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THE SYMMETRIC PLACING AND THE DATING OF PARTHENON AND HEPHAISTEION IN ATHENS (GREECE)

George Pantazis

National Technical University of Athens, School of Rural and Surveying Engineering,Laboratory of General Geodesy, 9 Heroon Polytechniou, Zografos, 15780, Athens, Greece

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Corresponding author: George Pantazis (gpanta@central.ntua.gr)

ABSTRACT

The planned astronomical orientation and positioning of all kinds of monuments was proved by numerous investigations all over the world since the 19th century. Some cult, social or utilitarian purposes dictate a concrete orientation for each one. In this paper are being determined the individual orientation and the dating of Parthenon and Hephaisteion as well as a strong relationship between these significant monuments of the classical era is emerged. The exceptional symmetric placing of these monuments, as proved by this research, in ancient Athens is truly remarkable. Thus the strong religious relationship between the temples is also geometrically documented. The modern instrumentation used today and the special developed astrogeodetic methodology permit the accurate (some arc seconds) determination of a monument's orientation. Additionally this fact may be also a long discussion between archaeologists, archaeoastronomers and humanists.

KEYWORDS: Parthenon, Hephaisteion, symmetric placing, astrogeodetic methodology, accuracy

1. INTRODUCTION

Parthenon is the main monument of Athens' Acropolis, which characterizes Greece all over the world. It is included in the UNESCO's world heritage list of monuments from September 11th, 1987 (http://whc.unesco.org/en/list/404). It is the brightest construction of the classical era in Athens, which symbolizes the Greek independence and civilisation. It is dedicated to Athena, the shield goddess of the city.

On the other hand the temple of Hephaestus (it is well known as Theseion, as it was believed that the temple was dedicated to Theseus, a hero of Greek mythology) is today one of the best preserved monuments of the classical era. The temple is dedicated to Hephaestus and to Ergane Athena, the goddess of labour. The statue of Athena Hephaistia was set up next to the cult statue of Hephaestus (Parke, 1977; Dinsmoor, 1939). Hephaisteion, as it is called today, is located on the hill of Kolonos Agoraios on the west side of the Athenian Agora about 600 meters far away from Athens' Acropolis.

Some common features characterize both monuments : they are dedicated to Athena goddess, they were designed by the great architecture Ictinus, they were constructed according to the Dorian order by using the same material that is the first quality of Penteli's mountain marble, they follow the rule 4:9 in the scale of their sides (width and length) (Lambrinoudakis, 1983; Orlandos, 1977), they have the same view, towards east, to Hymettus mountain and also they were founded the same period 450 BC- 448 BC (Orlandos,1977; Parke, 1977; Dinsmoor, 1939). Also it is noticeable that the days that "*The Chalkeia*" (the festival held in Hephaisteion) was celebrated, on the Acropolis the priestess set up the loom on which the "*peplos*" of Athena was woven due to be presented to the goddess at the Panathenaia (Parke, 1977). Thus it is obvious the strong relationships between the cult at these temples.

Both temples have some general respective attributes as Parthenon has 17 columns lengthwise and 8 columns widthwise, while Hephaisteion has 13 columns lengthwise and 6 columns widthwise. The length of Hephaisteion is approximately the same as the width of Parthenon about 32.50m. The height of Parthenon is 20m as the height of Hephaisteion is 9m. Also Parthenon was built at 156.72m height as Hephaisteion was built at 67.88m height above the mean sea level (they have height difference of 88.84m) and the distance between them is 638.50m.

The significance of both monuments and the major archaeological interest for them, lure scientists to investigate their astronomical orientation and dating since the 19th century.

The last two centuries several researchers were involved in the determination of the astronomical orientation of both temples by using simple instrumentation such as compasses and poles. (Orlandos, 1977; Dinsmoor, 1939; Dinsmoor, 1975; Lockyer, 1964; Penrose, 1894; Penrose, 1897; Fafoutis, 2004; Boutsikas, 2007). Table 1 presents the results of these investigations.

2. DEFINITIONS

By the term astronomical orientation of a monument is defined the determination of the astronomical azimuth of the monument's main longitudinal axis. This proved influential for the worship purposes as the goal was that the risen sun, principally on the celebration day of the temple, should mostly light the god's statue which was situated at a specific position.

As astronomical azimuth of an axis AB is defined the angle between the astronomical meridian plane of the point A and the plane containing the point B and the true normal (vertical) of the point A, measured in the plane of the horizon, clockwise from the astronomical north.

Table 1. The results for the astronomical orientation of Parthenon and Hephaisteion in former times

SOURCE	AZIMUTH (°)	SOURCE	AZIMUTH (°)
Parthenon		**Hephaisteion**	
Orlandos (1977)	77° 08′ 19″	Penrose (1851)	100° 20′
Penrose (1846)	76° ±1°	Burnouf	96° 11′±1°
J.N. Lockyer	72°	Sehope	103° 30′
Sault	76° ±1°	V. Alten	101° 26′±1°
NASA	72° ±2°	Penrose (1907)	103° 06′ 02″
Boutsikas (2007)	77° ±1°	Dinsmoor	96° 06′±1°
		Boutsikas (2007)	104° ±1°

The main longitudinal axis is defined the lengthwise proportion's line of the monument.

The profile of the perceptible horizon (skyline) at a specific position on the earth is defined as the projection of the outline of either hills, mountains or buildings situated at the direction of view of an observer standing at this position against the celestial sphere and celestial bodies (Sun, stars) (Pantazis, 2002; Pantazis *et al*, 2004; Pantazis et al, 2005). The perceptible or conventional horizon extending in front of a monument plays a significant role in the investigation of the dating and the meaning of a monument's orientation. This is due to the fact that the apparent positions of the celestial bodies at the time of their rising or setting as seen from the monument depend on the profile of the perceptible horizon in respect to the monument.

Today, by using modern instrumentation and by applying a concrete innovate methodology (Pantazis, 2002; Pantazis *et al*, 2004; Pantazis *et al*, 2005) it is feasible to determine the precise astronomical orientation of a monument and its dating. This precious information could help the archaeologists and humanists in their studies.

According to the applied methodology the date that the diurnal path of the sun coincides the point where the line of the main axis' astronomical azimuth and the line which defines the perceptible horizon intersect, (Figure 3) specify the monument's foundation date.

The total uncertainty of the methodology depends on the determination of the uncertainty of each one of the involved parameters that is the astronomical azimuth, the main longitudinal axis, the profile of the perceptible horizon, the Sun's path and the annual change of the Sun's diurnal path. The major influence to the total uncertainty comes from the determination of the monument's main longitudinal axis as it depends on the size of the monument. The larger the monument is the less the uncertainty is. The results of more than 80 monuments, which were investigated by using this methodology, have shown that the uncertainty could fluctuate from ±10 arc seconds to ±10 arc minutes.

3. THE PROCEDURE

The methodology, which is applied to Parthenon and Hephaisteion, consists of the next steps:

- Finding the position (the coordinates) of the monument's site on the earth surface using geodetic GNSS receivers and the relative positioning method, which provide accuracy of some millimeters.
- Creating the monument's digital plan by using appropriate design software. The survey of the monument is carried out using modern reflectorless geodetic total station, which emits a visible red laser beam (Figure 1). This permits the untouched and most accurate measurement of the monuments characteristic details without any contact and interposition.

The accuracy of the Cartesian coordinates X, Y for every measured point is of the order of ± 3mm.

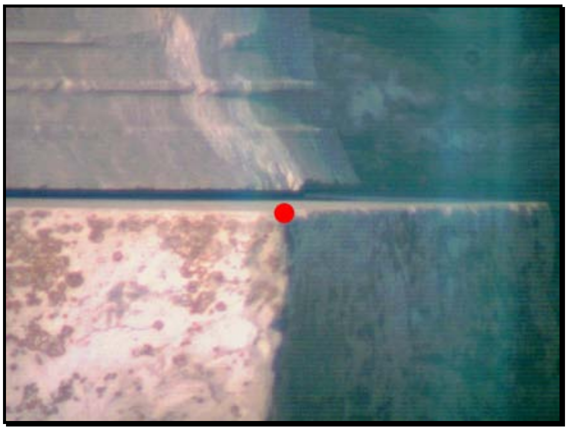

Figure 1 The measurement of the detail's points on a monument's body

- Finding the main longitudinal axis of the monument (Figure 2). The main longitudinal axis AB is defined by the best fitting line, on points, which represent the middles of numerous lines created by the homologous points of the monuments sides (Pantazis *et al*,2005; Pantazis *et al*, 2009). The least square method is used for the adaptation according to the formula $y = a \cdot x + b + u$, providing the line and its calculation uncertainty.
- Determination of the astronomical azimuth of the main longitudinal axis (Figure 2) by means of astrogeodetic observations to the Pole Star (Polaris, aUMi), using the hour angle method (Mackie, 1971). For these observations an original measuring system was manufactured (Pantazis, 2002; Lambrou, 2003). This system consists of a high end digital total station connected with a GNSS receiver. Also the developed appropriate software allows the determination of the astronomical azimuth in short fieldwork time (about 10 minutes) and with accuracy of few arc seconds (Lambrou *et al*, 2008). The reduction of the results due to the earth's Pole movement is taken into consideration.

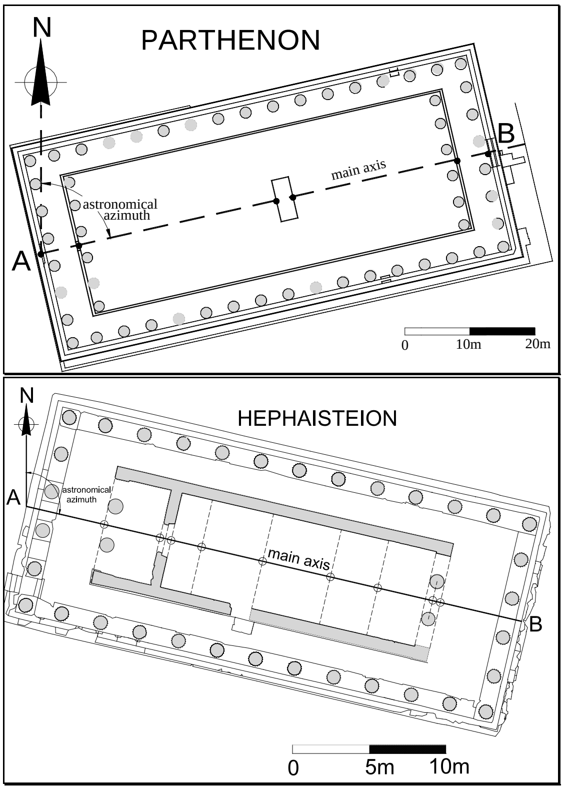

Figure 2 Definition of the main longitudinal axis of a monument

- Measuring and drawing the profile of the perceptible horizon (Figure 3), as seen from a specific position inside the monument that is the position of the statue. For this reason, it is necessary to define a reference direction and then measure the horizontal and vertical angles to specific points on the horizon's natural structure. On the diagram (Figure 3), x-axis shows the astronomical azimuth (Az) and y-axis shows the altitude (υ).

Mountain Hymettus is the perceptible horizon of both monuments towards east.

By the measurements of the same points on the horizon separately from each monument, it is come out that the homologous points of the horizon's profile coincide to each other. That means that the relative position and the height difference between the two temples were chosen so as the view towards east to be the same.

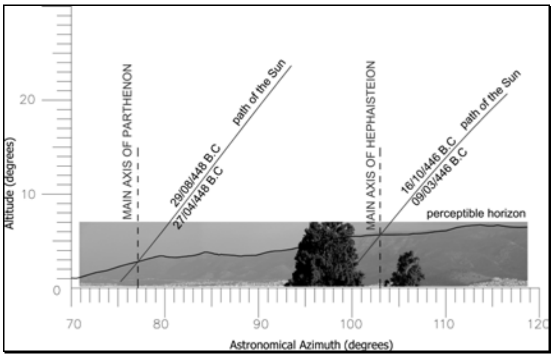

Figure 3 The combined horizon's diagram with the three representative lines

- Reconstruction of the apparent diurnal path of the Sun as seen from the monument's place, in specific dates (Fig. 3). The *Sky map Pro8* (Marriott, 2004) software - a digital almanac and virtual planetarium was used. The input data were, the celestial body of interest (e.g Sun), the coordinates φ, λ of the place and the date (any date between 4713 BC and 8000 AD). For both monuments the sun's path is drawn for specific days when the three lines (Main axis, perceptible horizon, Sun's path) coincide.

4. CONCLUSIONS

The basic results of this work are:

- The straightway determination of the astronomical azimuth of both temples with accuracy of ±1′.
- the remarkable symmetric placing of the two temples
- the remarkable relative horizontal and vertical position between the two temples in order to have the same view towards east.

Specifically, table 2 presents geodetic coordinates, orientation and dating of both temples. As far as it concerns the dating it is noted that the Sun's path coincide a specific point twice in a year. Thus the second dates that the Sun passes from these points are April 27th 448 BC for Parthenon and March 9th 446BC for Hephaisteion.

Evaluating the results, it is noteworthy that the placing and the orientation of the temples are symmetrical (Figure 4) in relation to the east.

The orientation of the main longitudinal axis of Parthenon is far from the east towards North 12° 54′ (≈13°) the same as the Hephaisteion is far from the east towards south. Also they have the same angular distance (≈17°) from the summer and winter solstice accordingly. Thus without taking into consideration the horizon's profile it is noticeable that the day that the sun rises at Parthenon's main axis astronomical azimuth sets at Hephaisteion's main axis astronomical azimuth towards West and vice versa. Additionally it takes about 50 days for the sun to travel from Parthenon's main axis to Hephaisteion's main axis.

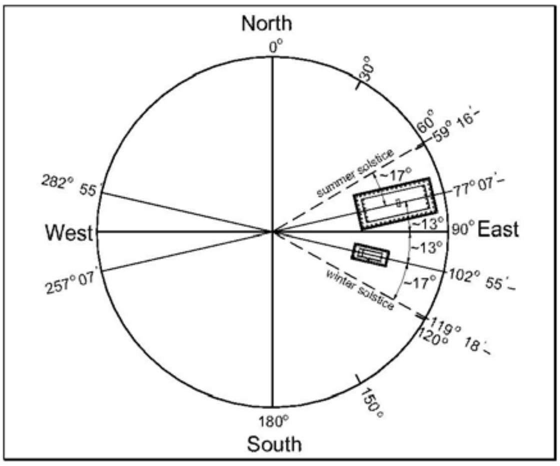

Figure 4 The radiosymetrical positioning of Parthenon and Hephaisteion

Also it is justified that the two temples had placed in such relative positions (horizontally and vertically) so as to have the same view to the mountain Hymettus, which is their common perceptible horizon towards east.

Could the above mentioned results be related to the foundation, the tradition and the celebration ceremonies of both temples?

As it is evaluated by many researchers, the two temples were founded at the same era and they have architectural, decorative, and adorating similarities as the worship of the same gods, namely Athena and Hephaestus (Parke, 1977; Dinsmoor, 1939; Thompson, 1962).

Also the relation of the two festivals, Panathenaia and Chalkeia is obvious as the "*peplos*" of Athena started to be woven during the Chalkeia festival.

According to all the above relations it will be an omission if there isn't a corresponding placing of the two temples in relation to the Sun. Probably, it would not be convenient to have exactly the same orientation as this would cause celebration problems as both temples must be celebrated on the same days. Moreover, another practical reason is to allow sufficient time between the two festivals for the elaboration of Athena's "*peplos*". Their symmetric placing towards East reveals their relationship. Thus, the worship of the same gods is emphasized. Additionally the ensuring of the same view towards East reflects the corresponding worship to the same gods, who make the Athenians proud.

Consequently the modern applied geodetic methodology proved the relation between the geometric characteristics and the celebration ceremonies of the two temples.

Table 2. The results for the astronomical orientation and dating of Parthenon and Hephaisteion

	Latitude (φ)	**Longitude (λ)**	**Main axis astronomical orientation**	**Dating Julian calendar**
Parthenon	37° 58′ 18″N	23° 43′ 39″E	77° 07′ ±1′ Northeastern	27 August 448 BC ±15years
Hephaisteion	37° 58′ 32″N	23° 43′ 18″E	102° 55′±1′ Southeastern	16 October 446 BC ±15years

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