The Functional Interrelation of Central Pillars in Enclosure D at Portasar (Göbekli Tepe)

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Abstract

This study aims to reinterpret the spatial relationship between the central Pillars 18 and 31 of Enclosure D at Portasar (Göbekli Tepe), considering it as a potential practical instrument for determining the summer solstice and equinoxes. A shadow-tracking simulation was conducted using positional data from the Pillars, architectural plans, and the Stellarium 24 astronomical software. The mutual positions of the Pillars' shadows were examined during the four key dates of the year—winter and summer solstices, and the vernal and autumn equinoxes, at sunrise and sunset.

The results show that only at sunrise on the summer solstice do the shadows align in such a way that a light-filled gap appears between the Pillars, directed southwest. During the equinoxes, the shadows produce a "gating" effect—opening at sunrise and close at sunset. The "H" and "I" symbols carved on Pillar 18 (as well as on other Pillars at the site) may correspond to the horizontal and vertical trajectories of the observed shadows. Furthermore, a visual correlation is observed between the imagery on a carved bone spatula and the sunrise during the summer solstice. These findings suggest a potential shadow-based calendrical application for the Pillars.

Keywords: *Göbekli Tepe, Enclosure D, Pillar 18, Pillar 31, Summer solstice, Bone spatula, Shadow tracking, Archaeoastronomy, Solar observation, Neolithic astronomy.*

1. Introduction

Portasar (Göbekli Tepe) is one of the most prominent megalithic monuments dated to the Pre-Pottery Neolithic period (Dietrich, 2011, Dietrich & Schmidt, 2010). The main characteristic of the site is its T-shaped, anthropomorphic Pillars adorned with symbolic carvings. Since the publication of the first excavation results (Schmidt, 2006), these Pillars have prompted a number of archaeoastronomical hypotheses that suggest possible correlations between the structures' orientations and iconography with celestial phenomena and calendrical systems.

In particular, the carvings on Pillar 43 of Enclosure D were interpreted by V. Vahradyan & Vahradyan (2010) as representations of constellations, based on the plausible correlation between the vulture motif and the Cygnus constellation. However, other hypotheses, such as Collins & Hale (2013) theory of Deneb observation or Magli (2015)'s interpretation of Sirius rising, require further substantiation.

Later, other researchers have proposed that the central Pillars and their symbolism are components of an astronomical (Sweatman & Tsikritsis, 2017), ideographic, or religious-philosophical system (Coombs, 2023, Seyfzadeh & Schoch, 2019). The T-shaped Pillars are ascribed divine symbolic meaning, and the H symbols are interpreted as heavenly or divine gateways. H. Martirosyan (2024) has presented a symbolic analysis of the iconography, interpreting the central Pillars as "gateways" to sunrise and sunset, also suggesting a possible shadow-measuring (gnomonic) function. Although similar ideas have previously been proposed by Dendrinos (2016) and Villamarin (2020), they have not yet undergone systematic examination.

Previous studies, particularly the analysis of Pillar 27 of Enclosure C at Portasar (Malkhasyan, 2024b) and Stone 137 at the Zorats Qarer megalithic complex (Malkhasyan, 2024a), have shown that

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the design, orientation, and placement of holes in these stones could serve as observational tools for observing star movements, solstices, equinoxes, and solar culminations.

The aim of the present study is to methodically examine the mutual shadow dynamics of Pillars 18 and 31 in Enclosure D during sunrises and sunsets on the calendar's most astronomically significant days, considering them as part of a shadow-measuring system. This approach offers a more comprehensive understanding of the Pillars' function, extending beyond mere symbolism to the realm of practical astronomical instrumentation.

2. Material and Methods

2.1. Selection of the Studied Pillars

The central Pillars 18 and 31 of Enclosure D at Portasar (Göbekli Tepe) (Figure 1) were selected for this study based on several objective criteria:

- Compared to the central Pillars of other Enclosures, these are relatively well preserved;
- Their upright positions and geographic orientations are considered close to their original state (Schmidt, 2006);
- The Pillars bear rich iconography, with certain motifs recurring on other Pillars, making their interpretation potentially applicable to broader analysis;
- From the available publications, it was possible to extract dimensional data for Pillars 18 and 31 that are reasonably suitable for shadow modeling.

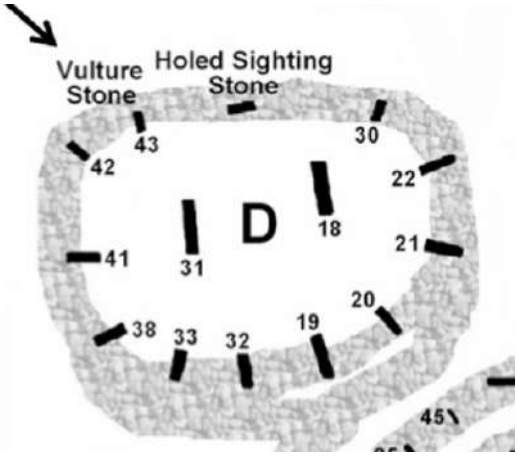
a)  b) 

Figure 1. a) Southwestern view of Enclosure D. Central Pillars 31 and 18 in a stabilized position; b) Floor plan of Enclosure D (Schmidt, 2006)

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2.2. Dimensional Criteria for the Experimental Model

Due to the limited availability of precise dimensional data on the Portasar site, shadow analysis was conducted using a simplified model (Table 1) of the central Pillars of Enclosure D. The model was constructed by combining available measurements, published floor plans, and photographic analysis (De Lorenzis & Orofino, 2015, Henkley & Gopher, 2020, Schmidt, 2006).

Based on these sources (Table 1), a pair of symmetric T-shaped Pillars were modeled, positioned vertically and oriented along a 173° azimuth in the horizontal plane. The line connecting the corresponding points of the Pillars forms a 7° angle with the parallel (azimuth A=83°). The layout of the Pillars in the model is based on the accurate archaeological floor plan (Henkley & Gopher, 2020)

Although the measurements used in the model align with the known data, the model remains simplified due to a lack of more precise records. Therefore, the resulting data are treated not as absolute quantitative values, but as qualitative indicators to reveal potential shadow tracking functionality.

Table 1. Criteria for the simplified model of the Pillars 18 and 31.

No.	Parameter	Value	Source
1	Distance between the Pillars	5 m	(Henkley & Gopher, 2020)
2	Orientation of Pillar width (azimuth)	173°	(De Lorenzis & Orofino, 2015)
3	Orientation of Pillar thickness (azimuth)	83°	Plan from (Henkley & Gopher, 2020)
4	Width at the base	1.2 m	Scaled analysis from photographs
5	Width at the top	1.8 m	Scaled analysis of the site plan

2.3. Shadow Observation Conditions

Shadow dynamics were modeled using the Stellarium (2024) astronomical software, based on the estimated archaeological dating of Enclosure D (c. 9500 BCE) (Dietrich & Schmidt, 2010). The site's latitude value (37°13′ N) was used consistently throughout the simulations.

Since there is currently no precise data on the angular elevation of the visible local horizon (affected by surrounding mountains), all calculations assume a mathematical (flat) horizon (0°). However, it should be noted that even with a 5° elevation of the visible horizon, the azimuthal[1] shift of sunrise and sunset in the calculations does not exceed 5° on any day of the year. The timing of sunrise and sunset is also only slightly affected—e.g., during the winter solstice, sunrise may be delayed by up to 30 minutes, and sunset may occur correspondingly earlier. We are not considering these deviations to significantly affect the qualitative assessment of shadow dynamics.

2.4. Selection of Examination Dates

Four key dates of astronomical significance were chosen for examination. The vernal and autumn equinoxes (henceforth referred to collectively as Equinox) were treated together, as the differences in shadow dynamics between them are negligible.

- Winter Solstice (WS) – December 21 (Sunrise A =122°, h=0°; Sunset A =238°, h=0°)
- Equinox (EQ) – March 21 and September 23 (Sunrise A =90°, h=0°; Sunset A =270°, h=0°)
- Summer Solstice (SS) – June 21 (Sunrise A =58°, h=0°; Sunset A =302°, h=0°)

The study focused on the position and interaction of shadows at sunrise and sunset on these key dates (Stellarium, 2024).

3. Results and Discussion

Winter Solstice

During the WS, when the Sun reaches its southernmost position, the shadows cast by the two central Pillars do not overlap in any way. These shadows appear at sunrise in the northwest (Figure 2 a) and disappear at sunset in the northeast (Figure 2 b).

Equinoxes

On Equinox days, the Pillars cast adjacent shadows in the west at sunrise (Figure 3 a), drift apart toward the north at midday, and converge again in the east at sunset (Figure 3 b).

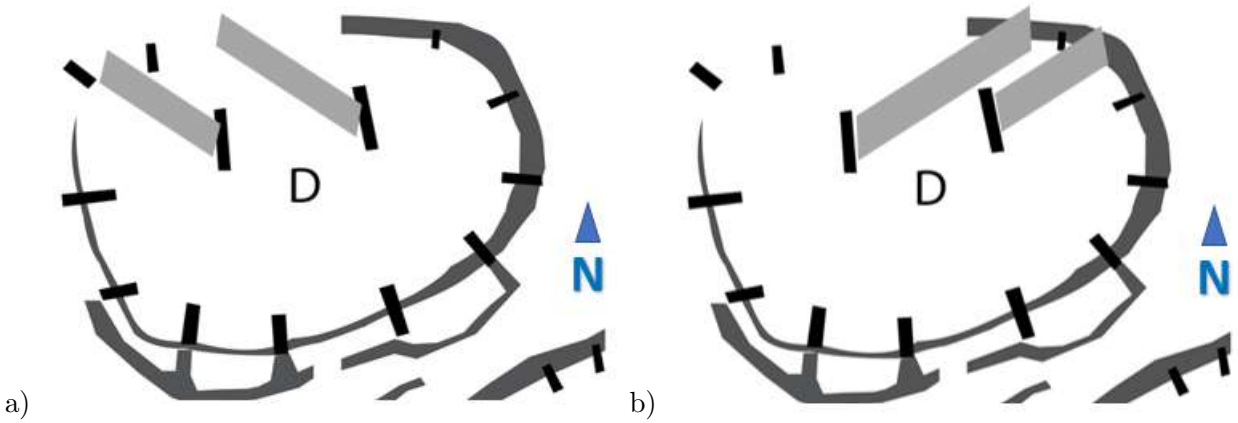
Summer Solstice

The positioning of the Pillars is such that only at sunrise on the SS do their shadows create a light-filled aperture directed on the enclosure's southwestern wall (Figure 4). Even a slight deviation in azimuth southward would eliminate this illuminated zone as the shadows would overlap.

3.1. "Heavenly Gates" in Practice

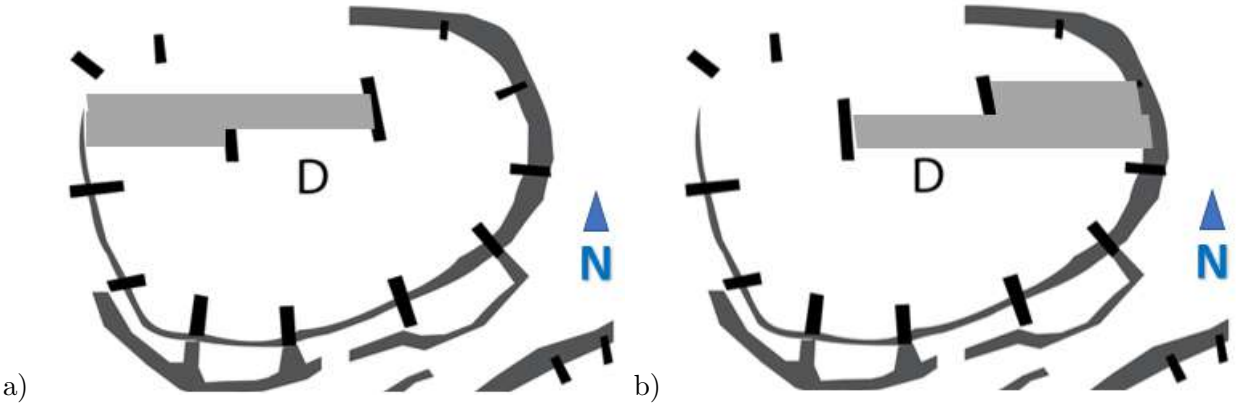
The shadow interplay between the Pillars only occurs during summer, between the vernal and autumn equinoxes. No such convergence occurs in winter. Therefore, the overlapping shadows may have served as a marker for Equinoxes—sunrise resembles the opening of "heavenly gates," while sunset

[1]The azimuth values presented in the article are calculated from the north point.



a) b)

Figure 2. Directions of shadows cast by the central Pillars of Enclosure D during the WS: a) at sunrise (A = 122°); b) at sunset (A = 238°).



a) b)

Figure 3. Arrangement of the central Pillars' shadows on an Equinox: a) at sunrise (A = 90°); b) at sunset (A = 270°).

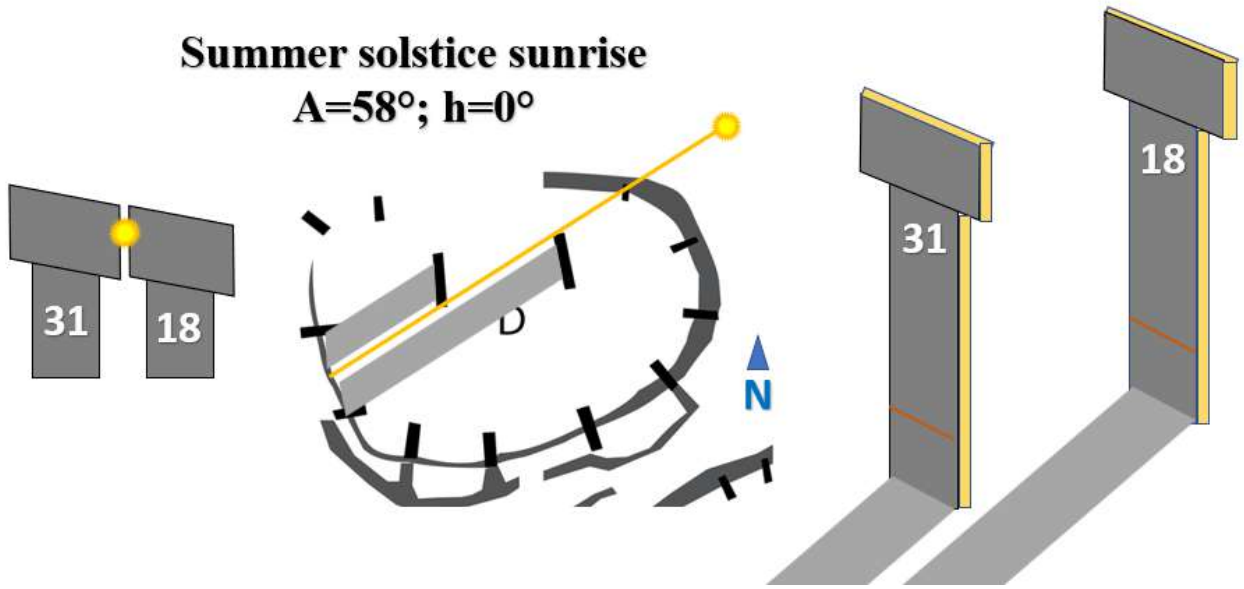


Figure 4. Schematic arrangement of shadows cast by Pillars 31 and 18 at sunrise on the SS.

marks their closing. At the same time, the rising Sun at dawn is comparable to the vernal equinox, whereas the setting Sun at dusk corresponds to the autumn equinox. Consequently, the shadows cast by the Pillars diverging in the morning evoke the image of opening "heavenly gates," while

their convergence in the evening suggests these gates closing. Thus, the shadows of the Pillars—which symbolically represent "heavenly gates" according to interpretations by Martirosyan (2024), Seyfzadeh & Schoch (2019), and Coombs (2023) —also take on a visually perceivable function: that of opening and closing "heavenly gates". Through these gates passes the light of the supreme deity—the Sun.

During the SS, the aperture created by the shadows opens horizontally toward the southwest at sunrise. As the Sun rises, the shadow of Pillar 18 slides down the eastern face of Pillar 31, creating a vertical "clearance" as well. This dynamic may explain the widespread use of " H " and " I " symbols at the site: they seem to depict the horizontal and vertical movements of the central Pillars' shadows.

3.2. Interpretation of the Bone Spatula's Imagery

Figure 5. Bone "spatula", area K10-45, Locus 7.2 (Dietrich & Notroff, 2016).

A decorated bone spatula from the site features two vertical T-shaped Pillars (Figure 5). The piece dates to the same period as the monument. Although interpretations (Collins & Hale, 2013) vary, no definitive conclusion has emerged (Dietrich & Notroff, 2016). The left T-shape continues horizontally with a bent top; both figures show four short parallel strokes on their "heads"

When viewed from the southwest (A=58°) (Figure 4) — as at sunrise on the summer solstice — the shadows cast by the central Pillars at that moment recreate the exact pattern carved on the bone spatula (Figure 5).

It is important to emphasize that the T-shaped Pillars and their shadows appear to have been intentionally engraved by hand on the bone plaque, suggesting their significance to the people of the time. However, the walls of Enclosure D are relatively close and considerably high, making it impossible to see the visual scene depicted in Figure 4 from the southern side today. This leads to the assumption that, at the time the bone was engraved, there were no structures yet built to the southwest of the central Pillars. Such a scenario is only plausible if the engraving was made during the construction phase.

Thus, the curving on the bone spatula serves as a kind of "architectural" and construction-related record, highlighting one of the key purposes behind the design of the building: to determine the summer solstice sunrise.

Concluding Remarks

The shadow analysis of the central Pillars 18 and 31 in Enclosure D suggests their role as functional astronomical instruments for determining the summer solstice and equinoxes. The findings indicate that only at sunrise on the summer solstice do their shadows create a southwest-pointing illuminated opening. On Equinox days, the interplay of shadows during sunrise and sunset may symbolically represent "opening" and "closing" "Heavenly Gates"—echoing iconographic and symbolic interpretations.

In particular, the alignment seen at sunrise on the summer solstice mirrors the carved design on the bone spatula unearthed at the site. This corroboration supports the idea that Enclosure D's Pillars functioned as an integrated shadow-based system, serving practical, symbolic, and religious purposes simultaneously.

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