

INVESTIGATING THE ORIENTATION OF ELEVEN MOSQUES IN GREECE

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Abstract: This paper investigates the orientation of eleven mosques situated in several regions of Greece. The aim of this work is to verify whether and how accurately the monuments have been constructed according to the Muslim tradition. As geodetic and astrogeodetic methods are used, the geometric documentation of each monument is carried out and its astronomical orientation is determined. The qibla for each monument is calculated by using geodetic equations. The mosques' main axis azimuths are determined by a precision of some arc minutes. Also, their orientation, relative to the Canopus star (Alpha Carinae)—which the tradition has closely related to Kaabah in Mecca—is examined. All the mosques seem to follow the religious rule.

Key words: geometric documentation, astrogeodetic observations, astronomical azimuth, mosque, Qiblah, Kaabah.

1 INTRODUCTION

Muslim tradition defines the orientation of the sacred buildings of Islam named mosques. Religious rulings require that Muslims must face Mecca during prayers. They must pray towards the Kaabah, the home of the holy black stone, in Mecca. The holy direction is named qibla. The qibla is the direction towards the Kaabah in Mecca, the sacred place of Islam. "The qibla is the direction that a human observer faces the Kaabah in Mecca." (Abdali, 1997).

The definition of qibla is the line of sight to a vertical line passing through the Kaabah. For example it is the direction in which an imaginary tower built over the Kaabah would appear or the line of sight of any observer on Earth who could see this tower. Many books, papers and studies had been carried out on this subject.

From the first Islamic centuries many astronomers and other scientists were occupied in computing this direction from many different places in the world. The fourteenth century astronomer Al Khalili produced a table where the qibla direction was calculated for any latitude between 10° and 56° North and longitudes between 10° and 60° East.

The most commonly-used methods for calculating the qibla direction are:

- Basic spherical trigonometrical formulae;
- Stellar observation; and
- Recording the solar shadow.

Depending upon whether the place in question was situated relatively east, west, north or south of Mecca, one of the eight cardinal directions of north, northeast, east, southeast, south, southwest, west and northwest was adopted for the qibla.

In the early ages of Islam, the qibla was also defined as the direction towards Jerusalem, where the Dome of the Rock, the other sacred Muslim place, is situated.

Over the centuries, different countries adopted different directions for the orientation of their mosques, as they calculate the qibla direction in different ways (see Saifullah et al., 2001).

The Kaabah itself has a specific orientation. The direction of its northeastern wall is almost perpendicular to the direction of the sunrise at the summer

solstice, as its southeastern wall face towards the rising point of Canopus (Alpha Carinae) on the horizon of Mecca (Figure 1). So it is interesting to investigate the orientation of mosques in different countries.

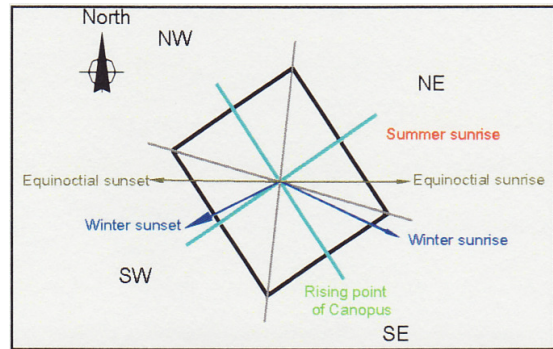


Figure 1: The orientation of the Kaabah (after Saifullah et al, 2001).

The architectural construction of a mosque follows some basic rules. The main parts of a mosque are shown in Figure 2 and comprise:

- The main hall of the temple for praying, which is called the 'haram';
- The altar, which is called 'mihrab';
- The 'imber', which is a pulpit for the preaching;
- The minaret; and
- An open air hall which is called the 'sahm'.

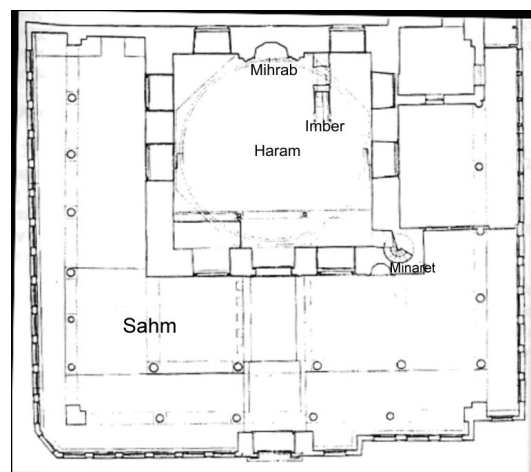


Figure 2: The main parts of a mosque.

In this paper, eleven mosques that were built in Greece between the fifteenth and nineteenth centuries are studied. They comprise

- The four remaining mosques in Ioannina (Epirus) (of the twelve that were originally built);
- Three mosques on the island of Chios;
- The Kursum mosque in Trikala town (in Thessalia, Central Greece);
- Two mosques in Nafplion town (Peloponnesus);
- A mosque in Argos town (Peloponnesus).

Their locations are shown in Figure 3.

2 HISTORICAL DATA

The Veli Pasha mosque (Figure 4) is a simple small construction. It was founded in the early seventeenth century at Ioannina. Its main hall is about $6\text{m} \times 5\text{m}$. The interior has a remarkable decoration of marble. Today the building is well conserved. It has an impressive octagonal dome but its minaret has not been preserved.

The Kaloutsiani mosque dates to the late fifteenth century, or to the second half of the seventeenth century according to different sources. It is maintained with its minaret (20.36m height) and its quadrangular main hall which is about $11.5\text{m} \times 11.5\text{m}$. The exterior of the mosque has been converted to shops (see Figure 5).

On the southeastern side of 'Its Kale' castle in Ioannina is the Fetiye mosque (Figure 6). It was constructed in 1597 or 1618 on the ruins of a Christian church that was dedicated to the archangel Michael. Its minaret is 20.8m high and its main hall is about $10\text{m} \times 10\text{m}$. It is a well-preserved monument.

The Aslan Pasha mosque (Figure 7) dates to 1600-1620 and is situated on the northwestern side of the Castle. It is an exceptional architecture monument. Its main hall is about $10\text{m} \times 10\text{m}$ and 13m in height. Its dome contains remarkable works of art. Its minaret is 26.4m high and has one hundred steps leading from the ground floor to the top. Today it is used as museum.

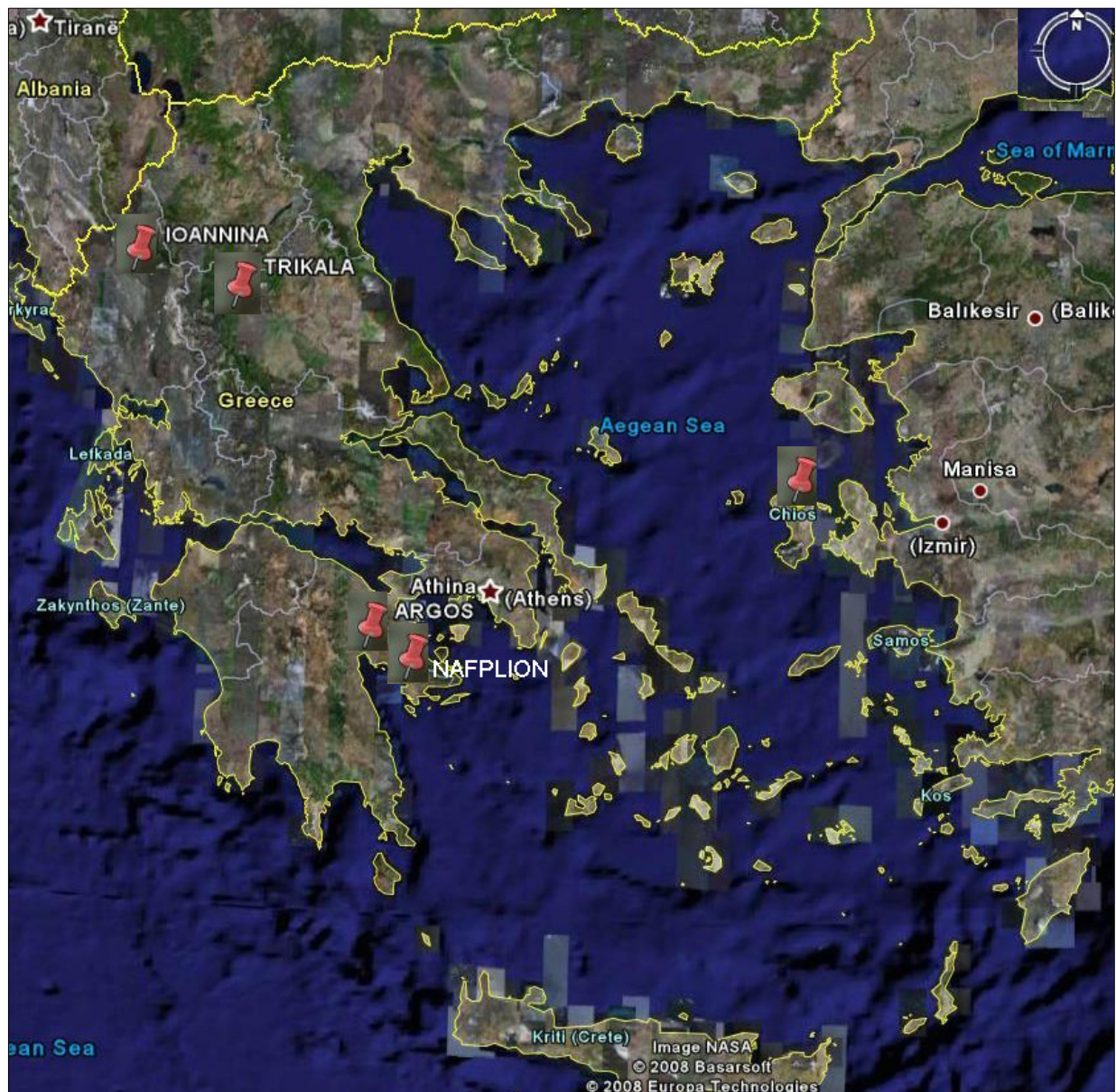


Figure 3: The geographical distribution of the Greek mosques discussed in this paper.



Figure 4: The Veli Pasha mosque.



Figure 5: The Kaloutsiani mosque.



Figure 6: The Fetiye mosque.



Figure 7: The Aslan Pasha mosque.



Figure 8: The Metzitie mosque.



Figure 9: The Osmanie mosque.



Figure 10: The Bairakli mosque.



Figure 11: The Kursum mosque.



Figure 12: The mosque in Argos.



Figure 13: The 'Trianon' mosque.



Figure 14: The Vouleftiko mosque.

The Metzitie mosque (Figure 8), situated in the center of Chios, is a large construction that was erected in 1843 by the Sultan Metzit. Today it is reconstructed and preserved with its minaret. It is used as a Byzantine museum and contains significant exhibits.

The Osmanie mosque (Figure 9), situated close to the center of Chios, was erected in 1893. It is a small and simple building with a minaret. Today it is used as an exhibition place.

The Bairakli mosque (Figure 10) is located inside the old castle in Chios. Originally it was probably constructed as a Christian church, in about AD 1410, but later was converted into a mosque. Today it is almost abandoned; it is in ruins and it is used as a storehouse.

The Kursum mosque (Figure 11) in Trikala is situated at the southern entrance to the town. It is one of the larger Greek mosques, and in the central region of Greece is the only one that has been preserved up till

the present day. Osman Sah Bey or Osman Pasha constructed this mosque in 1557. It has an impressive dome that is 22.5m high, many rows of windows for lighting the interior, and a minaret. Today the mosque is restored and is used as an exhibition hall.

The mosque in Argos (Figure 12) was founded between 1570 and 1600, and is the only Muslim monument in the town. It was abandoned and is almost in ruins today. In 1871 it was converted into a Christian church dedicated to Saint Constantine the Great.

The 'Trianon' mosque (Figure 13) is situated at the center of Nafplio. It is the oldest preserved building in the town, and dates to the late sixteenth century. It is a simple construction, and its minaret has not been preserved. Today it is used as a theatre.

The Vouleftiko mosque (Figure 14) was constructed in 1730 about a hundred meters from the 'Trianon' mosque. It is a building of remarkable architectural appeal with a rectangular main hall and an impressive dome. In 1825 it was used for the sessions of the first Hellenic Parliament. Today it is used as a special events center.

3 THE ORIENTATION OF THE MOSQUES

The determination of the astronomical orientations of the eleven mosques was carried out using a geodetic surveying method and astrogeodetic observations (see Pantazis, 2002; Pantazis et al., 2003).

The position of each monument, namely the ϕ and λ coordinates in the world's reference system, was calculated using GPS receivers. For the surveying of each monument a local arbitrary astronomically-oriented geodetic network was used.

The orientation of the network was determined by astrogeodetic observations of Polaris (α Ursa Minoris). The horizontal angle and the time of each observation of the star were registered (Lambrou et al., 2008). All the astrogeodetic and geodetic measurements were carried out using modern digital total stations. These instruments perform precise digital angular and distance measurements, using a visible laser beam which defined accurately the desired points on the monument's structure. The coordinates of each point in the 3-dimensional system were calculated. The points that were selected for measurement were characteristic ones, in order to draw the plan of each monument.

Generally, between 200 and 400 points were measured on each monument, depending upon the size and the complicity of the construction. The plans were drawn digitally. The coordinates have an accuracy (standard error) of $\pm 5\text{mm}$.

The orientation of each mosque was determined by calculating the astronomical azimuth of the main axis of the building, namely the longitudinal symmetrical axis of the building which passes through the center of the mihrab. Substantially, this axis reflects the direction that the believers are praying. In order to determine the main axis, the characteristic symmetrical points of the building were selected on the plan (e.g. the corresponding openings, the edges of the main entrance, the center of the mihrab) and the midpoint of each line, which joins them, was determined (see Figure 15). The main axis was calculated as the best fitting line to these selected points (1 to 8 in Figure 15) using the following equation:

$$y = ax + b \quad (1)$$

where x and y are the coordinates of the selected points in the local astronomically-oriented arbitrary reference system.

The least square method was used for the adjustment. The coefficients α and b of the line were determined, as well as their uncertainties (σ_α , σ_b). The astronomical azimuth A_A of this line was determined using the following equation:

$$A_A = 90^\circ \pm \arctan(\alpha) \quad (2)$$

as term $\arctan(\alpha)$ defines the angle between the line and the x -axis, but the azimuth A_A is the angle between the line (the main axis of the mosque) and the y -axis (Figure 16).

The precision σ_{A_A} of the determination of the main axis azimuth is given by the equation:

$$\sigma_{A_A} = \pm \left| \frac{1}{1 + \alpha^2} \cdot \sigma_\alpha \right| \quad (3)$$

The precision achieved fluctuated from $1'$ to $7'$, and depended upon the size of the monument, the number of the points which were used for the adjustment and the condition of the building. Figure 17 presents the astronomically-oriented plans of the eleven mosques, with the main axes drawn.

4 THE CALCULATION OF THE QIBLA DIRECTION

In order to investigate the orientation of the mosques according to the traditional rules, the geodetic azimuths of the directions which defined each place and the Kaabah in Mecca, namely the qibla directions, must be calculated. This calculation is carried out via the Vincenty equations for the geodetic conversion problems. These equations provide adequate accuracy for distances longer than 1000km (Veis et al., 1995). The geodetic coordinates, ϕ and λ , of the Kaabah are equal to $21^\circ 25' 24'' \text{ N}$ and $39^\circ 49' 24'' \text{ E}$ (Abdali, 1997), and the coordinates of each mosque were determined by using GPS measurements.

The astronomical azimuth A_A between two points can be calculated by the geodetic one, A_G , via the Laplace equation (Bomford, 1972):

$$A_G = A_A - \eta \tan \Phi - (\zeta \sin A - \eta \cos A) \tan v \quad (4)$$

where η and ζ are the components of the deflection of the vertical, Φ is the astronomical latitude of the point, and v is the altitude between the two points. The term $-(\zeta \sin A - \eta \cos A) \tan v$ is of the order of $1''$. For such long distances (thousands of kilometers) the value $\tan v$ is almost negligible, as the altitude v is very small. Also, the term $-\eta \tan \Phi$ is of the order of a few arcseconds. As the precision of the calculated astronomical azimuths of the main axes of the mosques is of the order of some arcminutes, this correction can be ignored, and so $A_G = A_A$.

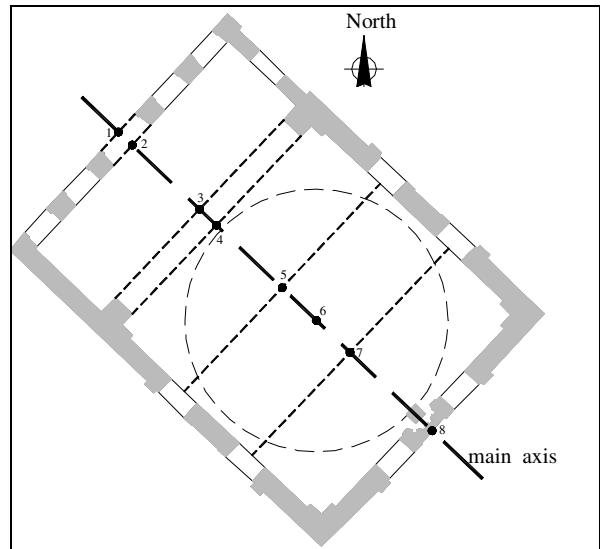


Figure 15: The calculation of the main axis of the building.

Table 1 presents the calculated Qibla direction for each mosque position and its astronomical orientation. Also, as the Kaabah is oriented towards the rising of Canopus in Mecca, that azimuth is determined via the virtual planetarium SkyMap Pro 10 [Marriott, 2001]. In the era that the mosques were erected the rising azimuth of Canopus in Mecca was about $148^\circ 03'$. It must be underlined that Canopus is invisible from Greece due to the latitude of that country and the declination (δ) of the star.

Figure 18 illustrates on a circular (mathematical) horizon the qibla direction, namely the azimuth of the direction from each mosque's position towards the Kaabah in Mecca relative to the astronomical orientation of each mosque. In addition, the direction of the rise of Canopus in Mecca and the azimuth from each place towards Jeru-salem are marked.

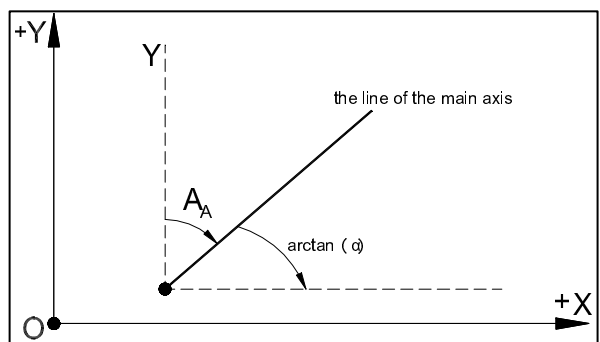


Figure 16: Calculation of the azimuth of the main axis

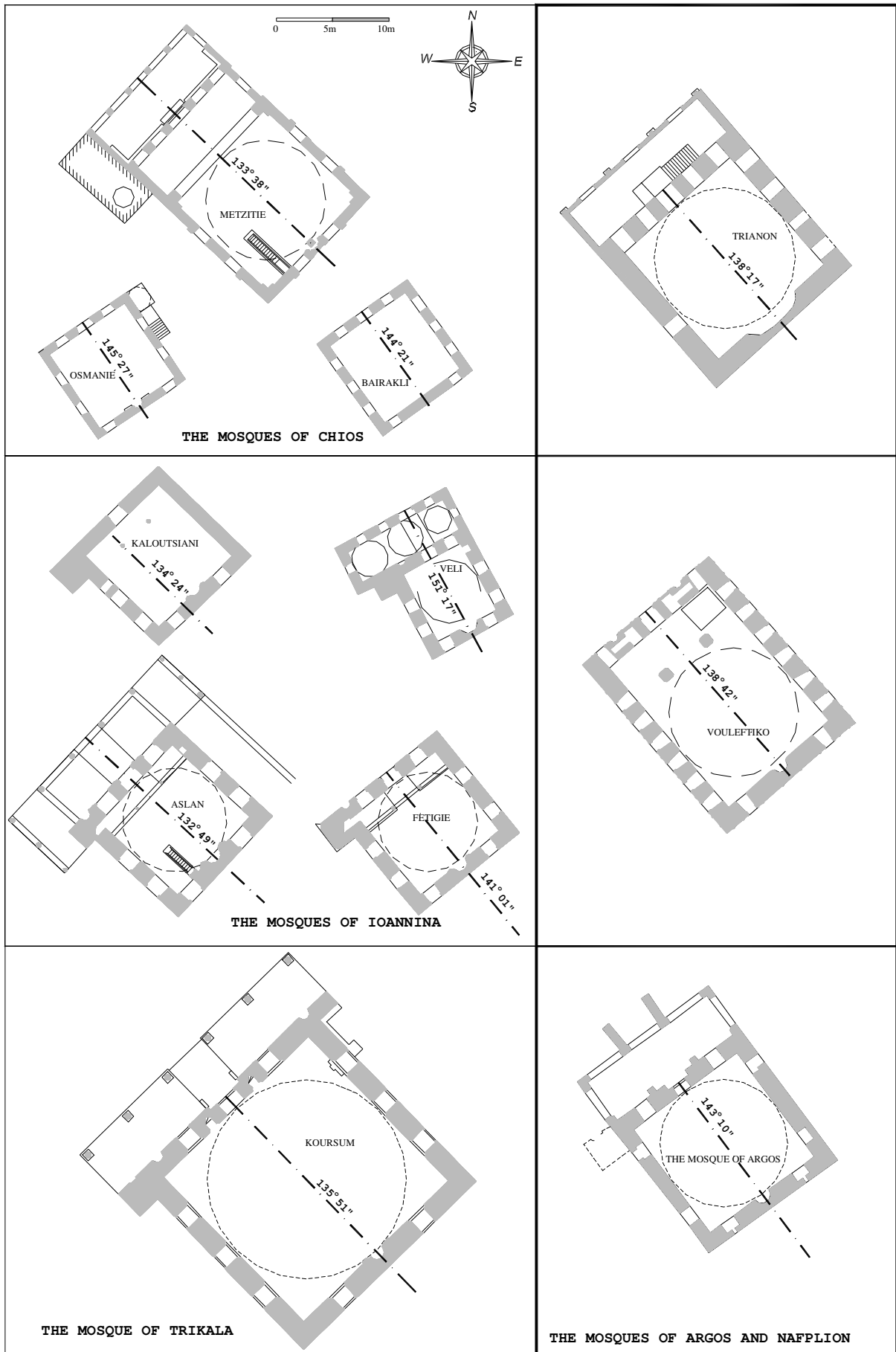


Figure 17: The oriented plans relative to the astronomical north.

Table 1: The astronomical orientation and the qibla directions of the mosques.

Region	Mosque	Qibla direction	A_A (of the main axis)	σ_{A_A} (')	S (Km) Site - Mecca
IOANNINA	<i>Veli Pasha</i>	132° 44'	151° 17'	± 5'	2708.8
	<i>Kaloutsiani</i>	132° 42'	134° 24'	± 8'	2708.6
	<i>Aslan Pasha</i>	132° 43'	132° 49'	± 4'	2708.9
	<i>Fetiye</i>	132° 44'	141° 01'	± 1'	2709.3
CHIOS	<i>Metzitie</i>	141° 12'	133° 18'	± 5'	2291.0
	<i>Osmanie</i>	141° 11'	145° 57'	± 7'	2291.0
	<i>Birakli</i>	141° 12'	144° 21'	± 2'	2291.1
TRIKALA	<i>Kursum</i>	134° 12'	135° 51'	± 1'	2643.0
ARGOS - NAFPLIO	<i>Argos</i>	132° 43'	143° 10'	± 4'	2435.8
	<i>Vouleftiko</i>	132° 44'	138° 42'	± 3'	2426.7
	<i>Trianon</i>	132° 44'	138° 17'	± 3'	2426.7

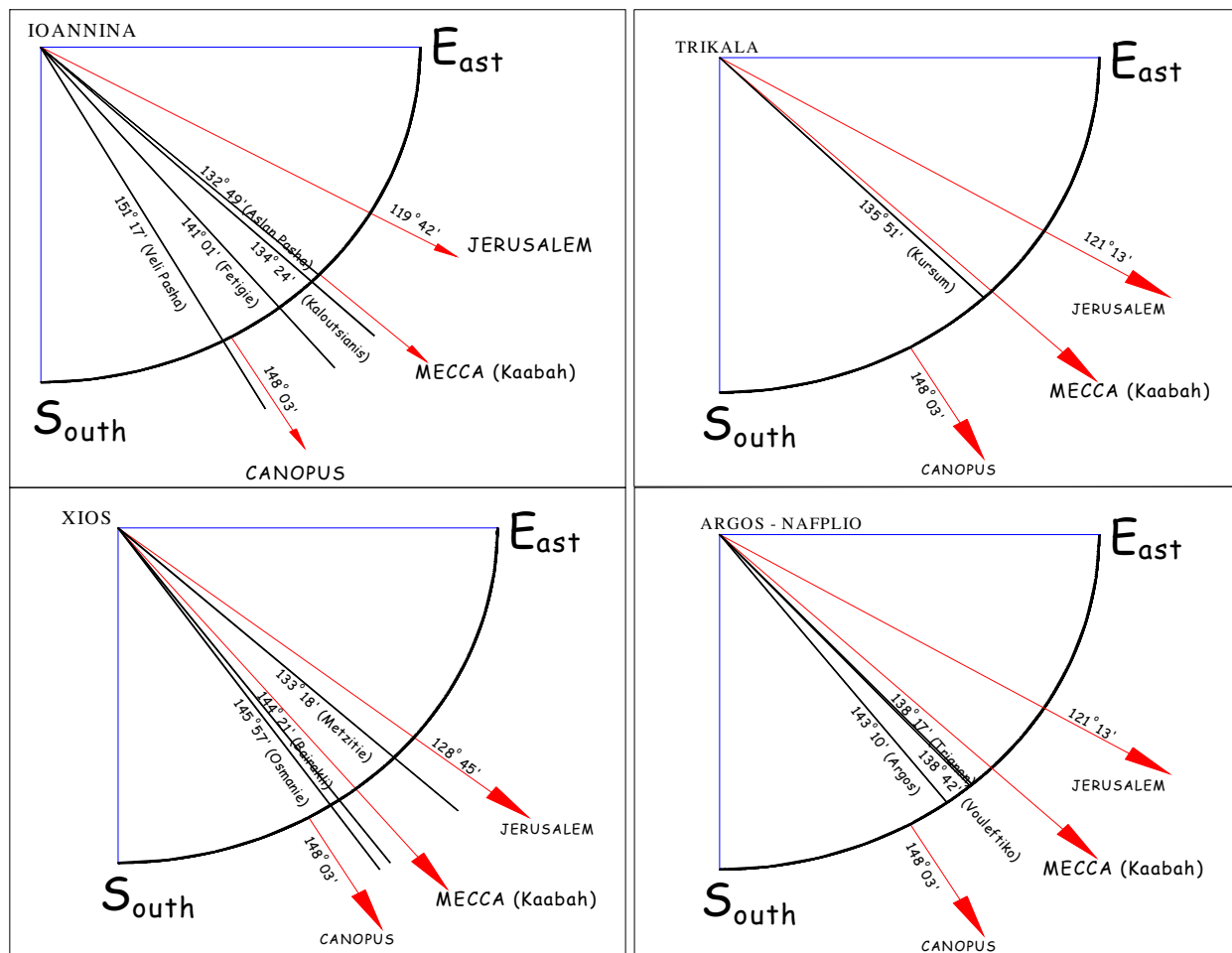


Figure 18: The astronomical azimuths and the qibla direction of each mosque and the rising azimuth of the Canopus star in Mecca.

5 CONCLUDING REMARKS

The results that emerge from the present investigation suggest that the scientific community, but particularly archaeologists, astronomers and archaeoastronomers, can expand their research on ancient mosques.

Firstly, the plans that we produced contain useful geometric data relating to the construction of the eleven mosques and their present-day condition. In addition, the astronomical orientation of each mosque was determined. The applied geodetic methodology

provides adequate accuracy both for the geometric documentation and astronomical azimuth determination.

All of the mosques have a southeastern orientation, which varies from $132^{\circ} 49'$ and $151^{\circ} 17'$. It was verified that all of the founders of the mosques followed the Muslim tradition. The effort involved in gauging the right orientation for each mosque is obvious. The deviations that were observed range between $6'$ and 10° for nine of the eleven investigated mosques. Given the limitations in making the qibla calculations during the periods when the mosques were built, errors of several degrees would seem justified.

The astronomical azimuths of the main axes of ten of the mosques were found to lie between the qibla direction, namely the direction that is defined between each site and the Kaabah in Mecca, and the rising azimuth of Canopus in Mecca. This agrees with the historical data presented in this paper, which indicates the devotional role of the qibla direction.

Furthermore, it should be noted that the Aslan Pasha mosque in Ioannina is exactly oriented towards the Kaabah in Mecca. According to the historical data, Aslan Pasha was a very significant person during that era, and following his orders scientists were invited to Ioannina in order to undertake the construction of the biggest mosque in the region. It is obvious that the founders had special knowledge, and they were able to make accurate calculations of the required orientation for the building. This is proven by our measurements.

The same conclusions apply to the Kursum mosque in Trikala and the Kaloutsiani mosque in Ioannina, which are also oriented towards Mecca with a deviation of $<2^{\circ}$.

The Vouleftiko and Trianon mosques in Nafplio have almost identical orientations, with a difference of only $25'$. These two mosques are situated within 100m of each other, and their founders probably followed the same rules and the same procedures when determining their orientations.

Finally, we found that none of the examined mosques was oriented towards Jerusalem.

In planning the eleven mosques, it is obvious that the founders paid special attention to their orientation during the laying of the foundations. It is remarkable how they managed this. How did they calculate their position on the Earth (the ϕ and λ coordinates), and how did they determine the qibla direction? Did they carry out astronomical observations of specific stars or did they use simpler methods?

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