagram. The selection of the site seems to have considered knowledge of the Sun and the shadows cast by a gnomon at solstices (gnomonic factor), and the petroglyphs themselves might have encoded various information on the solstices and equinoxes. The measured data (latitude of the site and radiuses) indicate a possible date of engraving for the 14th century BCE which corroborates the proposed dating from archaeological information. A statistical χ^2 test was used to verify that the measured radiuses in the engraving and the results from the solar observations converge (a value of 0.0233 is just above the 0.0216 for 0.975 confidence (Gutierrez and dela Vara 2008)). One question that arises concerns the actual measurements for the shadow lengths especially during winter solstice when the site is covered by meter thick snow. It is possible that the measurements of the length were done in the valleys below and that they were later encoded in the design of the engravings. The ritualistic and initiatic nature of the place is obvious from its isolation at an altitude of 2700 m a.s.l. far away from any other archaeological site. There is no sign of any habitation. Its connection to astronomy is also demonstrated – as indicated by Martirosyan in his study – by other elements found nearby such as rectangular boxes containing 31 dots (indicating a possible lunar calendar); crosses – used maybe for indicating cardinal directions which in turn seem to derive from how society perceived the world's directions: sunrise-sunset for East-West and left-right for North-South as derivates from the direction of viewing the phenomena (Brown 1983: 121-161); circles with possible sunrays (perhaps a depiction of the Sun); and circles with dots and rays around them which have been linked in other places to calendars.

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