

## Knowingly orientation of Ancient Greek Temples

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### ABSTRACT

It has been confirmed by many researchers in the past, like Dinsmoor, Heinrich Nissen, Norman Lockyer and Orlandos, that the orientation of the ancient Greek monuments it is not accidental. Also the same is true for monuments of other cultures. Previous years this research was carried out by simple instrumentation like compass and simple calculations due to the lack of computers. Today for the same research there is the possibility of using modern instrumentation and more accurate calculations in order to acquire more accurate and reliable results.

This paper presents a thorough research of monuments astronomical orientation based on the modern state-of-the-art geodetic and astrogeodetic measurements and data analysis. The acquisition of these data permit the acquirement of an astronomically oriented digital plan of the monument, a digital diagram of the perceptible horizon around the monument and a digital reconstruction of the apparent path of the Sun, as it rises above the horizon at characteristic dates. The data reduction procedures are reliable and lead to an accurate determination of monument's astronomical orientation. The study of this orientation relative to the Sun's circle reveals significant correlations with the days of their celebration and the adjacent monuments. Here the findings for the ancient Greek temples of Parthenon and Hephaisteion in Athens, Poseidon at Cape Sounion, Zeus and Hera in Olympia are presented.

**Key words:** Archaeoastronomy, ancient Greek temples, astronomical orientation, dating, Parthenon , Hephaisteion, Poseidon Cape Sounion, Zeus and Hera Olympia

### INTRODUCTION

#### Historical Data

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 11<sup>th</sup>, 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 (picture 1): they are dedicated to Athena goddess, they were designed by the great architect 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

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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.



**Picture1.** *The Parthenon (left) and the Hephaisteion (right) in Athens*

Cape Sounio is located at the most South-East edge of Attica peninsula. It has been a major navy strategic site of the ancient Athenian State. The Athenians began the construction of a porous (limestone) temple dedicated to Poseidon somewhere before 480 B.C. In the time of the Persian wars only the cella and the colonnade of the pteron had been constructed; but the temple has been destroyed before its roofing and the carving of the flutes of the columns. Many years later, in 444-440 B.C., during Pericles' Age, the Athenians constructed the new Poseidon's temple (picture 2) at the same site. The temple occupied the highest peak of the cape, which had been totally leveled in order to be used as Poseidon's precinct. Its architect is known as "the architect of Theseion. There is some evidence that he is the one and same person who designed three other monuments of the golden Age of Pericles.

The porous material of the old unfinished temple has been used for the fortification of the site. The new Poseidon's temple is of Doric order and it is built of an extra white and fine marble extracted from a local quarry. The temple is peripteral hexastyle (i.e. with six columns in the narrow side) in plan, with thirteen columns on the flanks like Hephaisteion. Today only 16 columns are preserved "in situ". The stylobate of the old porous temple measured 30.20m by 13.06m while that of the new marble temple was a little greater and measured 31.12m by 13.47m. Olympia has been the Panhellenic center of genuine sport and athletic, and has been a symbol, an idea to which the aspirations of the ancient Greek world touched. Every four years a nationwide truce was announced and people

from all over Greece came to Olympia to attend and watch the Olympic Games. In this place are situated two important ancient temples: the temple of Zeus and the temple of Hera.



**Picture 2.** *The Poseidon's temple at the Cape Sounio*

Heraion (picture 3) was the first temple that was built in Olympia and is one of the most ancient temples of Greece and a major example of Greek monumental architecture. The name of ancient Olympia comes from this first sanctuary of "Olympia goddess" .Hera was the ancient female deity, Zeus' (Jupiter's) wife and patron of marriage, family and homemade hospitality. Heraion, believed to have been built in the seventh century BC by the inhabitants of Skillous, a city of Triphylia. The temple was built at the foot of the Cronius hill, in the Early Archaic period and was Doric order [Korosevis D., 2003]. Heraion is the oldest Greek temple in which all columns have been preserved and mainly all the orthostats.It was oblong, with 6x16 columns, built on a stone base which has length 50.01m and width 18.76m. Because the roof of the temple is demolished, its height is estimated to be around 7.5m.



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The front columns have a diameter ranging from 1.20 to 1.28m as the others have diameter between 1.00 and 1.24m. All columns are of Doric order, but there are differences at their capitals, ribbons and their proportions. The roof

of the temple was tiled. As it is referred previously the temple was dedicated to goddess Hera, but Zeus was worshiped with her for a while.

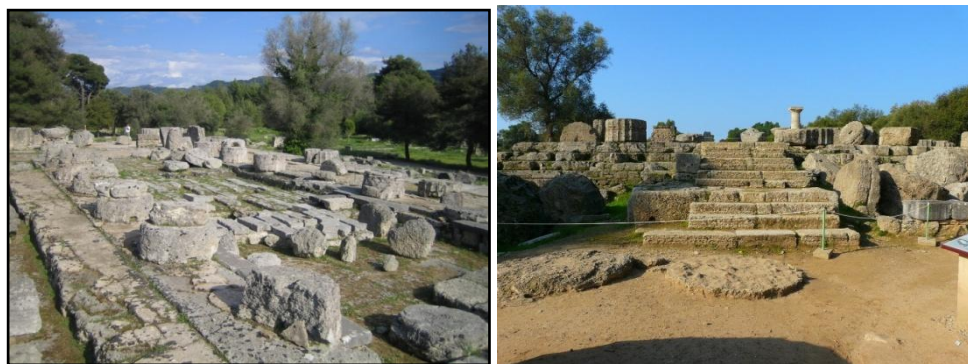


**Picture 3.** *The Hera's temple in Olympia*

The temple of Zeus (picture 4) was also the largest temple in the Peloponnese. It was Doric order and is considered the finest expression, the "canon", with length of 64.12m and width 27.68m and steps of stone leading to the eastern entrance (picture 4) of the temple. It is probably the first important monument of the original classical period and marks the transition from the Archaic period. It was built by local stone, with marble and exceptional decoration. The giant temple of Zeus, like most of the temples in ancient Greece (eg, Hera) was also oblong. On the side of the length there were 13 columns and of the corresponding width 6 columns. The height of the temple was approximately 16m. After the entrance, on the eastern side, there was the pronaos, as in the west there was the opisthodomos and in the

middle the lantern with bronze doors. The pediments and metopes of the temple were made of pure marble.

The altar or the sanctuary was the main part of the temple, 27.84m long and 8.35m wide, and brought two rows of seven columns on each side. The middle part of this three-dimensional sanctuary was divided into three spaces. The area near the entrance was accessible to the public. The second section was 10cm taller than the front and its surface was covered with black Eleusinian stone or white marble slabs. In the middle of this space, between the two rows of columns, there was an elevated pedestal. On the podium was a carved throne, made of gold and ivory, and decorated with many precious stones. On this throne was built the famous colossal golden ivory statue of Olympian Zeus!



**Picture 4.** *The Zeus's temple in Olympia*

The relative positions – places of the above mentioned monuments on the map of Greece is illustrated in Picture 5.

### Technical Process

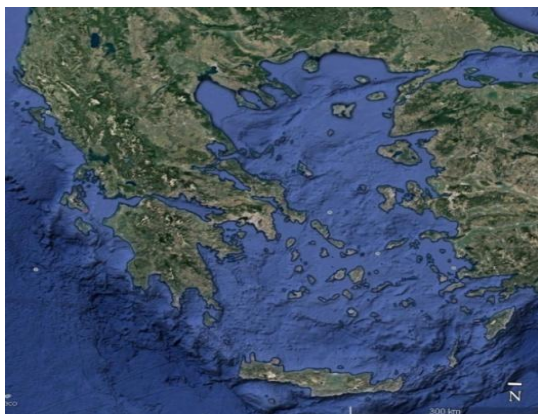
In order to investigate the orientation of these temples a reliable methodology was applied by

means of geodetic and astrogeodetic measurements which were carried out with adequate accuracy by using modern digital total stations. The methodology is applied according to the following steps:

- By modern geodetic methods using reflectorless total stations all the detail points

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of the monument are measured in an arbitrary local reference system.



**Picture 5.** The positions of temples on the Greece's map

- The accurate plan of the monument is drawn digitally.
- The orientation of the plan relative to the astronomical North is implemented. The astronomical orientation of the local reference system is based on astrogeodetic observations to *Polaris*.
- The main (longitudinal) axis of the temple is determined. The method of the least squares is used for the calculation of the best fitting line to selective characteristic points of the temple.
- The calculation of the astronomical azimuth of the main axis of the temple. As astronomical azimuth of an axis AB is defined the horizontal angle between the astronomical meridian plane which includes the point A and the vertical plane containing the true normal (vertical) of the point A and the point B. It is measured on the horizontal plane of a place, clockwise from the astronomical north (*Fig.1*).
- Measurement and drawing of the profile of the perceptible horizon, as it is seen from the monument's site. 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).
- Drawing the lines of the Sun's path, in different days and years, by using the digital planetarium SkyMap Pro (Marriot, 2004).

Shortly, the procedure requires the determination of the astronomical azimuth of one side of an established geodetic network by observations to *Polaris* star (*alpha* Ursae Minoris) with a digital total station. Actually, the astronomical azimuth can be determined through 50 sightings to *Polaris*, within 15 minutes, with an accuracy of  $\pm 0.5$  arcsec. [Pantazis 2002]

Moreover by using the exact monument plan, the main axis of the monument is determined. According to the present state of the monuments preservation, this procedure aims to the optimization of tracing the main axis and in this way to minimize the errors in the determination of its orientation. It becomes then clear that the resulting accurate data refer to our efforts for a better understanding of the orientation of an ancient monument.

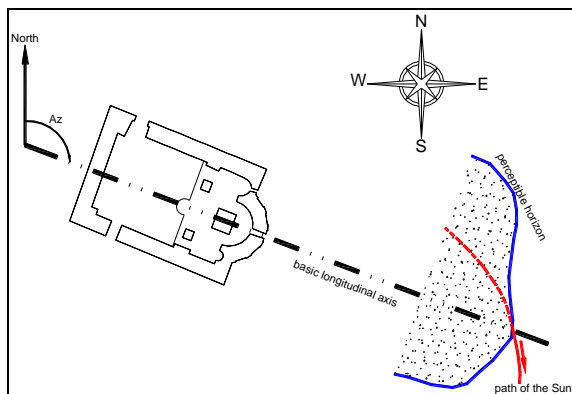
Under the condition that the monument has been oriented towards the Sun's rising or setting, it is feasible to calculate its possible date. For this reason also the drawing of the horizon's profile toward East may be created. The perceptible or conventional horizon extending in front of a monument usually plays a significant role for the investigation of the dating and the expedience 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.

According to the methodology the date of the foundation of a monument was determined by the exact intersection of three lines, namely, the main longitudinal axis of the monument, the profile of the perceptible horizon as it is seen from the monument and the path of the Sun (fig. 1).

In order to find the specific Sun's path which approximates better the point of intersection of the profile of the perceptible horizon and the azimuth line of the main axis of a monument, different lines of the Sun's path in different days and years were checked.

The uncertainty of the dating of each monument depends on the uncertainty of the astronomical azimuth of the main axis, the annual change of the diurnal path of the Sun in the year of the estimated date, the size of the monument, especially its length, and the number of points used for the determination of its main axis. Usually it is some arc minutes.

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**Figure 1:** Sketch of the methodology (Pantazis 2002)

### Geometric Results

The astronomical azimuths (Az) of the surveyed temples' main axes, the dating as well as their uncertainties are shown in Table 1. We should point out that the calculated foundation dates of these monuments are in agreement with both the related historical and archaeological evidence. Moreover it is obvious that the sun comes across the same astronomical azimuth at a place twice every year except the solstices dates. Thus both dates are referred on the table 1. Figure 2 illustrates the oriented plans of the temples and the dating diagrams.

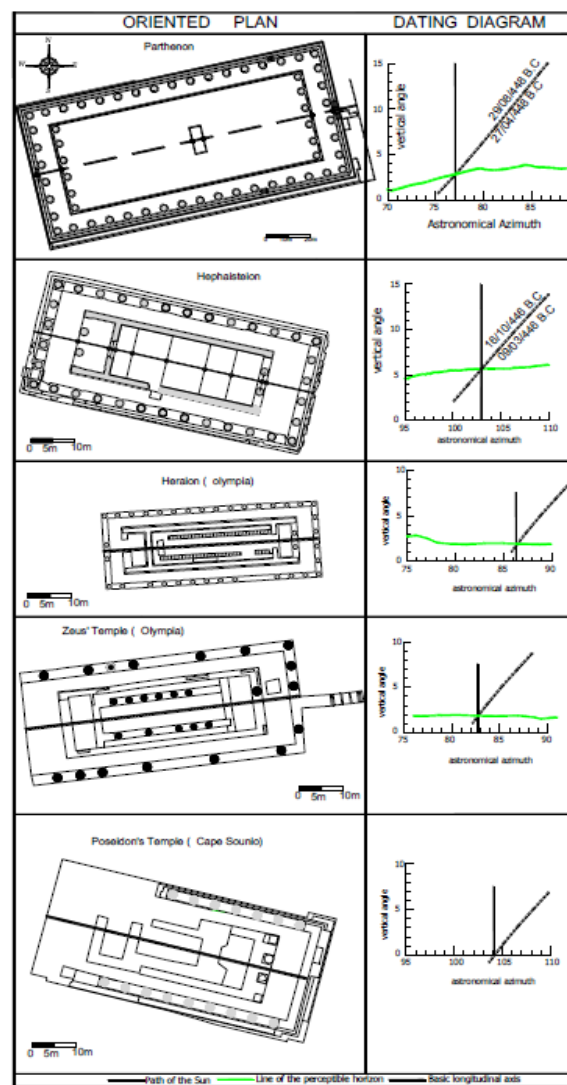
### Interesting Disclosures

Evaluating the results, it is noteworthy that the placing and the orientation of **Parthenon and Hephaisteion** are symmetrical (Figure 3) in relation to the east. The orientation of the main longitudinal axis of Parthenon is far from the east towards North  $12^{\circ} 53'$  ( $\approx 13^{\circ}$ ) the same as the Hephaisteion is far from the east towards south  $12^{\circ} 55'$ . Also they have the same angular distance ( $\approx 17^{\circ}$ ) from the summer and winter solstice accordingly.

**Table 1:** The astronomical azimuths and the dating of the monuments.

temple	Position		Main axis astronomical orientation Az	$\sigma_{Az}$	Dating Julian calendar	Uncertainty (years)
	Latitude $\phi$	Longitude $\lambda$				
Parthenon	$37^{\circ} 58' 18''$	$23^{\circ} 43' 39''$	$77^{\circ} 07'$	$\pm 1'$	August 29 <sup>th</sup> 448 BC & April 27 <sup>th</sup> 448 BC	$\pm 15$
Hephaisteion	$37^{\circ} 58' 32''$	$23^{\circ} 43' 18''$	$102^{\circ} 55'$	$\pm 1'$	October 16 <sup>th</sup> 446 BC & March 9 <sup>th</sup> 446 BC	$\pm 15$
Poseidon's	$37^{\circ} 39' 1''$	$24^{\circ} 01' 29''$	$104^{\circ} 12'$	$\pm 1'$	February 24 <sup>th</sup> 433 BC & October 28 <sup>th</sup> 433 BC	$\pm 14$
Zeus'	$37^{\circ} 38' 17''$	$21^{\circ} 37' 50''$	$82^{\circ} 44'$	$\pm 2'$	April 13 <sup>th</sup> 496 BC & September 13 <sup>th</sup> 496 BC	$\pm 29$
Heraion	$37^{\circ} 38' 20''$	$21^{\circ} 37' 48''$	$86^{\circ} 23'$	$\pm 1'$	April 6 <sup>th</sup> 621 BC & September 20 <sup>th</sup> 621 BC	$\pm 28$

Thus without taking into consideration the horizon's profile it is noticeable that the day that the sun rises at Parthenon's main axis



**Fig 2.** The oriented plans relative to the astronomical north and the dating diagrams

astronomical azimuth sets at Hephaisteion's main axis astronomical azimuth towards West and vice versa. Additionally it takes about 45

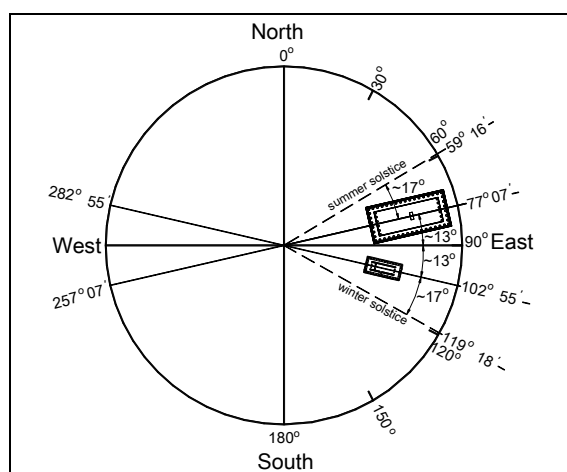


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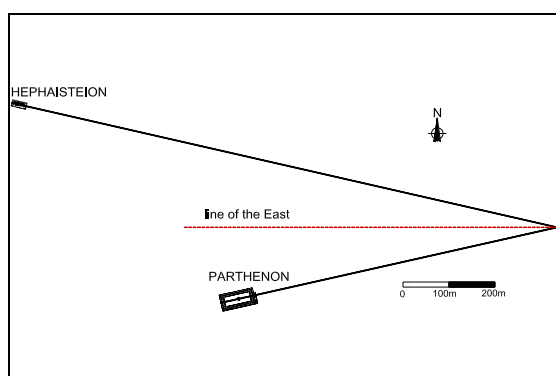
days for the sun to travel from Parthenon's main axis to Hephaisteion's main axis.

Moreover their axes (Figure 4) are intersected towards east at 1183m from Hephaisteion and 674m from Parthenon. The bisector of the angle that formed by the two temples axes is exactly the line of the east.

Also It is notable that the Hephaisteion orientation is towards the rise of the sun the day that *"The Chalkeia"* was celebrated on the ancient month "Pyanepsion" (October) according to the ancient Athenians' calendar. *"The Chalkeia"* was an Athenian's festival dedicated to the good Hephaestus and to Ergane Athena the goddess of labour.



**Figure 3.** The radiosymmetrical positioning of Parthenon and Hephaisteion



**Figure 4.** The relative position of both temples at the site and the line of the East

The Athenians were honoured god **Poseidon** on "poseideon" month (December). Apart from this month which was dedicated to Poseidon another significant festival was the "Athenian poseidia", which are took place on the ancient month "Pyanepsion" (October). The date on which the sun rises exactly on the orientation line of the temple October 28<sup>th</sup> is the day that the festival was started.

Moreover the Poseidon's temple faces South-east and its perceptible horizon is the level of the sea surface, so the perceptible horizon of the temple is throughout the Aegean Sea. Thus the most important remark is that the orientation of Poseidon's temple is towards Delos Island (fig. 5). As it is illustrated in figure 5, Delos is a tiny island, so special attention should be paid in order to succeed this specific orientation. Delos was the most famous and sacred of all Greek islands in antiquity. According to *Homeric Hymn to Apollo*, Goddess Leto, pregnant by Zeus, wandered in the Aegean Sea because of Hera's rage, the Zeus's wife. Only a small and "invisible" (a-delos) rock floating around the Aegean Sea dared to offer its ground to Leto to give birth. When Zeus anchored the floating rock to the sea floor, the rock became "visible" (delos), the Delos island! Leto gave birth first to Artemis and next day to Apollo. The cult of Apollo was established there in very early times and by about the 9<sup>th</sup> century BC Delos was already considered the birthplace of Apollo and his Sanctuary had been built. Apollo's sacred island, Delos, was the most famous religious center in the ancient era, as now is an extended archaeological site which contains important monuments dating from prehistoric to Hellenistic times. It is included in the UNESCO's world heritage list of monuments from 1990 (<http://whc.unesco.org/en/list/404>)



**Figure 5.** The orientation of Poseidon's temple towards Delos Island

**Hera's and Zeus' temples** face north – east and situated very close to each other in 106m distance. Twice every year, two significant festivals were be celebrated *the "Heraia"*, which took place on the ancient month Boedromion (September) and *the "Olympia"* which took place on the ancient month Mounychion (April). These festivals last about a week each one including several ceremonies, celebrations and athletic games.

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It is remarkable that the two main axes of Zeus and Hera temples are intersected at a distance of 1500 m, slightly ahead the little hill which presents the horizon towards the east (figure 6), behind which the Sun rises in order to light the temples.

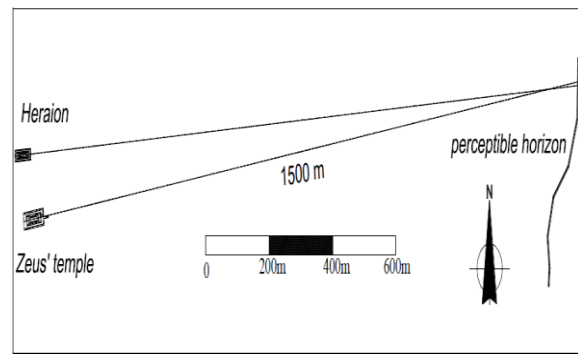
Zeus' temple is turned  $3^{\circ} 39'$  namely  $219'$  in order the two axes to be coincided just before the horizon and the Sun to be rise on each temple main axis azimuth with in 7 days time interval as the duration of the local festivals. The daily change of the sun's rising azimuth at the same place is about  $30'$ . Thus the orientation dates April 6<sup>th</sup> and 13<sup>th</sup> and September 13<sup>th</sup> and 20<sup>th</sup> obviously delimit the duration of these festivals. Thus the festival "Olympia" started on April 6<sup>th</sup> when the sun rises on the Heraion axis and ends on April 13<sup>th</sup> when the sun rises on Zeus' axis as the festival 'Heraia', started on September 13<sup>th</sup> when the sun rises on Zeus' axis and ends on September 20<sup>th</sup> when the sun rises on Heraion axis.

Additionally, as it is resulted by the survey, it is considerable that both are located exactly at height of 35.00m above the mean sea level. As the Hera's temple was firstly constructed the Zeus temple is elevated in order to reach the same height. For these reason ten steps of stone were constructed which are lead to the eastern entrance of the temple (picture 4)

Concluding the temples are located very close to each other at the same height (level), so the sun lights both the same time of the day (sunrise above the horizon) by the same way, as their elevation angles towards the horizon are identical.

Based on the above accurate measured elements it is confirmed that the specific orientation and the equal- leveling location of both temples on the site, was not incidentally but it was serve the ancient Greeks desire to indicate their common celebration.

Therefore, the synthesis of geodetic and astrogeodetic data, which are measured by using modern digital total stations, allow for the determination of the orientation of monuments with high precision and reliability. Combining the above geometric data with historical data referring to the time of construction, the final interpretation of the orientation of a monument may be achieved. It is obvious that so significant temples, they can only have determinate orientation.



**Figure 6.** The relative position of Hera and Zeus' Temple

Consequently the modern applied geodetic methodology proves the relation of ancient Greek temples' geometric characteristics, namely their orientation and placement, with their celebration ceremonies and adjacent monuments.

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