The Potential Lunisolar Gnomonic Function of Pillars 18 and 19 in Enclosure D at Portasar (Göbekli Tepe)

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Abstract

This study examines the possible gnomonic (shadow-measurement) function of Pillars 18 and 19 in Enclosure D at Portasar (Göbekli Tepe), based on precise architectural measurements, an analysis of the Sun's and Moon's culminations, and calculations of the astronomical conditions around 9500 BCE. Unlike previously proposed iconographic or symbolic interpretations, the present analysis is built exclusively on an empirical basis, without making prior assumptions about the meaning of the carved motifs.

The results show that the shadow boundaries produced by the mutual alignment of Pillars 18 and 19 correspond systematically to the winter solstice, the periods around the vernal and autumnal equinoxes, as well as to the Moon's culminations during its major and minor standstills. Particularly significant is the fact that the arrangement of the seven birds carved on the pedestal of Pillar 18 coincides with the movement of Pillar 19's midday shadow and reflects the period during which the seven stars of the Pleiades are not visible. This correspondence outlines a winter period of approximately 206.5 days, comprising seven synodic lunar months.

Overall, the findings suggest that Pillars 18 and 19 of Enclosure D may have functioned as elements of a shadow-based calendrical system capable of explaining the associated iconography. By contrast, the widely cited "roofed building" hypothesis faces substantial difficulties in accounting for the observed reliefs.

Keywords: *Göbekli Tepe, Enclosure D, Pillar 18, Pillar 19, Pillar 12, Pleiades, Seven Sisters, Shadow analysis, Ancient Gnomons, Lunar Standstill, Winter Solstice, Lunisolar calendar, Pre-Pottery Neolithic.*

1. Introduction

Portasar (Göbekli Tepe), as a major megalithic complex of the Pre-Pottery Neolithic (PPN) period, continues to attract increasing interest not only from an archaeological perspective but also from an astronomical one, owing to its structural and symbolic complexity. The site, dated to approximately 9600–8800 BCE, is distinguished by T-shaped Pillars adorned with a wide variety of symbols and figurative motifs, set within circular (elliptical) Enclosures surrounded by stone walls. At the centres of these Enclosures, a prominent place is occupied by pairs of larger anthropomorphic T-shaped Pillars (Dietrich, 2011, Dietrich & Schmidt, 2010, Dietrich *et al.*, 2012, Schmidt, 2006, 2010) (Figure 1).

Since the publication of the earliest excavation results, a number of astronomical hypotheses have been proposed, presenting interpretations that range from partially substantiated to mutually contradictory or incomplete. The Pillars and their iconography are generally examined as potential calendrical systems or as symbolic representations of celestial phenomena. However, no well-founded, unified theory capable of explaining both the structural, functional, and iconographic features of the monument has yet been established. Although several methodological and interpretative difficulties persist in the astronomical readings of Portasar's symbols and architectural arrangements, the main lines of inquiry can nonetheless be broadly outlined as follows.

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Figure 1. General view of Enclosure D at Portasar from the north. The central T-shaped Pillars 31 and 18 are fixed in an upright position. Pillar 19, unlike the others, is set upon several flat stone slabs (indicated by the arrow). The photograph is available on Wikipedia (accessed 12 November 2025).

a. Correspondences Between Animal Figures and Constellations

As early as 2010, the reliefs on Pillar 43 of Enclosure D at Portasar (Figure 2a) were interpreted by Vachagan Vahradyan as depictions of constellations (Vahradyan & Vahradyan, 2010). Basing his argument on the vulture figure carved on the Pillar and the fact that medieval Armenian sources refer to the modern Cygnus constellation as "Angegh" (Vulture) (Vanandeci, 1695), he proposed a direct correspondence between the two. In a similar manner, attempts were made to associate constellations adjacent to Cygnus with the images surrounding the vulture on the Pillar (Vahradyan & Vahradyan, 2010). However, several inconsistencies emerged. In particular, the relative positions of the scorpion and vulture figures on the Pillar do not match the positions of Scorpius and Cygnus in the sky.

In contrast to Vahradyan, later studies take as their starting point not the vulture–Cygnus correspondence but rather the identification of the scorpion figure with the Scorpius constellation. The remaining correspondences follow Vahradyan's general logic (adjacent images representing adjacent constellations), supplemented by certain statistical analyses. The conclusion drawn is that the vulture on the Pillar is associated with the summer solstice and symbolises the modern Sagittarius constellation (Sweatman & Tsikritsis, 2017). This view, with some reservations, is partly shared by Burley (2017). However, significant issues remain. First, the Sagittarius constellation corresponded to the summer solstice at least a thousand years earlier than the archaeological dating of the monument would allow. This discrepancy has been addressed by proposing that the reliefs on Pillar 43 represent a memory of a major cosmic event dated to around 10,950 BCE (Sweatman & Tsikritsis, 2017) (the Younger Dryas Impact Hypothesis)—a presumed cometary or meteoritic strike that may have triggered global cooling, biodiversity loss, and socio-cultural transformations. A second issue arises from

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the fact that, in celestial star maps, the Scorpius constellation is depicted not with its head facing Sagittarius (whereas on the Pillar the scorpion is shown facing the vulture (Figure 2a)), but in the opposite direction.

b. Interpreting the Orientations of the Enclosures as the Rising and Setting Directions of Celestial Bodies

Taking into account the aforementioned possible Cygnus–vulture association, Collins proposed that the northward orientation of the central Pillars 18 and 31 in Enclosure D may have been intended for observing the settings of Deneb (α Cygni), the principal star of the Cygnus constellation, through the opposite perforated stone. The authors further suggested that the orientations of the central Pillars in other Enclosures (B, C, E) may likewise be associated with Deneb's setting positions (Figure 2b), and that the differences in their alignments and dating could be explained by changes in the star's coordinates over time, resulting from precession and the star's proper motion (Collins & Hale, 2013).

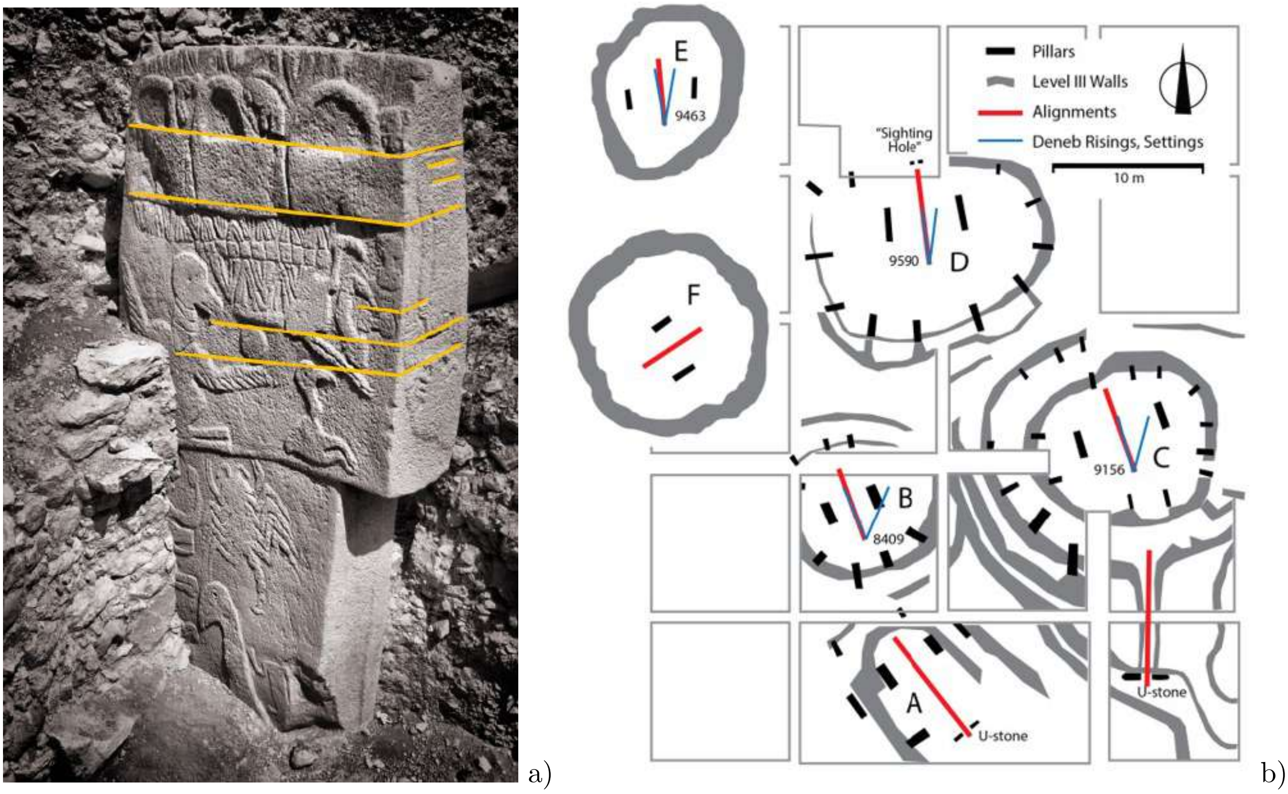

Figure 2. a) Southwestern view of Pillar 43 at Enclosure D; b) On the excavation plan, the orientations of Enclosures A, B, C, D, E, and F are shown in red (Banning, 2023).

Collins's proposed correspondences between the time-varying setting positions of Deneb and the orientations and dating of the various Enclosures (B, C, D, and E) were recalculated by De Lorenzis & Orofino (2015), this time incorporating corrections for atmospheric effects. However, the resulting values did not differ qualitatively from those obtained previously. In the same study, the orientations of Enclosures F and A were also examined. It was concluded that Enclosure F is oriented toward the sunrise position corresponding to the midpoint between the summer solstice and the autumnal equinox, whereas the orientation of Enclosure A appears to align with the Moon's rising direction during the southern major standstill (Figure 2b) (De Lorenzis & Orofino, 2015).

It is, of course, also possible to consider the orientations of the enclosures in the opposite, southern direction. Magli (2015), examining these reverse azimuths and relating them to the time-dependent shift in the rising position of Sirius—the brightest star in the night sky—emphasises that during the millennium in question Sirius would have been a newly emerging phenomenon for observers at this latitude, as prior to that it had not been visible above the southern horizon due to the Earth's axial tilt. Collins does not exclude this possibility either (Collins & Hale, 2013), although Magli's proposal

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effectively offers an alternative model of Sirius observations that is broadly analogous yet in certain respects contradictory to the Deneb-based interpretation. It should be stressed, however, that the gap between the two central Pillars provides a fairly wide field of view—up to 5 m—and that claims of this kind require the specification of an exact observation point as well as accurate data for the actual horizon.

c. Comparative Analysis of the Symbols

Some archaeoastronomical studies have focused primarily on interpreting the symbolic motifs at Portasar in the context of astronomical phenomena. In a recently published study, the V-shaped signs on Pillar 43 were successfully interpreted by (Sweatman, 2024) as markers of a lunisolar calendrical system, incorporating 11 additional days to reconcile the discrepancy between 12 synodic months and the tropical year. According to the author, the principal event of this calendar is the summer solstice, represented by the V-shaped sign on the neck of the vulture (Figure 3).

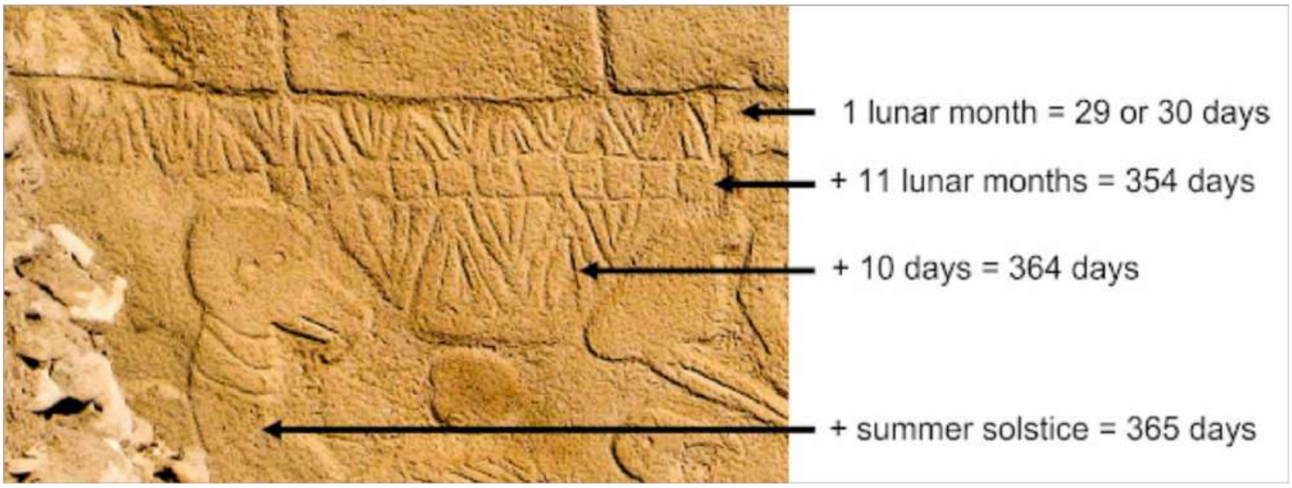

Figure 3. Interpretation of the V-shaped and square symbols on Pillar 43 at Portasar. The image is reproduced exactly as published in Sweatman (2024).

Although, as noted above, an inconsistency can be observed in Sweatman's juxtaposition of the vulture motif with the constellation Sagittarius (Sweatman & Tsikritsis, 2017), we nonetheless accept the principal conclusions of his more recent analysis, particularly regarding the association between the summer solstice and the V-shaped mark on the vulture's neck (Figure 3) (Sweatman, 2024). We arrived at the same conclusion—along with its underlying interpretative rationale—by an entirely different route, examining the observational function of Angular Stone No. 7 at the Zorats Qarer monument, as well as the bird depiction on an Early Bronze Age vessel bearing a calendrical ornamental scheme. These materials were then compared with the vulture relief on Pillar 43 at Portasar. On the basis of this comparative analysis, we concluded that the V-shaped sign on the vulture is linked to the summer solstice and to the star Sadr (γ Cygni) (Malkhasyan, 2024c).

The diverse interpretations and symbolic analyses of the imagery at Portasar are not limited to the work of Sweatman. Coombs (2023), examining the symbolism of the paired central Pillars, interprets them as representations of twin deities functioning as gatekeepers of temporal transitions. Seyfzadeh & Schoch (2019), drawing on the signs carved on the Pillars and their parallels with Luwian inscriptions, propose that these motifs constitute the earliest ideograms written in a pre-script language. They attribute a divine symbolic status to the T-shaped Pillars and interpret the H-symbols as celestial or sacred gateways. At the same time, Martirosyan (2024) presents a symbolic analysis and attempted reading of the monument's iconography by comparing it with features of the Armenian language, medieval Armenian sign systems (ideograms), and the rock art of Syunik. In parallel with this analysis, he also interprets the central Pillars as 'gateways' of sunrise and sunset, further noting their potential function in shadow measurement. Indeed, such conclusions have found further support in our study of the shadow dynamics of the Pillars 18 and 31 (Malkhasyan, 2025b).

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d. The Shadow-Measurement Function Hypothesis

The hypothesis concerning the shadow-measurement function of the T-shaped Pillars has long been discussed in non-academic publications. In particular, some authors have linked their potential function to timekeeping based on the dynamics of shadows cast by sunlight and moonlight, while noting that this hypothesis requires verification once more precise metric data become available (Dendrinos, 2016, Villamarin, 2020). Thus, the shadow-measurement function of the T-shaped Pillars remains a relatively underexplored area, which is precisely the focus of the present study.

1.1. The Roof Hypothesis in Contradiction

The identification of the functional purpose of this monument, or of its individual structural units, is undoubtedly a matter of great importance, as one fundamental question remains unanswered: why would Neolithic communities invest immense resources in constructing structures of such dimensions, when carved imagery could be produced far more quickly and with considerably less effort—for example, on bone (Dietrich & Notroff, 2016)? In an effort to address this question, the "roof hypothesis" has been actively promoted, suggesting that the Pillars served to support roofing structures (see Banning (2023, 2011) and references therein). However, this proposed hypothesis, being in deep contradiction with the astronomical—particularly shadow-measurement—interpretation, fails to offer any coherent explanation for the iconography carved on the Pillars, resulting instead in a proliferation of disparate assumptions and arbitrary interpretations.

1.2. A Note on Our Previously Obtained Results

In our earlier study dedicated to the astronomical function of Pillar 27 in Enclosure C at Portasar, we examined four specific directions defined by the Pillar's structural features and the characteristics of its relief carving. The analysis showed that these directions may have served for observing the simultaneous culminations of certain stars. At the same time, we identified a potential shadow-measurement function determined by the T-shaped structure and orientation of the Pillar, which appeared to be interconnected with the days on which these stellar observations would have taken place—namely, around the vernal and autumnal equinoxes (Malkhasyan, 2024b). Although described there with a degree of simplification, the proposed shadow-measurement function was grounded in clearly measurable and verifiable parameters, and the resulting observations provided reliable premises for interpreting the symbolism of the animals depicted on the Pillar—a subject that will be addressed in a separate forthcoming study.

We have also described a potential shadow-measurement function in our examination of the T-shaped structure and orientation of the central Pillars 18 and 31 of Enclosure D (Malkhasyan, 2025a,b). In particular, it was shown that the symbols carved on the upper sections of their southern faces may have served as markers for the shadows cast at local noon during the winter solstice (WS) and the equinoxes. At the same time, we did not analyse in detail the function of the reliefs on the lower sections of the Pillars' southern faces, as such an examination required more precise surveying data.

1.3. Methodological Features of the Study

The methodology employed in the study of Pillars 27, 18, and 31 at Portasar builds upon our previous experiences, particularly on the research of Zorats Qarer megalithic complex (Broutian & Malkhasyan, 2021, Malkhasyan, 2021, 2022, 2023, 2024a,c). The analysis does not presuppose any particular significance for individual menhirs or their groupings. Instead, it is grounded in precise laser-measured data and their causal interpretation, using straightforward logical reasoning. This approach enables the systematic identification of observable celestial bodies and the determination of the dates on which they could be observed. By synthesising the results, the morphological, positional, and functional significance of stones that may initially appear irregular or roughly hewn is revealed.

Consider, for instance, Stone No. 137 at the Zorats Qarer monument. It was previously hypothesised that the stone's specially perforated aperture could have functioned as a "periscope" for observing bright stars passing through the zenith, provided that a polished piece of obsidian—serving as a flat

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mirror—was placed within the opening (Herouni (2006) pp. 57-59). However, our measurement-based analyses demonstrated that, without any prior assumptions, the principal directions determined by the stone's distinctive carvings and orientation reveal the potential for observing circumpolar stars (Malkhasyan, 2024a). It was further established that the stone's northern side, with its particular configuration, could have served as a shadow-measuring instrument, enabling the determination not only of the dates of the equinoxes and summer solstice but also of their intermediate points. By combining these two functions, it was possible to infer that this system may have been employed for observations of the star Sadr (γ Cygni) at the summer solstice in 15,500 BCE (Malkhasyan, 2024a). The same methodology, as noted above, was also applied to the study of Pillar 27 of Enclosure C at Portasar (Malkhasyan, 2024b), where the archaeological dating of the monument provides additional validation for the astronomical calculations.

A distinctive feature of this approach is that it considers motifs and symbols not in isolation, but as integral components of the functional system of the object under study—in this case, the T-shaped Pillar. By integrating iconographic, structural, and functional analyses, this system is situated within a unified astronomical and calendrical framework.

1.4. Research Aim

The aim of this study is to examine the potential shadow-measurement function of Pillars 18 and 19 of Enclosure D at Portasar (Göbekli Tepe). The dynamics of shadows formed by the mutual orientation and spatial arrangement of the Pillars are investigated without relying on prior assumptions. At the same time, the relief carvings on the southern face and pedestal of Pillar 18 are examined as possible components of a shadow-measurement system.

The ultimate goal is to integrate the obtained results in order to reveal the features of the calendrical structures and their conceptual characteristics during the period in question.

2. Material and Methods

2.1. Selection of the Studied Pillars

Pillars 18 and 19 of Enclosure D at Portasar were selected as the focus of the present study on the basis of the following criteria:

- Both Pillars are relatively well preserved (Schmidt, 2006),
- Their upright positions and geographic orientations can be regarded as close to their original configuration (Schmidt, 2006),
- Existing publications provide sufficiently precise dimensional and positional measurements for Pillars 18 and 19 (Dietrich (2021) fig. 2.2, p. 7), enabling the modelling and evaluation of potential shadow-measurement phenomena without reliance on speculative reconstruction.

These criteria collectively render Pillars 18 and 19 particularly appropriate for the investigation of their possible gnomonic and calendrical functions.

2.2. Iconography of Pillars 18 and 19

The northern face of Pillar 19 bears a single relief depicting a downward-oriented ("crawling") snake (Figure 4a). This Pillar is further distinguished by its installation upon multiple stone slabs of varying thickness, a feature that sets it apart from the majority of Pillars within the enclosure (Figures 1 and 4a).

The upper section of the southern face of Pillar 18 is carved with an H-shaped symbol featuring a central depression. Beneath this motif appears a horizontally oriented crescent, together with a circular sign containing a central pit, conventionally interpreted as a "lunisolar symbol" (Schmidt, 2006) (Figure 4c). From this ensemble originate the so-called "arms," which ascend at a defined

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angle, extend onto the eastern and western faces of the Pillar, and then bend downward. Upon reaching the central zone of the northern edge, they turn downward once more, forming elbow-like bends that extend further and terminate on the southern face in clearly rendered hands with five fingers each (Figures 4b,c,d).

Figure 4. Relief carvings on Pillars 18 and 19 of Enclosure D at Portasar: a) Pillar 19 from the north; b) Pillar 18 viewed from the south-west; c) upper section of the southern face of Pillar 18; d) lower section of the southern face of Pillar 18.

In the belt region on the southern face of Pillar 18, a partial low-relief of a canid or felid, with its tail oriented downward, is depicted, showing only the torso, hind legs, and tail. A corresponding motif is replicated on Pillar 31 in the same zone. Above the animal figure, two upward-opening semicircular forms are carved, surmounted centrally by two short vertical grooves (Figure 4d). A total of five H and I symbols (or H rotated 90°) are incised on the southern face of the belt zone . On the western side, they are arranged vertically in an I–H–H sequence, whereas on the eastern side, they appear in an I–I configuration (Figure 4d). On the southern face of the pedestal of Pillar 18, seven identical bird reliefs are carved, all oriented with their heads facing west (Figures 4b, 10, and 11).

2.3. Principal Measurement Data of the Studied Pillars

Accurate measurement data for Pillars 18 and 19, recorded in the meridian plane, are provided in the monograph by Laura Dietrich (2021). These data include the precise heights of the Pillars above sea level, as well as the distances between them. They enable the analysis not only of the shadow dynamics generated by the T-shaped structure of Pillar 18, but also of the shadows cast by Pillar 19 onto its southern face.

Based on the recalculated measurement data, the altitudes (L) above sea level (masl) of the light–shadow boundary on the southern face of Pillar 18 were determined for the following cases:

- Midday on the winter solstice - h_a=27°30′ (Figure 5a)
- Culmination of the Moon at its northern major standstill - h_b=83°06′ (Figure 5b)
- Culmination of the Moon at its southern major standstill - h_c=22°27′ (Figure 5c)
- Culmination of the Moon at its southern minor standstill - h_d=33°15′ (Figure 5d)

The solar and lunar culminations were determined based on the aforementioned measurement data, yielding reliable and robust results.

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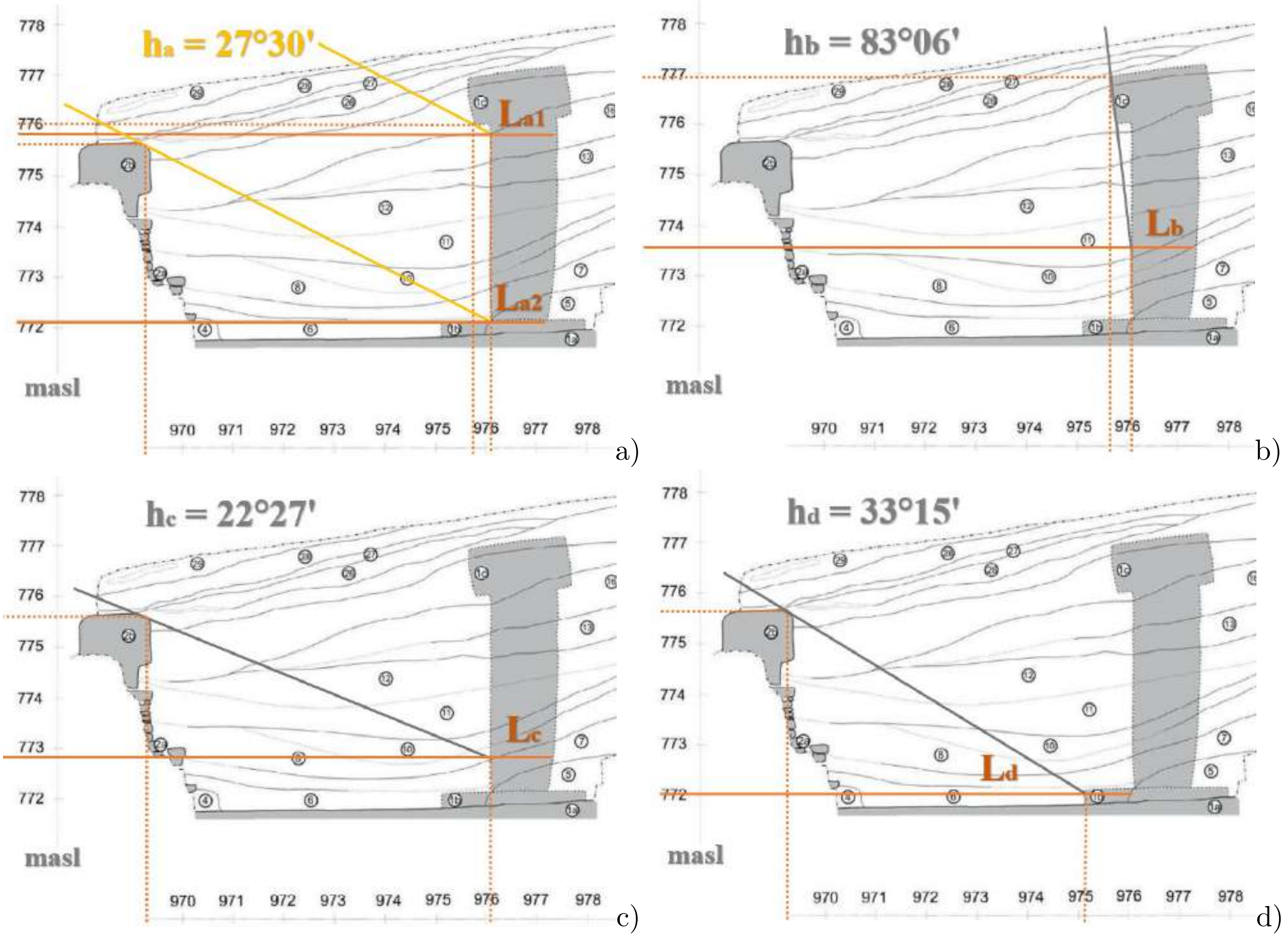

Figure 5. The measurement data were taken from (Dietrich, 2021) (fig. 2.2, p. 7 © German Archaeological Institute, compilation Jens Notroff). The constructed right-angled triangles used to calculate the light–shadow boundary levels (L) in metres above sea level (masl), according to the formula $L = A - B \times \tan(h)$, where A is the absolute altitude of the shading point above sea level, and B is the relative horizontal distance between the two points. a) Winter solstice - $L_{a1} = 775.8$ masl, $L_{a2} = 772$ masl; b) Northern major lunar standstill - $L_b = 773.6$ masl; c) Southern major lunar standstill - $L_c = 772.8$ masl; d) Southern minor lunar standstill - $L_d = 771.9$ masl.

2.4. Shadow Observation Conditions

The coordinates of the centres of the Sun and Moon disks were determined using the astronomical software Stellarium (2024). Given that the apparent angular diameters of the Sun and Moon disks are approximately 30 arcminutes, an uncertainty of ± 15 arcminutes (± 0.25°) in azimuth and altitude measurements was taken into account, which does not significantly affect the results. The geographical latitude of the monument, 37°13′ N, was adopted for all calculations. Shadow dynamics were analysed in accordance with the archaeological age of Enclosure D (Dietrich, 2011, Dietrich & Schmidt, 2010)(ca. 9500 BCE, with an ecliptic obliquity of $\varepsilon = 24°11'$). Deviations in radiocarbon dating do not materially affect the results, as the nutation-induced variations in angular positions within this interval are less than ± 2 arcminutes. It should also be noted that the observations pertain specifically to the culminations of the Sun and Moon, rendering the actual horizon altitude irrelevant for such analysis. The obtained data are verifiable, and any subsequent recalculation would yield only minor quantitative differences without altering the overall conclusions.

This study examines the shadows generated by the position and orientation of Pillar 19 in Enclosure D. These shadows fall on the southern face of Pillar 18 and its pedestal at moments of notable astronomical and calendrical significance. The resulting light–shadow boundaries were systematically recorded, along with their direct correspondences to the carved symbols.

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3. Results and Discussion

The analysis of shadow dynamics on days of major astronomical significance (e.g., the winter solstice, vernal and autumnal equinoxes, and lunar standstills) reveals systematic correspondences with the iconographic elements on the southern face of Pillar 18. The following sections present the findings, organised according to the observed shadow patterns and their alignment with the Pillar's iconography.

3.1. Shadowing of the Southern Face of Pillar 18 Due to Its T-Shaped Structure

Previous research has shown that at the winter solstice, when the Sun reaches its southernmost position, the shadows cast by the central Pillars do not overlap or coincide with one another. In the morning, these shadows appear in the northwest and disappear in the northeast by evening (Malkhasyan, 2025b). A particularly interesting pattern emerges at midday, when the Sun passes through its culmination point (Figures 6 and 7). At this time, due to the T-shaped structure of the Pillars, the upper portion of the southern face of Pillars 18 and 31 becomes shadowed, as illustrated in Figure 7 (Malkhasyan, 2025a).

The iconography of the upper portion of the Pillars is further illuminated by the shadows cast at midday during the equinoxes (Figure 6). Over the approximately six-month interval from the autumnal to the vernal equinox, the shadow on the southern face of these T-shaped Pillars traverses the designated grooves and symbols (Figure 7). The precise construction of Pillar 18 emphasises its "headpiece," an upper section inclined southward. Consequently, during the culmination of the Moon at the northern major standstill, the shadow extends across the southern face of Pillar 18, from the neck down to the belt mark[1] (Figure 8). On this basis, the primary iconography of the southern face of Pillar 18 can be interpreted as follows (for a detailed discussion, see Malkhasyan (2025a)).

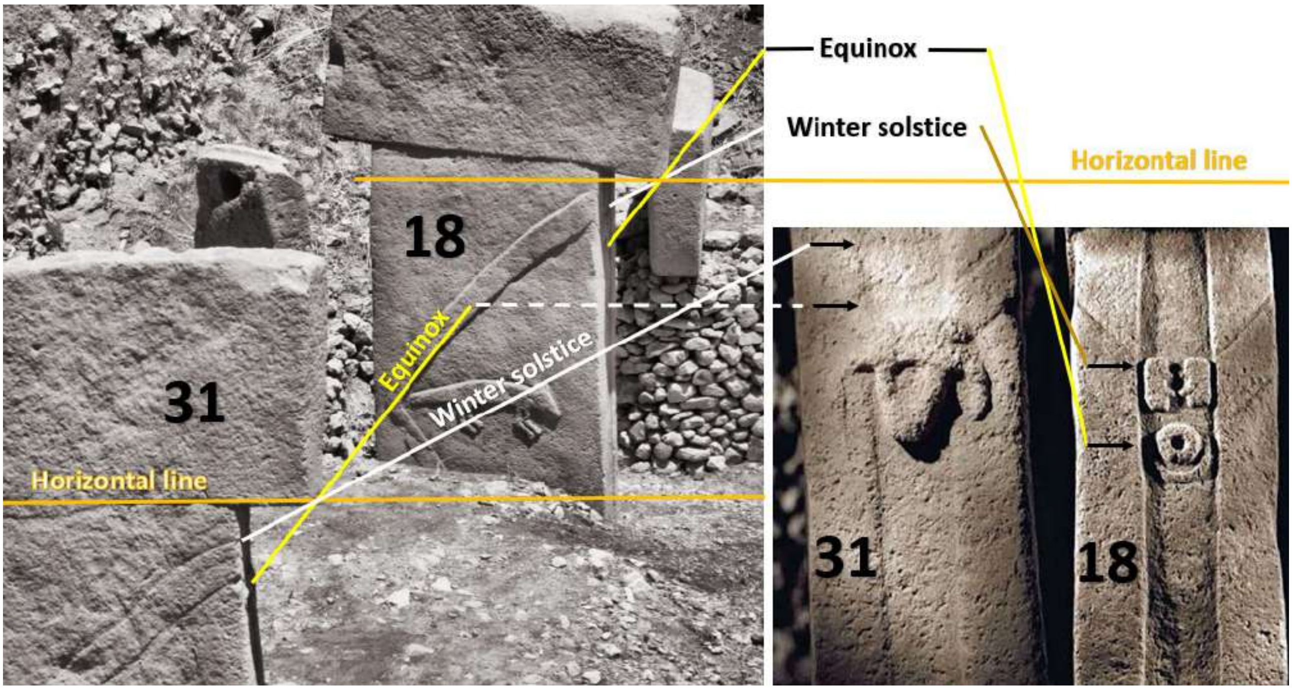

Figure 6. On the photographs, we have indicated the directions of sunlight at midday on the equinoxes (solar altitude h=51.5–54°) and winter solstice (h=27.5°) in relation to Pillars 31 and 18. The photographs were taken at a time when the bases of the Pillars had not yet been excavated by archaeologists, and can therefore be considered closer to the preliminary conditions (Schmidt, 2006).

[1]In the previous publication (Malkhasyan, 2025a), the length of the shadow cast on the southern face of Pillar 18 during the Moon's culmination at northern major standstill was calculated as 2.44 m. This did not correspond to the belt mark in the simplified model. However, precise modeling in the present study demonstrates a close correspondence (Figure 5b).

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- Upper horizontal and inclined grooves – mark the shadow boundary at midday during the winter solstice.
- Lower horizontal and inclined grooves – mark the shadow boundary at midday during the equinoxes.
- H-shaped symbol with central pit – represents the persistent gap between the Pillars' shadows throughout winter.
- "Lunisolar" motif – corresponds to the Sun and Moon at the equinoctial points of the ecliptic, and possibly to their eclipses.
- Upper boundary of the belt – indicates the shadow at the Moon's culmination during its maximum declination (northern major standstill).

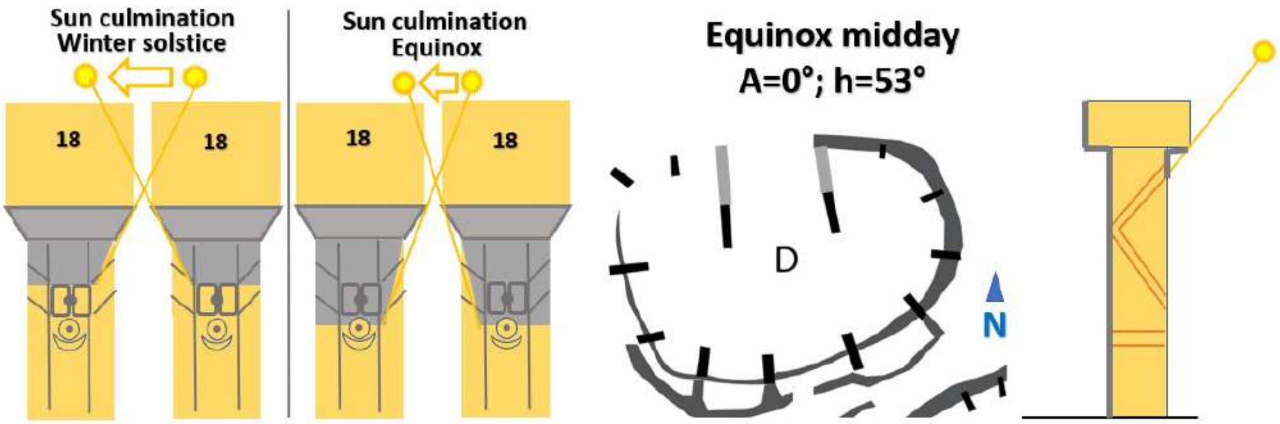

Figure 7. Schematic representation of the shadow movement on the southern face of Pillar 18 at midday on the equinoxes and winter solstice, respectively.

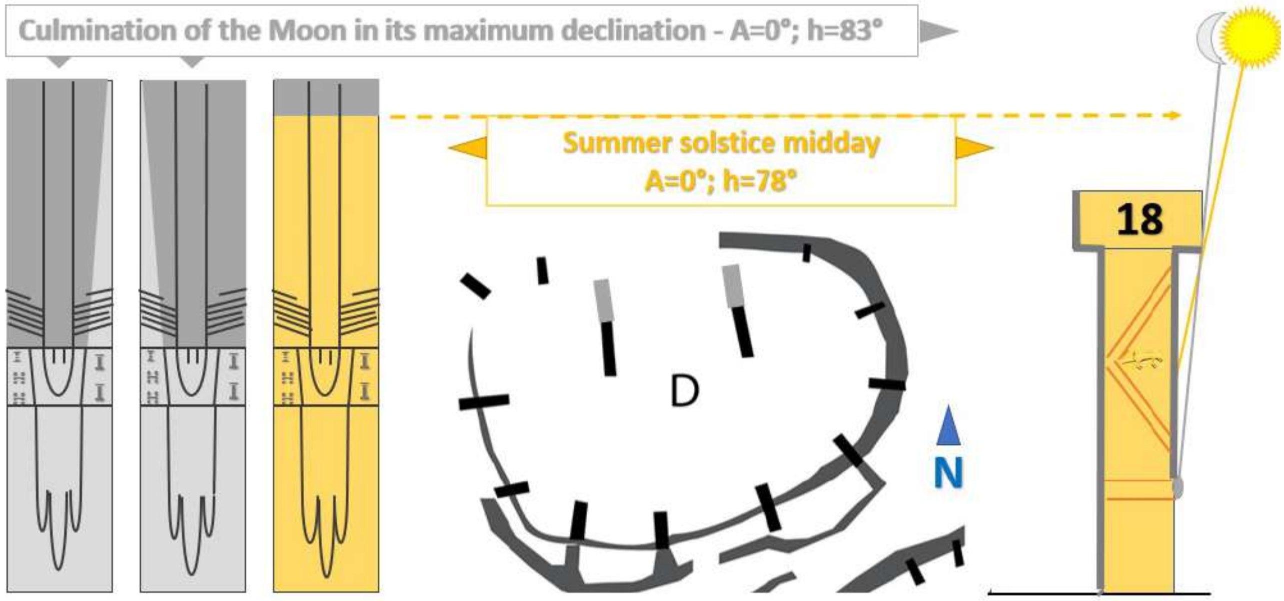

Figure 8. Schematic representation of the shadows on the southern face of Pillar 18 during the Sun's and Moon's culminations at their maximum declinations (summer solstice and northern major lunar standstill).

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3.2. Shadow of Pillar 19 on the Southern Face of Pillar 18

At the Moon's culmination during its southern major standstill, Pillar 19 casts a shadow on the southern face of Pillar 18, reaching the base of the depicted animal's tail and encompassing the central bird among the seven carved on the pedestal (Figures 9 and 10). Approximately two weeks before or after, at the Moon's northern major standstill, the shadow extends from the neck to the upper boundary of the belt on Pillar 18's southern face (Figures 8 and 10). Accordingly, the upper boundaries of the belt and the animal's tail serve as markers of the major lunar standstills. During the Moon's culmination at its southern minor standstill, Pillar 19 shadows only the central bird on the pedestal (Figures 9 and 10). When the Moon culminates while crossing the ecliptic aligned with the winter solstice point, Pillar 19 casts a shadow on the pedestal of Pillar 18, reaching either the base of the Pillar or the tip of the depicted animal's tail. Throughout the annual cycle, the midday shadow cast by Pillar 19 does not extend above the base of Pillar 18. Approximately one month before and after the winter solstice, however, the midday shadow reaches only the centrally positioned bird carved on the pedestal (Figures 9 and 11).

As demonstrated, the lower sections of Pillar 18—from the base of the animal's tail down to the row of seven birds—are associated, respectively, with the Moon's southern major and minor standstills. Notably, the complete cycle of this systematic shift in shadow boundaries aligns with the lunar nodal cycle (18.6 years).

The observed shadow alignments reveal a precise and consistent relationship between the position of Pillar 19 and the iconographic elements on Pillar 18. The alignment of the belt, the animal motif, and the row of birds with these shadows suggests that the carvings were intentionally designed to interact with solar and lunar phenomena. Building on these findings, the following section explores the iconography and its implications for the Pillars' potential observational and calendrical functions.

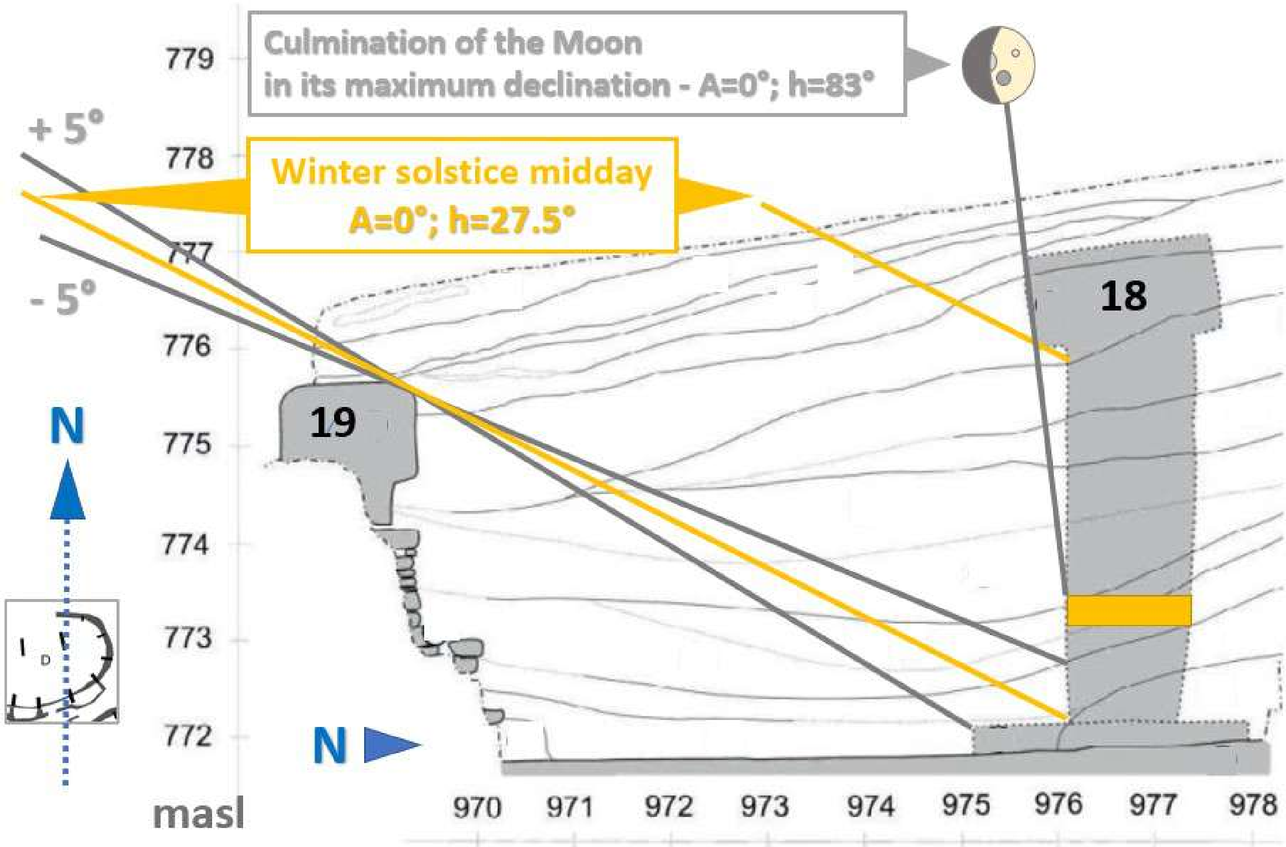

Figure 9. Precise relative positions of Pillars 18 and 19 in the meridian plane (Dietrich (2021) fig. 2.2, p. 7) (© German Archaeological Institute, compilation Jens Notroff). The figure shows the culminations of the Sun and Moon and the directions of light on specific days.

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Figure 10. Shadowing of the southern face and base of Pillar 18 during the Moon's culminations. The two images on the left show shadows at the major lunar standstills, respectively, while the image on the right shows the shadow during a southern minor lunar standstill at right ascension α=18^h00^m.

Figure 11. Noon shadow of Pillar 19 on the base of Pillar 18. Left — winter solstice; right — one month before and after the winter solstice.

3.3. Interpretation of Iconography Based on the Gnomonic Function

The occurrence of a midday shadow covering the centrally carved bird on the pedestal approximately one month before and after the winter solstice may be explained as follows. During the period to which Enclosure D is dated (ca. 9500 BCE), the winter solstice point was located in the constellation of Taurus, in close proximity to the Pleiades. As a result, for approximately one month preceding the winter solstice, the Pleiades were rendered invisible due to solar conjunction (Stellarium, 2024), spanning the interval between heliacal setting (symbolically expressed by the shaded bird) and heliacal rising (symbolically expressed by the illuminated bird). Accordingly, the seven birds may be interpreted as a symbolic representation of the seven stars of the Pleiades, corresponding to the mythological tradition of the seven daughters of Pleione, often depicted or associated with birds (doves) (Myths.WP (2008) p. 812).

When the Moon transits the winter solstice point, the visibility of the Pleiades varies according to the lunar phase and the Moon's position relative to the ecliptic. As the Moon moves northward from the ecliptic toward the Pleiades, their visibility decreases due to the Moon's illumination. On the pedestal of Pillar 18, the Moon's high position is likewise reflected in the approach of Pillar 19's shadow toward the depicted birds. Simultaneously, the mythological Seven Sisters are traditionally associated in ancient Armenian calendars with the winter months (Broutian, 1997, 2018), approximately spanning the period from the autumnal to the vernal equinox. Notably, however, this calendar system comprises six months rather than seven. This apparent discrepancy is clarified by the birds depicted on the pedestal of Pillar 18. As the shadow of Pillar 19 moves from west to east across the carvings, it covers only one bird at a time, culminating on the central figure. This pattern aligns precisely with the

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mythological narrative: six of the sisters remain continuously visible, while the seventh, the youngest, descends to the underworld and later returns. Accordingly, the six winter months correspond to the six visible sisters, whereas the invisible one represents the month during which the Pleiades become obscured around the winter solstice. Thus, the seven depicted birds can be fully interpreted within the period spanning the autumnal to the vernal equinox, with its midpoint—the winter solstice—associated with the Pleiades. The beginning and end of this interval correspond to the Pleiades' appearance at sunset and disappearance at sunrise during their culmination.

The feasibility of observing these events was demonstrated through the study of Pillar 27 in Enclosure C at Portasar, where the carved "predator's" tail and the aperture at its base establish a line of sight aligned with the Pleiades' culmination (Figure 12a) (Malkhasyan, 2024b). Moreover, the possible observation dates of the Pleiades' appearance and disappearance at culmination were recorded 16 days before the autumnal equinox and 11 days after the vernal equinox, respectively (Malkhasyan, 2024b). The duration of the intervening winter period thus totals $16 + 90 + 89 + 11 = 206.5$ days[2], corresponding precisely to seven synodic months ($29.5 \times 7 = 206.5$ days).

The dividing line between the pedestal and Pillar 18 is indicated by the tip of the depicted animal's tail. Accordingly, the pedestal corresponds to the entire 206.5-day interval, while its centre—marked by the centrally carved bird and the base of the Pillar—corresponds specifically to the midpoint of this interval, namely the winter solstice. Both the temporal extent of the 206.5-day period and its midpoint are therefore referenced to the pedestal: the boundaries of the interval align with the tip of the tail, whereas the winter solstice aligns with the pedestal's centre. The equinoxes[3], in turn, correspond to the base of the animal's tail, as demonstrated by the functional role of the predator's tail carving on Pillar 27 in Enclosure C (Malkhasyan, 2024b).

The lower mark of the belt, positioned midway between the shadow boundaries formed during the Moon's northern and southern major standstills (Figures 9 and 10), represents the midpoint of the same interval. The shortest interval between these two extremes spans approximately two weeks (e.g., from the first-quarter phase at maximum declination to the third-quarter phase at minimum declination). In this context, the lower mark of the belt may be interpreted as indicating—and symbolically representing—the midpoints of these two-week intervals, namely the equinoxes (for example, when a full or new Moon crosses the plane of the ecliptic). Accordingly, the occurrence of a quarter Moon at either major standstill could have, to some extent, allowed the anticipation of eclipses near the equinoxes. This function may be reflected in the "lunar–solar" symbol—serving as an equinox marker—carved on the upper part of Pillar 18 (see Malkhasyan (2025a) for details). On this basis, it can be stated that:

- The approximately two-week periods following the vernal equinox and preceding the autumnal equinox are generally associated with the "tails."
- The intervening winter period is associated with the seven birds, symbolising the seven stars of the Pleiades and the seven lunar months of winter. This interval begins with the Pleiades' appearance at their culmination point approximately two weeks before the autumnal equinox at sunset—a date closely corresponding to the Christian Feast of the Nativity of the Virgin Mary (September 8) (Liturgical Calendar (2025) p. 63) —and concludes with their disappearance at the same point roughly two weeks after the vernal equinox at sunrise (Malkhasyan, 2024b), which aligns with the Feast of the Annunciation (April 6-7) (Liturgical Calendar (2025) p. 142) and the pre-Christian Armenian spring festivals dedicated to the Mother Goddess Anahit (April 6) (Melik-Pashayan (1963) pp. 127-128).
- The central bird among the seven on the pedestal of Pillar 18 is associated with the youngest sister spending one month in the underworld (from heliacal setting to heliacal rising) during the month preceding the winter solstice. In other words, one of the seven months is not counted, corresponding to the period when the Pleiades are invisible. The duration of this month closely aligns with the two distinct two-week intervals described above.

[2]The 0.5-day fraction arises from the fact that the specified period begins at sunset and ends at sunrise.
[3]The equinox could be roughly determined from the Moon's monthly cycle.

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Such concepts are particularly well illustrated by the upper part of Pillar 12 in Enclosure C, which features an arrangement of seven similar birds (Figure 12b). Of the bird figures depicted here, six are rendered as distinct elements, whereas the seventh is shown in a decapitated form (Figures 11 and 12b). The figure of Bird No. 3 is positioned between the head and the body of Bird No. 7, and its placement may correspond to the approximately one-month interval preceding the winter solstice, on the assumption that the six birds arranged from left to right represent six winter months. During this one-month period, the Pleiades were not observable at this latitude (i.e. during their "death" or "Underground" phase). Accordingly, the 206.5-day period may tentatively be divided as follows:

$$(1)+(1)+(0.5)+(1-or-0)+(0.5)+(WS)+(1)+(1)+(1)=7-or-6(months)$$

As discussed above, the torso of the animal depicted on Pillar 18 may symbolise a one-week time interval. This interpretation is further supported by the iconography on the northern and western faces of Pillar 33 within the same Enclosure D. There, a fox is depicted with a total of fourteen snakes emerging from its abdomen and hind legs, arranged in two groups of seven (Figure 12c). This configuration permits the additional inference that the snakes symbolise days and may likewise have functioned as shadow-measurement markers.

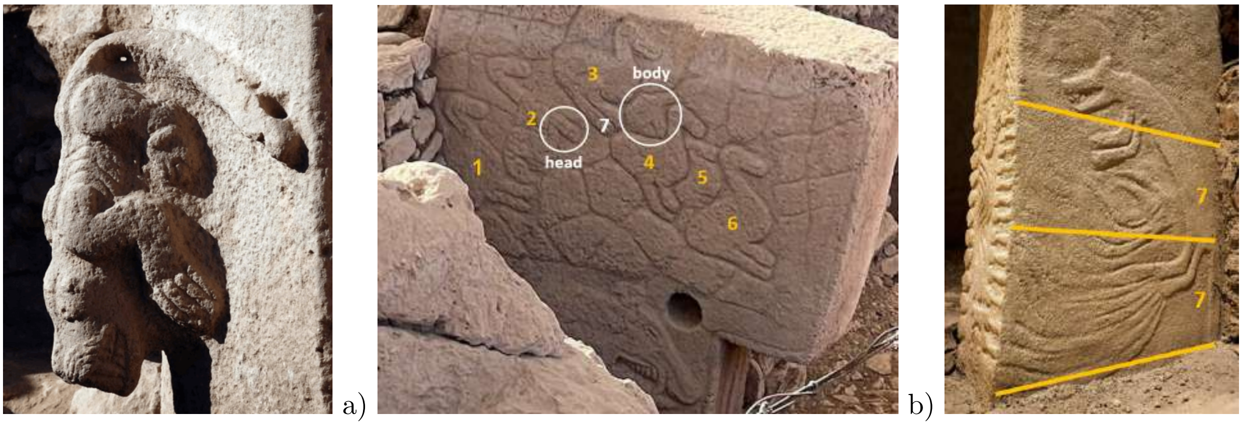

Figure 12. a) The high-relief of a "predator" carved on the eastern face of Pillar 27 in Enclosure C; b) Seven bird figures carved on the upper part of Pillar 12 in Enclosure C at Portasar, whose style repeats the seven birds depicted on the base of Pillar 18 in Enclosure D; c) View of Pillar 33 in Enclosure D from the north-west. Fourteen snakes emerge—seven from the hind legs and seven from the abdomen. Their heads tilt toward the northern face of the Pillar, forming a downward-widening "ladder," characteristic of shadow dynamics.

3.4. Research Prospects

Although the iconography of the southern face and pedestal of Pillar 18 finds a coherent explanation within the framework of the Pillars' shadow-measurement function, the meaning of symbols H and I on the belt remains unresolved (Figure 4d). Their interpretation may be clarified through a comprehensive analysis of the eastern and western faces of Pillar 18. In particular, it is necessary to examine the movement of the shadow cast by Pillar 31 across the western face of Pillar 18.

At the same time, as noted in the previous subsection, Pillar 33 in Enclosure D—with its rich iconographic program—constitutes a promising subject for further shadow-measurement analysis. On the basis of precise metric data, it is especially important to examine the dynamics of the shadows cast by the adjacent Pillars 32 and 38 onto the reliefs of Pillar 33 (Figures 1 and 12c).

By analogy with the analysis of Pillars 18 and 19, the shadow cast by Pillar 31 onto the southern face of Pillar 43 may likewise be investigated. This surface is notable for its horizontal incisions, which

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closely correspond to the rich iconography on the western face of Pillar 43 (Figure 2a). The latter has been interpreted by Sweatman (2024) as a lunisolar calendrical system (Figure 3). A targeted shadow-measurement study could help elucidate the internal structure of this system and provide an independent means of testing the conclusions derived from that interpretation. Indeed, the system proposed for Pillar 43 is associated with subdivisions of the tropical year, while variations in shadow length yield comparable temporal divisions.

In sum, the megaliths of Portasar constitute an exceptional repository of astronomical information for the investigation of Pre-Pottery Neolithic calendrical systems based on shadow measurement and orientation. Consequently, access to accurate and detailed metric data represents a crucial prerequisite for future research.

Summary

This study of Pillars 18 and 19 in Enclosure D at Portasar (Göbekli Tepe) demonstrates that their relative positioning, structural features, and iconographic elements form a coherent system with a shadow-measurement function. The results indicate that these Pillars were constructed not only for symbolic or iconographic purposes but also as a combined instrument for observing solar and lunar shadows—a gnomon—potentially serving both calendrical and eclipse-prediction functions.

A detailed analysis based on precise metric data revealed the following:

a) The shadow cast by the T-shaped top of Pillar 18 produces a stable and recurring pattern corresponding to the winter solstice and the equinoxes. The grooves on the upper part of the Pillar, the H symbol, and the "luni-solar" motif coincide with the shadow limits of the Sun's and Moon's culmination heights. The "luni-solar" symbol apparently represents the phenomenon of eclipses.

b) The upper mark on the belt functions as an indicator for the Moon's northern major standstill, highlighting key temporal boundaries of the lunar cycles.

c) During the Moon's southern major and minor standstills, the shadow of Pillar 19 reflects on the corresponding portions of Pillar 18, emphasising that both Pillars operate within a single, unified gnomonic system. Flat slabs beneath Pillar 19 could have served to regulate shadow length.

d) The base of the animal's tail on the southern face of Pillar 18 may have served as a gnomonic marker for observing the southern major lunar standstill.

e) The seven birds carved on the pedestal of Pillar 18 correspond to the seven stars of the Pleiades in ancient mythological perception. The shadow cast by Pillar 19 across them represents the shadow of one of these birds during the winter solstice period, consistent with observations from Pillar 27 in Enclosure C (Malkhasyan, 2024b). Together, these observations reveal a potential seven-month winter period ($29.5 \times 7 = 206.5$ days). The seven stars of the Pleiades symbolise these seven months, and the invisibility of one of them corresponds to the month in which the Pleiades are not visible (from heliacal setting to heliacal rising).

Thus, the shadow-measurement system of Pillars 18 and 19 clearly reflects:

- The winter solstice and equinoxes (with approximate lunar phase observations),
- The nodal cycle (18.6 years), and
- A seven-month winter period based on the observation of the Pleiades.

These results are not only consistent with previous research but also mutually complementary. In particular:

1) The hypothesis concerning lunar observations (De Lorenzis & Orofino, 2015) finds additional support here.

2) The lunisolar calendar described by Sweatman (2024) is further corroborated.

3) Previous astronomical studies of Pillars 27, 18, and 31 in Enclosures C and D align fully with the current findings, providing mutual reinforcement (Malkhasyan, 2024b, 2025a,b).

These results suggest that Pillars 18 and 19 of Enclosure D formed a multifunctional ancient astronomical system, integrating solar and lunar observations within a cohesive iconographic program. The alignment of top, belt, and pedestal symbols with actual shadow dynamics demonstrates a fully operational calendrical–astronomical framework.

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