



THE ORIENTATION OF DELOS' MONUMENTS

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Received: 22/3/2008

Accepted: 7/8/2008

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ABSTRACT

Apollo's sacred island, Delos, is an extended archaeological site, which contains important monuments dating from prehistoric to Hellenistic times. In this article the orientation of some of the most significant monuments of the site are studied.

Each monument has been measured by means of modern accurate geodetic and astrogeodetic methods and instrumentation so that its plan, its main (longitudinal) axis, the profile of the perceptible horizon as seen from the monument and the astronomical azimuth of the main axis are determined.

Special attention and study have been reserved to the Cave of Kynthos (Andron), as the latter was considered as an ancient observatory.

This study attempts also a possible dating of the measured monuments based on their orientation and its relation to special celestial bodies.

All data deduced by measurements and calculations, as well as historical information have been used for the creation of a database in Macromedia software.

KEYWORDS: Geometric documentation, astrogeodetic observations, azimuth, Dating, data base, Delos monuments.

HISTORICAL INTRODUCTION

Delos was the most famous and sacred of all Greek islands in antiquity (Fig.1). 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. Remains of a prehistoric (probably Minoan) settlement, dating in the 3rd millennium BC, were found on the summit of Kynthos mountain. In the late 15th century BC, the Myceneans settled in the

valley by the sea. The cult of Apollo was established there in very early times and by about the 9th century BC Delos was already considered the birthplace of Apollo and his Sanctuary had been built. The earlier Propylaea of the Sanctuary, as well as the Oikos of the Naxians, were built by the Naxians (Pic. 1). The earlier building, the "Pro-Oikos", considered as the earliest temple of Apollo, is dated back to the 7th century BC or earlier. In the second half of the 7th century the Oikos of the Naxians took its final form; its foundation was of large granite blocks and its main entrance was on its east side. The saved building dates in the 575 BC and has another entrance in the west side, which became its main entrance.

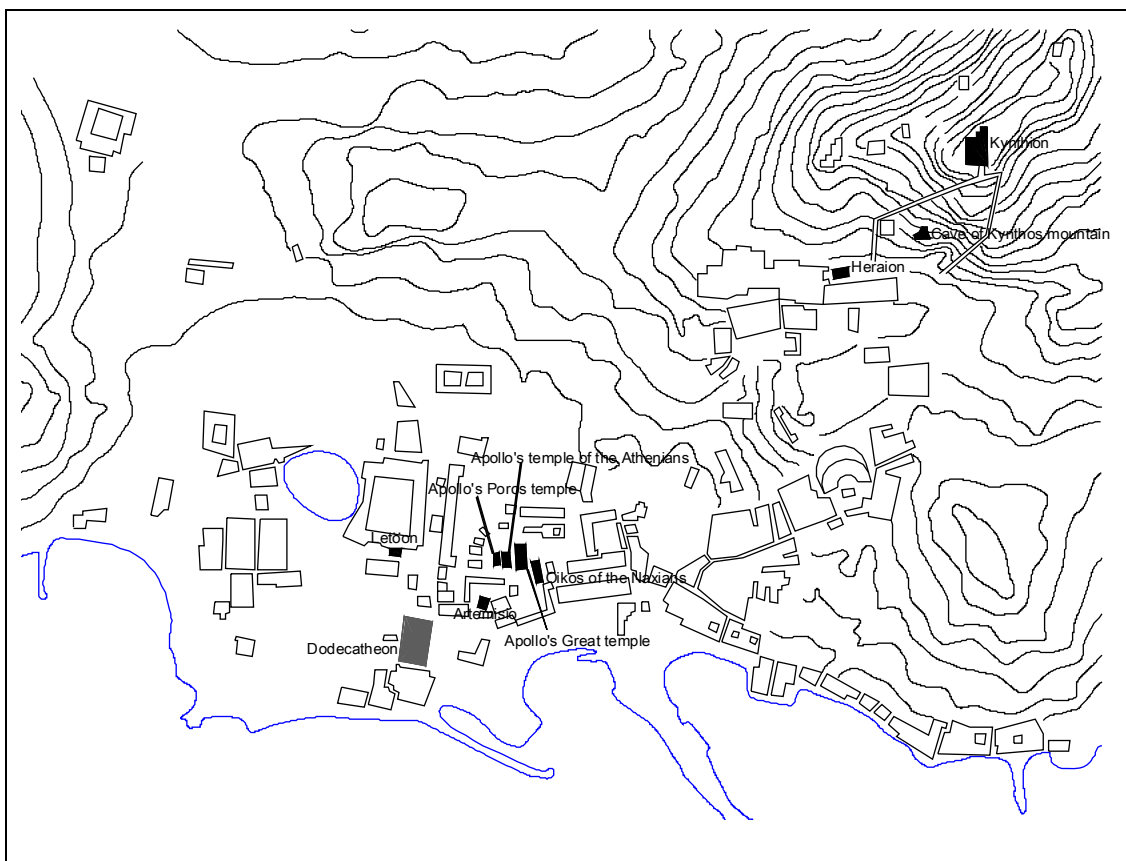


Figure 1. The archaeological site of Delos Island.



Picture 1. The Oikos of the Naxians.

Immediately after the Oikos of the Naxians, the three temples of Apollo are located, one next to the other. All three temples have their entrance on the west side. The oldest among them is the Poros Temple built during the rulership of Peisistratos, tyrant of Athens in 540-528 BC (Pic. 2).



Picture 2. The Poros Temple and the Apollo's temple of the Athenians.

Two years later, in 476 BC, the construction of the second temple of Apollo, the Great Temple, in Doric order began. It is the only peripteral temple on Delos, the construction of which was interrupted in 454 BC, when the League's funds had been transferred to Athens, and went on again during the Independence (314-166 BC), but the temple was never completed (Pic. 3). Finally, in 425-420 BC the Athenians built the third temple of Apollo, sending white Pentelic

marble for its construction. It was an amphiprostyle Doric temple, with six columns on each narrow side and thirteen on each of the long ones. The Temple of the Athenians has been inaugurated very probably in 417 BC by Nikias.



Picture 3. The Apollo's Great temple.

In the same area other sanctuaries are the following; The Artemision, a sanctuary sacred to Artemis, Apollo's sister, has been built during the Independence on much earlier remains; inside the cella are clearly seen a rectangular structure, dating in the early 7th (or late 8th) century BC, and parts of a much longer Mycenaean building. Large granite blocks are still visible in its foundation. The entrance of this prostyle temple is faced towards east and it had a portico with six Ionian columns (Pic. 4).



Picture 4. The Artemision

The Dodecatheon contained altars of the twelve gods, whose archaic statues are dated to 500 BC. It was a small Doric amphiprostyle temple dating in the early 3rd century BC. The Letöon is a temple being dated in the 6th century BC (Pic. 5,6).



Picture 5. The Dodecatheon.



Picture 6. The Letöon.

Far up the hill the later Heraion, is a Doric temple being dated in circa 500 BC, which has been built upon an older temple being dated in the 7th century BC. A marble altar is located south of the temple (Pic. 7).



Picture 7. The Heraion.

On the way towards the summit of the Kynthos mountain, the Antron (Cave), regarded as the most ancient temple of Apollo, is formed in a natural cavity in the rock, roofed by enormous granite slabs and closed in front by a wall. In the center of its interior there is the granite pedestal of Heracles's Hellenistic statue and a table of offerings in front of it. In the outside court there are two tables and a cylindrical altar. On the summit of Kynthos mountain, there is the sanctuary of Zeus Kynthios and Athena Kynthia. Evidence of the cult of Zeus being dated in the 6th century BC, but that of Athena was later introduced (Pic. 8).



Picture 8. The sanctuary of Zeus Kynthios and Athena Kynthia.

TECHNICAL INTRODUCTION

To investigate the orientation of the monuments geodetic and astrogeodetic measurements were carried out with adequate accuracy by means of modern digital total stations. The geodetic methodology, developed for this purpose and used for the study of several monuments with reliable results, has been applied for the determination of the accurate astronomical orientation of ten significant monuments in the archaeological site on Delos Island.

The application of this modern accurate astrogeodetic method in the determination of the main axis of a monument, as far as it is possible according to its present state of preservation, aims to the optimization of the tracing the main axis and in this way to minimize the errors in the measurements of its orientation, and consequently of that of the monument. It becomes then clear that the so resulting accurate data refer to our efforts for a better understanding of the orientation of an ancient monument and not to any attempt to estimate and criticize the accuracy of the orientation of the monument planned or achieved by its architect and builders.

The method for the determination of the accurate astronomical orientation of a monument is based both on precise measurements and calculations, so that the exact plan of the monument is created, and on astrogeodetic observations to the star *Polaris* (*alpha* Ursae Minoris), so that the astronomical orientation of the monument is precisely calculated (Pantazis 2002). Shortly, this method requires the determination of the astronomical azimuth of one side of the polygonometric network, a work done through observations of the *Polaris* with a digital total station. Actually, through 50 sightings of *Polaris* made in 15 minutes the astronomical azimuth of one side of the polygonometric network has been determined with an accuracy of ± 0.5 arcsec, which is much higher than any other achieved by using classical methods with poles and compass.

Under the condition that these monuments have been oriented towards the Sun (rising or setting), we are able to calculate their possible date. For this reason the profile of the perceptible horizon, as it is seen from the monument

should be measured very accurately, so that the accurate drawing of it may be created. Moreover, the investigation is extended to other fixed stars, whose path could intersect the main (longitudinal) axis of the monument in the specific point on characteristic dates of the year.

In this investigation the following temples are included:

- The three temples of Apollo
- The Artemision (temple sacred to Artemis)
- The Letöon (temple sacred to Leto)
- The Dodecatheon (temple sacred to the twelve gods)
- The Heraion (temple sacred to Hera)
- The Oikos of the Naxians
- The Kynthion (temple on the top of Kynthos mountain)
- The Cave of Kynthos mountain

THE ORIENTATION OF THE MONUMENTS

The astronomical orientation of each one of the monuments was determined according to the following steps:

- The drawing of the accurate plan of the monument. We used modern geodetic methods in order to measure it and draw it digitally in an arbitrary local reference system. Figure 2 illustrates the plans of the monuments. The orientation of the plan relative to the astronomical North. The orientation of the local reference system was based on astrogeodetic observations to *Polaris*.
- The determination of the main (longitudinal) axis of the monument. The method of the least squares is used for the determination of the best fitting line to selective characteristic points of the monument.

- The calculation of the astronomical azimuth of the main axis of the monument.

The astronomical azimuths (Az) of the surveyed monuments as well as their uncertainties are shown in Table 1, while Figure 3 illustrates the same values on a circular (mathematical) horizon.

The differences observed in the determined uncertainties regarding the main axis of the monuments are due to two very important factors:

- a) the size of the monument, especially its length, and
- b) the number of points used for the determination of its main axis.

The reason becomes obvious: the greater is the length of a monument, the

greater also is the number of points used in the measurements and consequently, the greater is the accuracy achieved in the tracing of the line of its main axis.

In Table 1 there are also given the orientations of these monuments according to the old measurements and calculations of H. Nissen (Nissen 1907) and to the recent ones of M. Papathanassiou – Z. Papadopoulou (M.P.) (Papathanassiou - Papadopoulou 1997), who have used the simple classical method of poles, compass and altimeter for their measurements. According to M. Papathanassiou the accuracy of their observations is between $\pm 1/4$ and $\pm 1/2$ of the degree.

Monument	Az (°')	σ_{Az} (')	Az (°') by Nissen	Az (°') by M.P
<i>Apollo's Great temple</i>	83°20'	$\pm 3'$	84°45'	83°
<i>Apollo's Poros temple</i>	83°35'	$\pm 6'$		83°
<i>Apollo's temple of the Athenians</i>	83°18'	$\pm 3'$		83°30'
<i>Dodecatheon</i>	97°02'	$\pm 3'$		97°
<i>Artemision</i>	107°14'	$\pm 10'$		106°
<i>Heraion</i>	351°28'	$\pm 3'$		352°
<i>Letöon</i>	5°25'	$\pm 5'$	4°45'	5°
<i>Oikos of the Naxians</i>	77°11'	$\pm 2'$		77°30'
<i>Kynthion (South wall)</i>	102°50'	$\pm 3'$	102°30'	-
<i>Kynthion (South-East wall)</i>	92°12'	$\pm 8'$		91°
<i>Cave of Kynthos mountain</i>	97°55'	$\pm 8'$		99°

Table 1: The astronomical azimuths of the ten monuments.

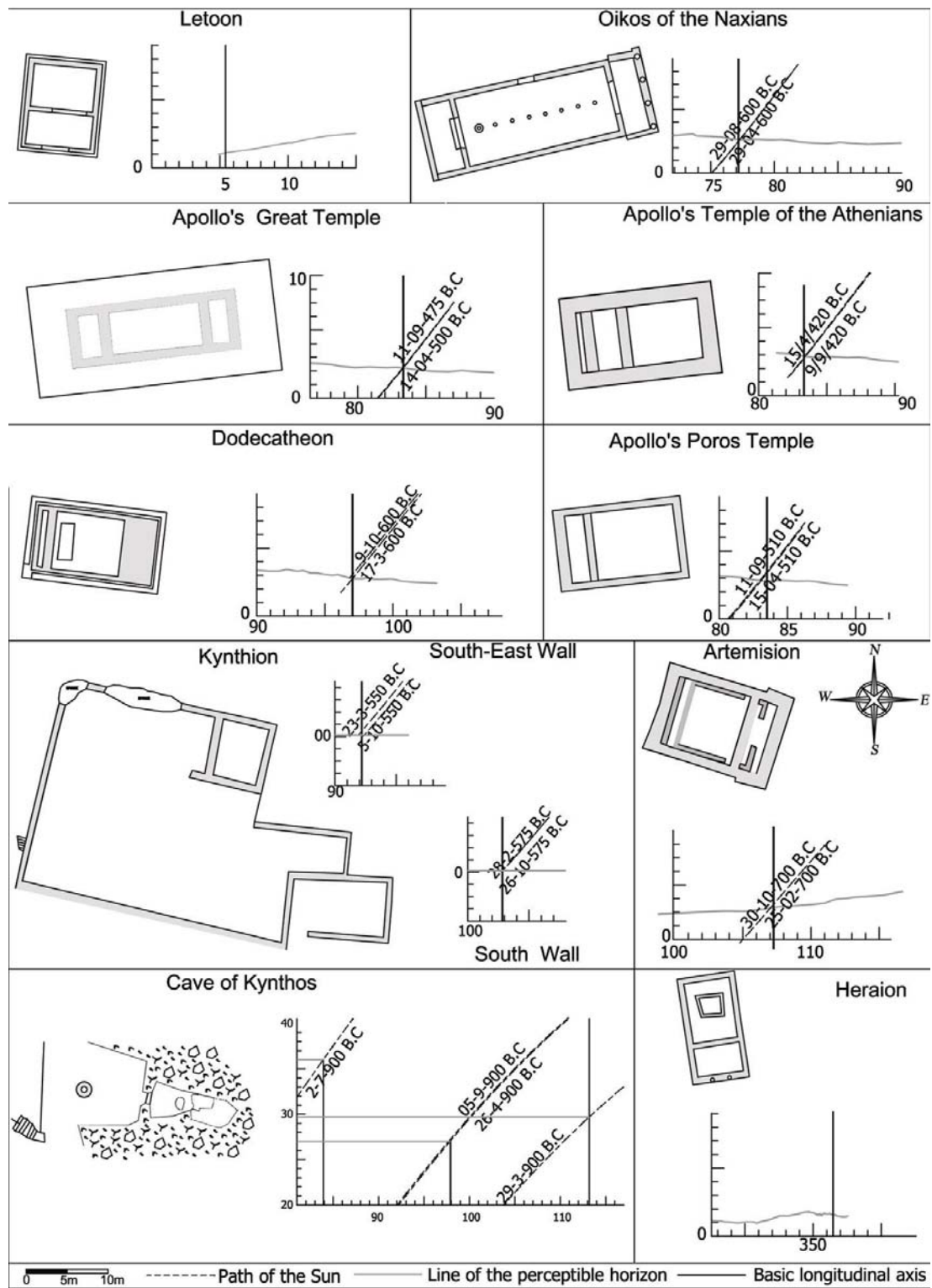


Fig.2: The oriented plans relative to the astronomical north and the dating diagrams.

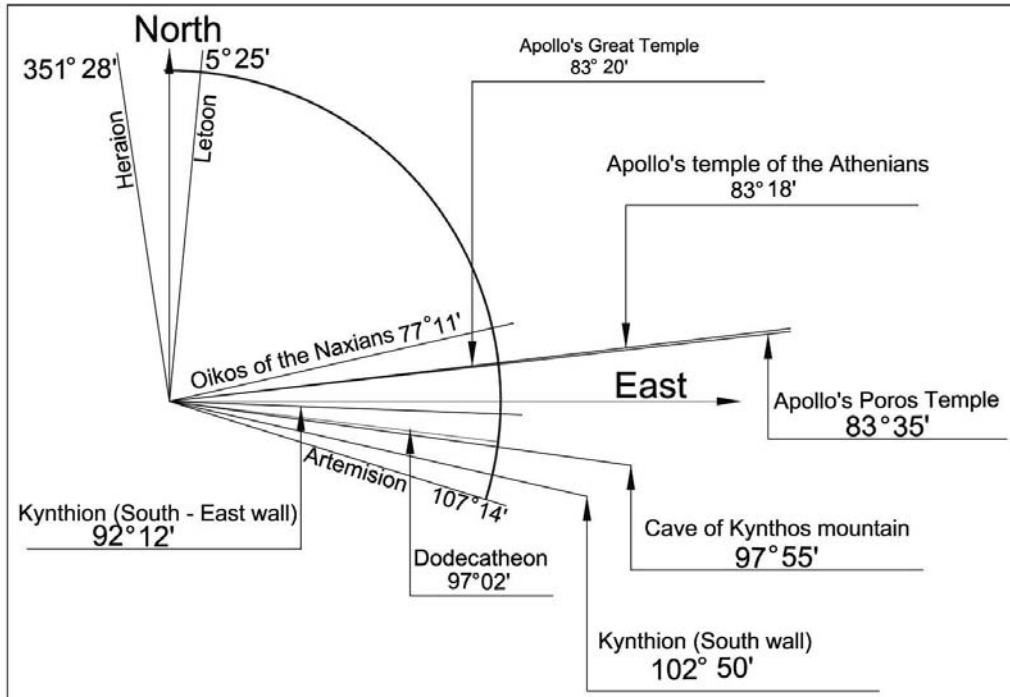


Fig. 3: The astronomical azimuths of the ten monuments.

THE DATING OF THE MONUMENTS

The exact date of the monuments was determined according to our methodology which is based on the exact drawing of three lines for each one of them. The date of the foundation of the monument is given by the point of intersection of these 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. 4).

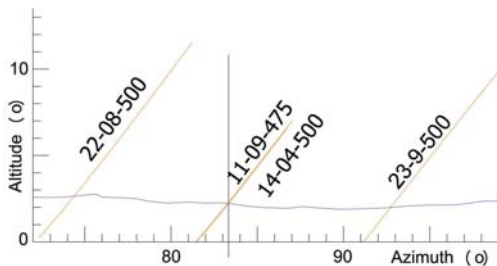


Fig. 4: The dating of the Apollo Great Temple

In order to find the Sun's path the most approximate to the point of intersection of the profile of the perceptible horizon and the line of azimuth of the main axis of a monument, we checked different lines of the Sun's path in different days and years. Figure 4 illustrates the example in the case of the Apollo's Great Temple.

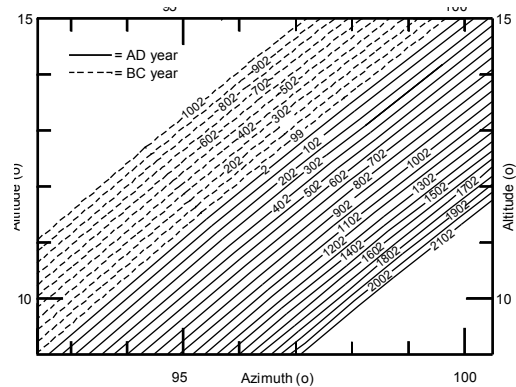


Fig. 5: The change of the apparent path of the Sun through the centuries.

Two symmetric dates have been found for each monument. Table 2 illus-

trates the results. Figure 5 displays the progressive change of the apparent path of the Sun through the last thirty centuries, namely, from the 1000 BC to 2100 AD, based on made by the digital planetarium Skymap Pro Version 8 (Marriot 2001). The uncertainty of the dating of each temple it is calculated according to the formula:

$$\text{Date uncertainty} = \pm \sigma_{Az} / d_{Sun} \text{ where:}$$

- σ_{Az} is the uncertainty of the astronomical azimuth of the main axis (table 1).
- d_{Sun} is the annual change of the diurnal path of the Sun in the year of the estimated date (the uncertainty on their estimated "dates of foundation" depend also on the errors made by the builders in aligning the monuments, and that such errors are, of course, unknown).

Monument	1 st date	2 nd date	Uncertainty (years)
<i>Apollo's Great temple</i>	14/04/500 BC	11/09/475 BC	± 21
<i>Apollo's Poros temple</i>	15/04/510 BC	11/09/510 BC	± 38
<i>Apollo's temple of the Athenians</i>	15/04/420 BC	09/09/420 BC	± 20
<i>Dodecatheon</i>	09/10/600 BC	17/03/600 BC	± 17
<i>Artemision</i>	25/02/700 BC	30/10/700 BC	± 72
<i>Oikos of the Naxians</i>	29/08/600 BC	29/04/600 BC	± 13
<i>Cave of Kynthos mountain</i>	26/04/900 BC	05/09/900 BC	± 55
<i>Kynthion (South wall)</i>	26/10/575 BC	28/02/575 BC	± 22
<i>Kynthion (South- East wall)</i>	05/10/550 BC	23/03/550 BC	± 47

Table 2: The dates of the monuments

We should point out that the calculated foundation dates of these monuments are in agreement with both the related historical and archaeological evidence.

The temples of the Heraion and the Letöon can't be dated by using the Sun path as their main axis is oriented towards the North.

THE CAVE OF KYNTHOS MOUNTAIN

Special reference should be done to the Cave of the Kynthos mountain. It is the only cave in the island, formed in a natural cavity of the ground. Its strange construction and its orientation are unique. Some scholars identified it with the "cave of the Sun" mentioned by Homer, while others were of the opinion

that this cave has been used "for the observation of the sky".

The front of the cave is closed by a wall having an entrance (Pic. 9) the height of which is about 4.25m. In the center of its interior there is the pedestal of Heracles statue and in the outside court there is a cylindrical altar.



Picture 9. The entrance of the cave.

The cave is roofed by enormous granite slabs which form a gap (picture 10) permitting to the sunrays to pass through during some hours in special days during the year.



Picture 10. The profile of the gap projected to the sky as it is seen from the interior of the cave.

For a better study of the construction of the cave we have drawn both its plan (Figure 6) and its West-East longitudinal section (Figure 7). The main axis of the cave is defined by the line passing through the center of the altar outside the cave and that of the pedestal of the statue in the middle of its interior.

The calculated astronomical azimuth of the main axis of the cave is $97^{\circ} 55' \pm 8'$. The results of our research for a possible orientation related to the annual path of the sun are as follows:

- The sunrays crossed the main axis of the cave through the gap on the roof in the two equinoxes, namely in 26/4/900 BC (vernal equinox) and in 5/9/900 BC (fall equinox).
- The Sun was visible from the place of the statue during three hours per day from the spring equinox to the summer solstice and also at its return to the autumn equinox, namely during six months.

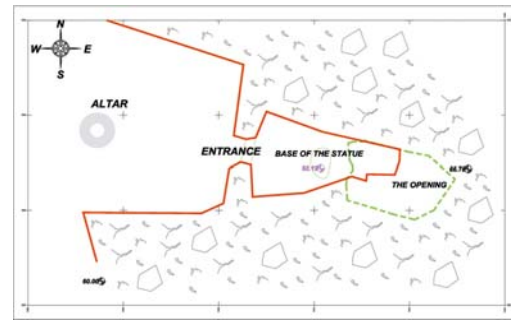


Figure 6: The plan of the cave.

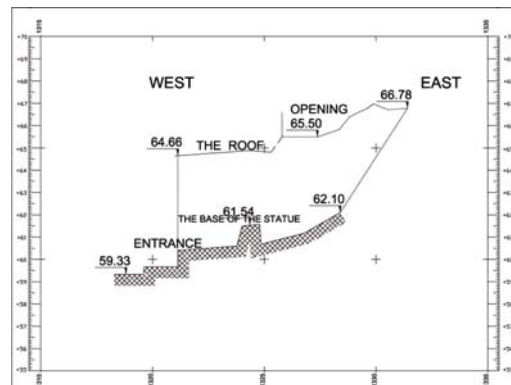


Figure 7: The longitudinal section of the cave.

INVESTIGATION RELATIVE TO THE FIXED STARS

We should point out that we have checked especially two constellations which mythology and tradition have closely related to Delos island, namely the cluster of Pleiades in Taurus and the Orion.

Although a possible explanation based on a stellar orientation seems not convincing because of the lack of any historical or archaeological evidence, there are some very important relations between Orion and Apollo in Greek mythology; Orion, «*the tallest and most beautiful of men*», was a huge and brave hunter who felt in love to Eos (namely, the Dawn), Pleione (η Tauri), the hyperborean virgin Opis and other maiden. He actually was an old solar deity of the region of the Aegean who did not survive Apollo's new cult. He was killed

either by Artemis's arrows in the island of Ortygia (Homer, *Odyssey*, V 123) or by a scorpion's sting and then he became a constellation in the sky (Aratos, *Phaenomena*, 635). It is well known that whenever a new deity rivals an older one to impose his cult, the new cult incorporates in itself many rituals and traditions of the old one. Usually both old and new deities are identified or they silently share the same cult. Consequently, the orientation of Apollo's Great temple towards *delta* Orionis, one out of three stars of Orion's belt (*delta*, *epsilon* and *zeta* Orionis), seems to be an indication of a strong link between the two solar deities of the island. Taking into account also that both Apollo and Artemis were archers and killed with their arrows their rivals and enemies, it seems very likely that the three stars of Orion's belt were linked with the sacred triad of Delos, namely, Apollo, Artemis and Leto.

On the other hand, Aries (the ram) played a very important role in temple orientation, as from about the middle of the second millennium BC until about the third century AD, he was the constellation of the vernal equinox. According to F.C. Penrose, at least eight Greek temples at various places and dates ranging from 1580 to 360 BC were oriented to the star *alpha* Arietis; those of Zeus and his daughter Athena being especially thus favored, as Aries is the symbol of Zeus in the sky. Therefore no wonder that the Kynthion, sacred to Zeus and Athena, has been oriented to Aries. We should also point out that the axis of Oikos of the Naxians is oriented towards the rising Sun in 29/04/600 BC, very likely indicating the beginning of spring.

The star *beta* of the Little Bear (β Ursae Minoris) might have been considered

by the Greeks as the pole-star, for it was near the north celestial pole about 1000 BC.

So our search included the following prominent stars: α of Pleiades; γ , δ , ϵ and ζ of Orion; α , β and γ of the South Cross; α and β of Libra; α of Leo, α of Virgo; α of Dragon; β of the Little Bear (Ursa Minor). The results of this search are shown in Table 3.

Star	Monument	Hour	Date
δ Orionis	Apollo's Great temple	Setting 21 ^h 24 ^m 22 ^{sec}	14/4/500 BC
α Arietis	Oikos of the Naxians	Rising 4 ^h 35 ^m 50 ^{sec}	29/4/600 BC
α Arietis	Kynthion	Setting 5 ^h 53 ^m 4 ^{sec}	26/10/575 BC
β Ursae Minoris	Letöon	Rising	26/10/575 BC

Table 3: Possible orientation towards prominent fixed stars.

THE DATABASE

A data base had been created, so that any visitor can easily acquire all necessary information regarding these monuments (Picture 11).



Picture 11. The first page of the data base.

The data base created in Macromedia software is easily accessible by any user. As the file has an executable extension (.exe), the user does not need any special software in order to open and run this

file in any pc. As the total size of the file is 70Mb, the data base is accessible and it can be widely used.

More analytically the pages of the data base are as follows:

- About Delos. In this page there are given geographic, mythological and historical information regarding the island, the archaeological site and the excavations. This page also includes the final conclusions regarding the astronomical orientation of the monuments (Picture 12).



Picture 12. The page "About Delos."

There follows a series of pages referring to each one of the monuments (Picture 13).

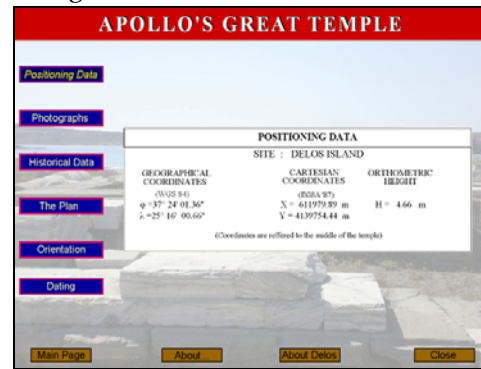


Picture 13. The initial page referred to a monument.

- Positioning. Here, the coordinates of a selected point of the monument in the World geodetic reference system (WGS 84) and in the Hellenic geodetic reference system (GGRS 87) as well as its height above the mean sea

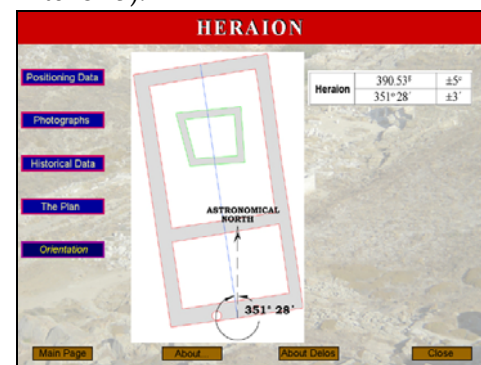
level have been registered (Picture 14).

- Photographs. All photographic material displayed here for the documentation of the monument is taken during the measurements "in situ".
- Historical data. This page refers shortly to the most significant historical data related to the monument with an emphasis to its date according to other sources.



Picture 14. The positioning page.

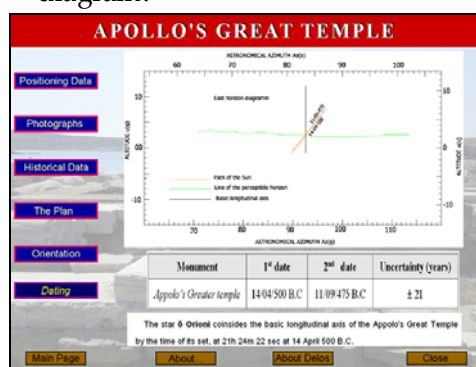
- The plan. This page displays the accurate digital plan of the monument, measured by means of modern geodetic instruments (total station) and oriented in relation to the astronomical North.
- Orientation. This page gives the astronomical azimuth of the main longitudinal axis of the monument and the uncertainty of its calculation (Picture 15).



Picture 15. The orientation page

- *Dating*. Here the following are given:
- a) the foundation date of the monument under the presupposition that it has been oriented according to the apparent path of the Sun, as it is seen from the monument.
- b) the diagram of the profile of the perceptible horizon in which there are also shown the following lines:
 - The main longitudinal axis of the monument with the corresponding figure of its astronomical azimuth.
 - The apparent path of the Sun at the specific date of its foundation.

So it is clearly seen the point of intersection of these three lines on the diagram.



Picture 16. The page referred to the dating.

The same page includes also the uncertainty of the calculation of the year of the foundation of the monument according to the applied meth-

odology and the results of the search for a possible relation between the orientation of the monument and the rising or setting of some prominent fixed stars (Picture 16).

CONCLUSIONS - REMARKS

- The geodetic methodology used in the search of a monument's orientation has been proved both as very accurate and easy in its application.
- The time needed for the detailed investigation of a monument, including measurements and the elaboration of the data, covers one day of fieldwork and two days of calculations.
- By using the geodetic methodology we can calculate the coordinates x , y , z of each measured point of the monument. Then, based on them, any horizontal plan or longitudinal section of the monument can be drawn in order to facilitate the further research and have a better documentation of the monument.
- This data base is very useful both for the registration and the spreading of the results of the project.
- The choice of its software makes the data base easily accessible to any visitor who is interested in it.

ACKNOWLEDGEMENTS

The authors express their many thanks to the Hellenic Ministry of Culture, sponsor of this project.

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