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ON THE DATE OF THE KATHOLIKON OF DAPHNI MONASTERY. A NEW APPROACH BASED ON ITS ORIENTATION

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ABSTRACT

The exact date of the foundation of the Katholikon of Daphni monastery is unknown. Based on the stylistic data of its mosaic decoration the archaeologists suggest that its mosaics date to the end of the eleventh century, which is either a terminus ante quem for the construction of the Katholikon or the mosaic decoration is contemporary to this construction.

In this paper we attempt to determine the foundation date of the Katholikon of Daphni, on the base of its astronomical orientation and by applying the general astrogeodetic method elaborated by one of us (G. Pantazis) in this case. As results from our investigation, the Katholikon, which is sacred to the Virgin Mary, was very likely founded on the day of the celebration of the Dormition of the Virgin in 1153, i.e. in August 15, 1153 (±8years). If it is so, both the church and its famous mosaic decoration date circa half a century later than it is generally accepted by the archaeologists.

KEYWORDS: Geometric documentation, astronomical observations, azimuth, Perceptible horizon, diurnal path of the Sun.

THE DAPHNI MONASTIC COMPLEX HISTORICAL DATA

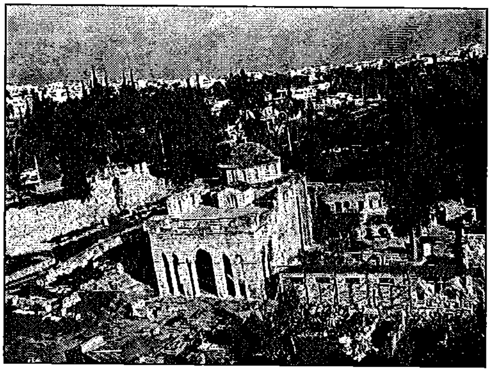

Fig. 1: The Daphni monastic complex

The famous Daphni monastic complex (Fig. 1) is situated in the middle distance (c. 10km) between Athens and Eleusis, and on the left side of the ancient ≤sacred road≤ to Eleusis. It is built on the place of an ancient sanctuary dedicated to Apollo, later also to Athena, Demeter and Kore, according to Pausanias (Description of Greece, Attica, ch.37, 6-7). In Pausanias' time (c. 150) there was a surrounding wall enclosing at least one temple and one gallery (or another building with columns), as there are many drums of columns and capitals doric and ionic. The ancient sanctuary survived at least during two and half centuries after Pausanias, i.e. until the edicts against pagan religion issued by emperor Theodosius I and his successors.

Some prechristian remains have been used in the buildings of the monastic complex. On the other hand, rectangular stone blocks of the ancient surrounding wall have been used in the Byzantine fortress wall.

The best saved side of the latter is its lower part along the National Road, which is the same northern side of the ancient wall, while its upper parts and the towers, built with common stones and in a different style of stonework, are part of restoration works and completion of the surrounding wall in Byzantine times. According to the archaeological evidence, the Byzantine surrounding wall was a square with a side of one hundred meters. Its main entrance was at the West Side and not at the east one as it is today.

Archaeological evidence shows further that in the seventh century at the center of this enclosure an Early Christian 'Basilica' was built possibly as the 'Katholikon', i.e. the main church, of the early Byzantine monastery (Kambouroglou 1920). This Basilica is not saved but in the eleventh century a new church was built almost at the same place. This latter is the finest Byzantine monastic church of the district of Athens.

The domical method of construction governs the plan of Byzantine churches, which are all distinguished by a central square nave, covered with a dome on pendentives. Short arms on each side form a Greek cross, and the filling in of the angles brings the plan nearly to a square. In early examples the dome is supported by semi-domes. In later examples, the churches are much smaller and the dome is raised upon a high drum with, occasionally, additional smaller domes rising at a lower level. At the west end is usually a narthex, or entrance porch, which forms an entrance vestibule, frequently crowned with domes. At the east end, opposite the entrance, is the apse for the altar in the sanctuary, which is screened off by the characteristic 'iconostas' (screen of icons, i.e. pictures), with its three doors, and there were also lateral ritual chapels (Banister 1961).

The Katholikon of Daphni is a slender construction bathed in light because of its large dome on a squat barrel, supported by squinches and eight pillars (i.e. a regular octagonal plan). This type of dome, which allowed space that might be used for a larger chamber – the diameter of domes on pendentives being generally smaller- was much admired in Greece in the eleventh century (Grabar 1966).

The Katholikon of Daphni has one out of the three important mosaic decorations in Greece, the other two being the church of Hosios (the Blessed) Lucas in Phokis and that of the New Monastery in the island of Chios. Although we know nothing about either date or their origin, according to A. Grabar the theoretical place occupied by Daphni in the history of Byzantine painting can be found thanks to stylistic similarities between various details. Namely, in Daphni we discover the future style of the Comnenian period in the second stage of its formation. So it is reasonable to date the mosaics of Daphni to the end of the eleventh century, as suggested by G. Millet (Grabar 1966, 127).

On the northern side of the Katholikon was a long building, the Refectory of the monastery, almost always the next most splendid building in a monastery after the Katholikon. Here the monks eat together and this meal taken in common and served immediately after the main religious service, is regarded as its continuation.

Earthquakes in 1886, 1889 and 1894 produced great damages in the narthex of the Katholikon, as whole parts of it collapsed. The works of restoration under the supervision of the French architect Troump included the reconstruction of the narthex, of the north west chapel and of the walls of the upper floor, as well as that of the dome according to the initial plan. The last earthquake of September 1999 produced more serious damages and until now is going on works for the restoration of the building and especially for the conservation of its famous mosaics.

METHODOLOGY

In order to determine the date of the foundation of the Katholikon, we should firstly calculate its exact orientation by the following steps:

- Geometric documentation of the Katholikon and digital drawing of its plan.
- Astronomical observations for the determination of the astronomical azimuth of any direction.
- Geometric determination of the main axis of the monument and its astronomical azimuth.
- Geometric determination of the profile of the perceptible horizon, as seen from a specific position inside the monument.
- Reconstruction of the apparent diurnal path of the Sun as seen from the monument, in specific dates.

In the following paragraphs we explain each one of the above mentioned steps.

GEOMETRIC DOCUMENTATION

First of all by using the GPS system the geographic coordinates (φ= latitude, λ=longitude) of the place of the monument ($\varphi = 38° 00' 46''$N, $\lambda = 23° 38' 10''$E) were measured. Both are necessary for the calculation of the astronomical azimuth and the reconstruction of the apparent diurnal path of the Sun as seen at the place.

Further a polygonometric network consisting of 31 points had been established inside and outside the monument (Figure 2) (Project 'Development of modern Topographic and digital Photogrammetric methods for the geometric documentation and the total architectural digital drawing of Byzantine monuments, Application at the Daphni Holy Monastery', NTUA 1999).

Its 'elements' (namely the distances between selected points and the angles formed by these line segments) were measured by using the total station TC

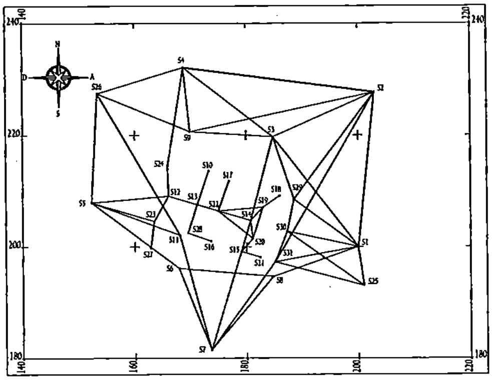

Fig. 2: The polygonometric network

1600, the accuracy of which in measuring angles is ±3″ and in measuring distances is ± 3mm ± 3ppm.

All the detail points of the building were carefully measured by using a reflectorless total station with a laser pointer, in order to mark the position of each point with great precision. The accuracy of the determination of the coordinates X, Y of each point of the monument is ± 3mm so that we can draw the monument's digital plan in a scale 1:50. All characteristic geometric elements of the Katholikon of Daphni monastic complex are displayed in the following digital plan (Fig. 3).

DETERMINATION OF THE ASTRONOMICAL AZIMUTH

The astronomical azimuth of the side of the polygonometric network, which is defined by the points S_1 and S_3, has been determined by means of astrogeodetic observations of the Pole Star (Polaris, aUMi), using the hour angle method.

These observations have been done with a system of a high precision digital total station, Leica TDM 5000 connected to a Trimble 4000DL GPS receiver, providing accurate UTC time, placed at the point S_1 in front of the central apse of the Katholikon. This system, with the appropriate software, allows the determination of the astronomical azimuth of a direction in short fieldwork time and with high accuracy (Lambrou 2003).

Three sets of measurements were carried out. The table 1 gives the calculated values of the astronomical azimuth of each set and the corresponding uncertainties.

The mean value of the astronomical azimuth is determined by using weights and assuming that the standard deviation of the unit weight is $\sigma_o = \pm 0.3''$.

To the final determined uncertainty must also be added:

1. The influence of the difference δφ between the astronomical and the geodetic latitude used for the determination of the astronomical azimuth. Taking into account that the difference δφ at the place of the monument is about ±10″, this increases the uncertainty by an amount of ±0″.1.

Astronomical azimuth $S_1 - S_3$ (°)		Uncertainty (″)
1^{st} set	310° 7′ 16″.6	± 0″.4
2^{nd} set	310° 7′ 17″.1	± 0″.3
3^{rd} set	310° 7′ 16″.8	± 0″.6
Mean value	310° 7′ 16″.9	± 0″.2

Table 1: The value of the astronomical azimuth.

2. The influence of the difference δλ between the astronomical and the geodetic longitude used for the determination of the astronomical azimuth. Taking into account that the difference δλ at the place of the monument is about ±20″, this increases the uncertainty by an amount of $\pm 0.''2 \cdot 10^{-3}$ (Lambrou 2003).

The final value of the astronomical azimuth of the direction S_1-S_3 and its uncertainty is:

$A_{S1-S3} = 310° \ 7' \ 16''.9 \pm 0''.2$

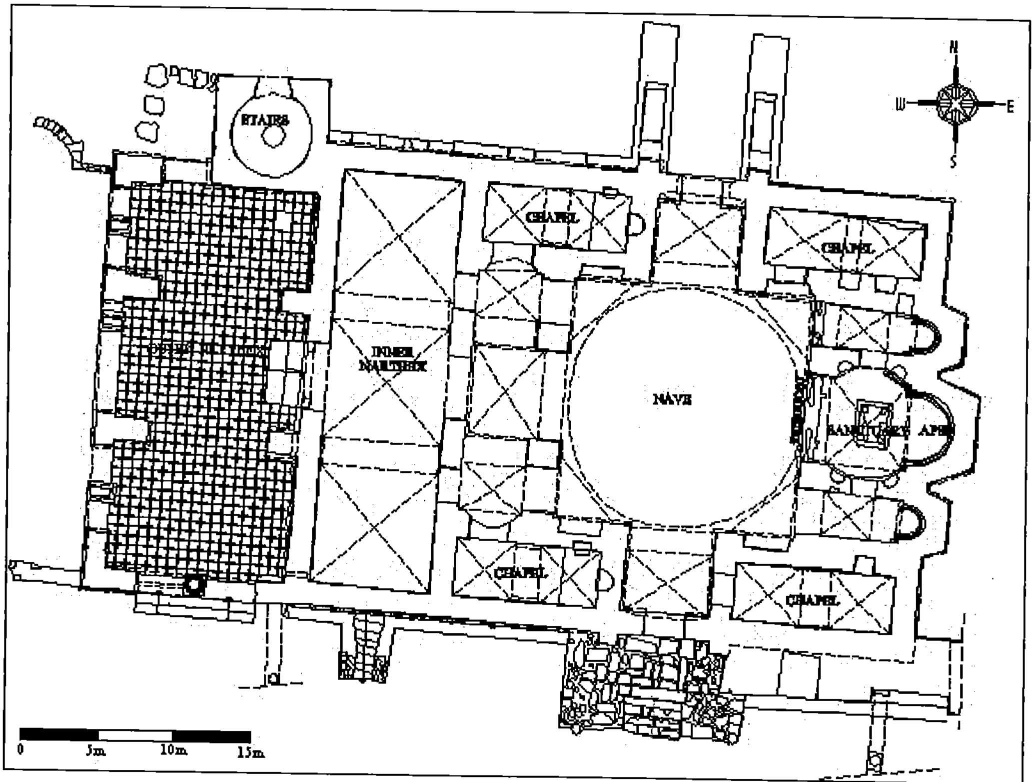

Fig. 3:The plan of the Katholikon of Daphni monastic complex

DETERMINATION OF THE MAIN AXIS OF THE MONUMENT.

The Katholikon of the Daphni complex is a symmetric building in respect to its main longitudinal axis. The basic points of this axis are determined by the digital plan of the monument, after its documentation. These points are the following (Fig. 4):

- Points 1 and 2 define the middle of the west entrance.
- Points 3,4,5,6 and 7 define the middle of the distances between five pairs of columns.
- Point 8 defines the middle of the west side of the altar. At this point the priest stands during the Holly Service.
- Point 9 defines the middle of the altar.
- Finally, point 10 defines the middle of the narrow window at the central apse.

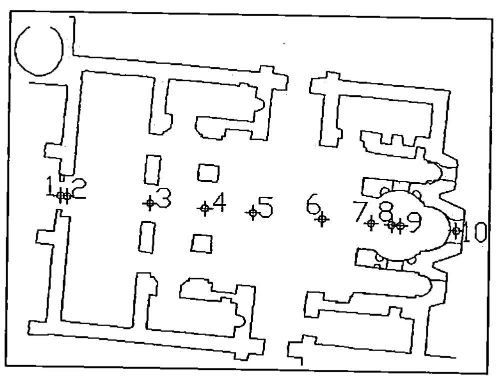

Fig. 4: The points of the main longitudinal axis of the church.

The coordinates of the above points in the arbitrary reference system are (table 2):

Point	X(m)	Y(m)
1	164.116	211.098
2	164.459	211.066
3	168.966	210.751
4	171.928	210.529
5	174.485	210.338
6	178.259	210.062
7	180.932	209.892
8	182.088	209.808
9	182.541	209.769
10	185.543	209.553

Table 2: The coordinates of the points of the main longitudinal axis.

The final longitudinal axis of the monument is the best fitting line to those ten points according to the formula

$Y = a \cdot X + b + u$

The parameters α, b, u are calculated by means of the least square method and the astronomical azimuth of this line is determined with the corresponding accuracy:

A = 94° 6′ 44″ 0′ .6

The astronomical azimuth of the calculated longitudinal axis of the monument will be used for its orientation.

DETERMINATION OF THE PROFILE OF THE PERCEPTIBLE HORIZON.

The perceptible or conventional horizon extending in front of a monument plays a very important role in the investigation of the meaning of the 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.

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 point against the celestial sphere and celestial bodies (Sun, stars). In the case of a monument the direction of view coincides with that of its characteristic axis (Pantazis 2002).

In order to determine the profile of a perceptible horizon, it needs first to calculate the coordinates of the specific position – point, to find a reference direction and then measure the horizontal and vertical angles having this point as vertex.

The perceptible horizon of the Katholikon of Daphni Monastery is the wall built on the east of the church. The study and the analysis of historical sources and other related documents lead to the conclusion that the east side of the enclosure saved until now was the same as that of its north side (Bouras 1998). Consequently both had the same height, namely that of the northern wall, ca. 5.00m.

Fig. 5: The photographic panorama of the eastern part of the horizon.

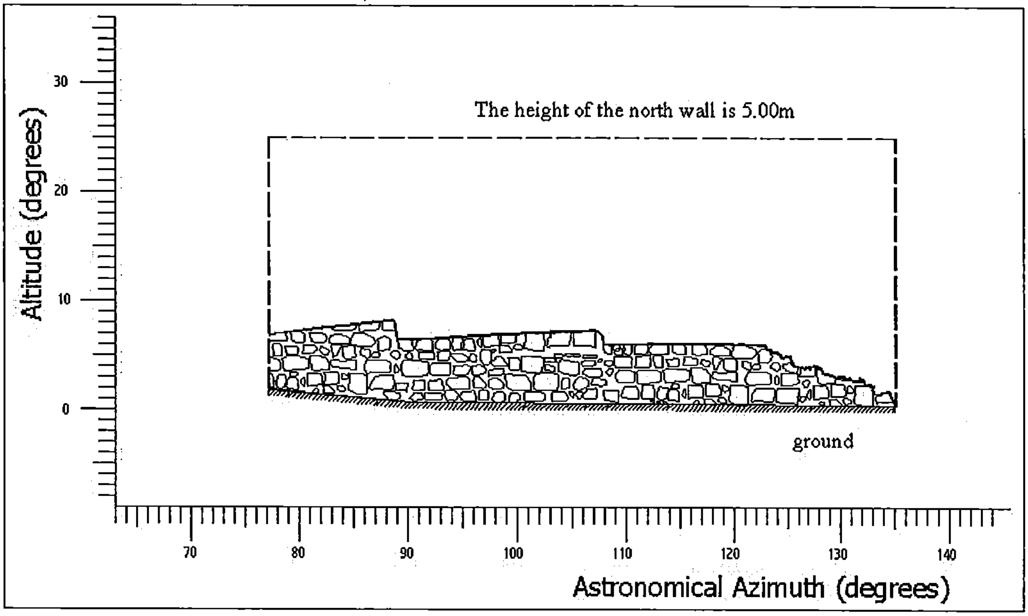

Fig. 6: The profile of the east wall.

The results of the measurements are illustrated in a diagram (Fig. 6) where the x – axis shows the azimuth (Az) and the y – axis shows the altitude (υ) of each point of the profile. The dashed line shows the original profile of the east wall of the enclosure, as seen from the middle of the altar.

The photographic documentation of the horizon profile is illustrated in Fig. 5.

The total error in the determination of the profile of the perceptible horizon is $\sigma_{hor} = \pm 1'.2$

DETERMINATION OF THE PATH OF THE SUN

In order to determine the apparent diurnal path of a celestial body, as seen from the monument's place, in a given date, we used the *Sky map Pro8* software - a digital almanac and virtual planetarium (Marriot 2001). Our data were the following:

- The celestial body (the Sun) whose path must be calculated.
- The astronomical coordinates Φ, Λ of the monument's place.
- The date (any date between 4713 B.C. and 8000 A.D.).

The apparent diurnal path of the Sun, is calculated for August 15 – celebration day of the 'Dormition of Virgin Mary' - during four hundred years, namely from 900 to 1300 A.D., and is illustrated in a diagram where the x-axis shows the azimuth (Az) and the y-axis the altitude (υ).

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Thus the series of successive diagrams drawn for the 15 August shows that the diurnal path of the Sun for the year 1153 A.D. passes through the point at which intersect the direction of monument's main longitudinal axis defining its astronomical azimuth and the profile of the percrptible horizon (Fig. 7). Moreover, as shown in this diagram there is no other day or year in which the Sun's path passes through this point of intersection. Consequently, it becomes obvious that the Sun's path for the 15th August 1153 A.D. is unique, namely the only one which passes through this point.

ACCURACY OF THE DATE

The final accuracy of the determination of the foundation date of the church can be calculated if they are known:

- The total error of the methodology.
- The annual change of the diurnal path of the Sun for a specific date (d_{sun})
  According to the formula:
  Date uncertainty = $\pm \sigma_{total} / d_{Sun}$
- The error of the methodology depends on:
- The error of the determination of the astronomical azimuth of the main longitudinal axis, which is **±0′.6**.
- The error of the determination of the profile of the perceptible horizon, which is **±1′.2**.

The error of the determination of the diurnal path of the Sun, which is **±2″**.

The striped area ABCDA in the figure 8 corresponds to the total error of the methodology, which is $\sigma_{total} = \pm 73'$.

The annual change of the apparent diurnal path of the Sun for August 15th from the monument's place is $d_{Sun} = 10"$

Consequently the date uncertainty is:

$$\sigma_{total}/d_{Sun} \frac{\pm 73''}{10''/\text{year}} = \pm 7.3$$

practically ±8 years

CONCLUSIONS

An accurate determination of the orientation of a monument can be made by means of modern digital total stations in which a combination of geodetic and astronomical methods and procedure are used.

It is possible to determine approximately the foundation year of the monument (**date**) as well as to identify the saint to whom it was sacred.

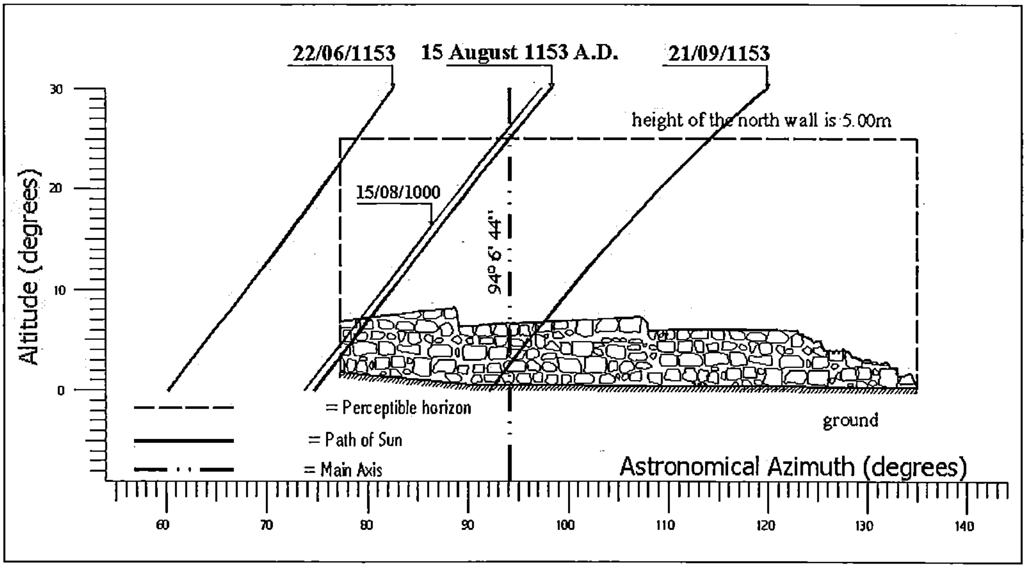

Fig. 7: The diagram of the perceptible horizon towards East, the apparent path of the Sun and the main longitudinal axis.

In the case of the Katholikon of Dapnhi having as data:

- The digital plan of the monument;
- The main longitudinal axis of the monument (determined by a geometric method) and the value of its astronomical azimuth.
- The profile of the perceptible horizon;
- The geographic coordinates (latitude and longitude) of the place of the monument.
- The diurnal path of the Sun drawn for the place of the monument in a special date; we find that the accurate value of its orientation is **94° 6′ 44″** with an accuracy of **±0.6′**; consequently it faces South – East. Further we arrive at the conclusion that the Katholikon of Daphni is oriented to the Sun and it dates in **1153 A.D.** ±8years, which means that it has been built sometime between the years 1145 A.D. and 1161 A.D.

Moreover, as in 15 August the diurnal path of the Sun, the azimuth of the main longitudinal axis of the monument and the profile of the perceptible horizon meet at the same point, it is confirmed that the Katholikon of Daphni Monastery is sacred to the **Dormition of Virgin Mary.**

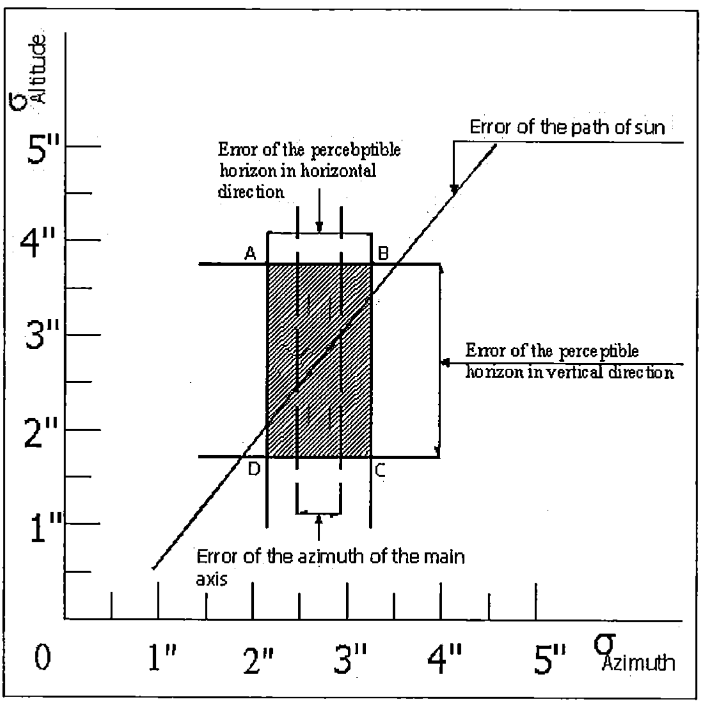

Fig. 8: The total error of the methodology for the orientation of the Katholikon

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