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Further solar alignments of Greek Byzantine churches[1]

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Abstract

Following the recent work on the solar alignment of Greek Byzantine churches (Liritzis and Vassiliou, 2006 a, b, c), the solar orientations of twenty one more churches are presented. The question examined is if the day of solar rise across the eastern direction of the Church is related with the feast day of Patron Saint. Measurements were carried out with magnetic compass, inclinometer, portable GPS and appropriate corrections for the solar declination. The alignments towards eastern sunrise were examined for various angular altitudes of the perceptible horizon. At least for all Rhodean churches the patron's day is met when sun's oblique path crosses horizon a few degrees beyond the intersection of extrapolated eastern axis of the church with horizon's skyline. Therefore, taken the orientation as the glitter of first sunrays - early dawn- correlation of thirteen present churches are aligned near the autumnal equinox, three have relation with the feast of Patron Saint, four are related to other important feast of Christianity, and one seem orientated randomly. However, accounting for a due east sun position a few degrees above horizon in early liturgy hours (6:30-9:30 am) all the Rhodean alignments coincides with Saint's name day.

Keywords: *Byzantine churches, Rhodes, orientation, azimuth, horizon, saint's day, Gregorian date, julian date.*

1. Dedicated to late Dr. Elias Kollias pioneer on Byzantine archaeology for his unselfish attitude, encouragement and continuous support to IL at the start of this project.

Introduction

Astronomical orientation of medieval churches has been reported since very early times (Thijm, 1858; Charlier, 1902).

Over 800 churches have been investigated for their orientation in Europe: the results point to, a) the rising sun shines through longitudinal axis of the church on days of equinoxes, b) solstitial orientation though accepted not found so often, and c) numerous churches orientation was carried out on the feast day of the patron saint, on the day of the laying of the foundation of the church or on the day the building actually begun (Barlai, 1989).

In Christianity a cycle of four feasts celebrating Christ's birth and conception (Christmas, 25th of December and, the Annunciation, 25th of March respectively) and St. John's birth and conception (24th June and 24th September respectively) became the solstitial and equinoctial points in the Christian calendar with theological and cosmological symbolism. Augustine in Sermones makes clear the contrast between the pagan worship of the visible Sun with the Christian creator of the sun, Jesus Christ, the Sun of Justice (McCluskey, 2000:25-27)

On the other hand, as far as English churches is concerned there is a lack of coincidence with specific feasts.

For demolished churches from fire, war or natural catastrophes, when rebuilt the axis of reconstruction often deviated from former axis due to inconsistency between the old Julian calendar and the tropical year (Gregorian Calendar).

Early Christian communities followed the ancient tradition considering the orientation towards the east as sacred – known from literature of Origenes, Clemence of Alexandria and Tertullianus. Indeed in 400-450 AD Pope Leo the Great (440-461 AD) issued a decree against the veneration of the rising sun shows that the sun only had to be taken as a symbol of the Christ entering his church and not as a deity itself (Firneis and Ladenbauer, 1978). On the other hand Pope Vigilius (537-555 AD) confirmed the east orientation of churches put forward by Bishop Athanasius during the first Synod of Nicea (325 AD) when it was ordered that a priest specifically had to turn eastward during prayer in church (as specified in the Rationale *Divinorum Officiorum* V.2.57) (Guzsik, 1978).

In fact, Saint Athanasius writes about orientation in the 4th century: *"...the location of the churches was generally such that the faithful, in praying, with their faces toward the altar, would be looking toward the rising sun, the symbol of Christ, who is the sun of justice and the light of the universe"*.

An earlier reference, concerning not only the spiritual symbolism of the orientation towards the rising sun, but also the structure of a Christian Church in the model of the temple of Zerubbabel, is given by Eusebius of Caesarea, in the early 4th century, in his Panegyric on the building of the churches, addressed to Paulinus, Bishop of the Tyrians, where he quotes: *"... while he spread out a porch, great and raised aloft, towards the rays of the rising sun, and even to those standing far outside the sacred precincts supplied no scanty view of that which is within ..."* (*Ecclesiastical History, X.IV.38-39*).

During the 6th century Procopius of Caesarea, describing the rebuilt of St Sophia of Constantinople, writes that *"...and the face itself of the church, which would be the part which faces the rising sun, that portion of the building in which they perform the mysteries in worship of God..."* (*Buildings, I.i.31-32*).

This direction still was considered sacred by tradition during the age of the Renaissance, as can be seen from the figure given in Apianus' *Astronomicum Caesareum* printed in 1540, depicting four professions related to the cardinal directions: a priest to the east, a cosmographer to the north, the poet to the west and the astronomer to the south (Apianus, 1540, p.FIIIv).

Though early churches show this east orientation in two ways – either the altar is positioned in the eastern main apse while the entrance door points to the west, or the door might be in the east so that the rising sun beams illuminate the altar then positioned in the west- only few churches actually point to the cardinal directions (Firneis and Koberl, 1989). Early

Christian churches followed the earlier practice from pre-existed cultures, as Mithraic and Jewish worship meeting places in Rome and Jerusalem (White, 1982;27), and Classical and Hellenistic practices in Greece (e.g., see, Penrose, 1893, 1897, 1901; Liritzis & Vassiliou, 2003, 2006c; Vassiliou forthcoming), where the temples and the position of deity's statue within the temple related to the illumination by the first sun rising beams (e.g. Aeschylus, Agamemnon 519-520, *"gods who face the rising sun... with gleaming eyes"*).

However, how high from horizon's skyline the sun must be positioned during its oblique path, in order to align with the extrapolated altar axis is not known and is a matter of investigation by trial and error tests to meet the day of patron's feast. The first glittering of sunrays is not always the point towards which the church was founded. Surely this could have been the practice in the first centuries AD following ancient Greek tradition. Later, this eastern direction could have been chosen when sunrise stands above perceptible horizon during the first morning hours of liturgy (7-9 am).

However, it is not known whether the Christian churches built during later centuries (throughout Byzantine period) continued to keep or ignored this building concept rule of the orientation, or as a consequence of the clash between eastern and western World cultures, some heathen sighting practice, and even practical reasons from the architectural structure of crowded settlements in villages and capitals, in building new churches, influenced the actual orientation of those churches.

In our earlier project (Liritzis and Vassiliou, 2006 a, b) Christian and Byzantine churches were measured for their orientation towards rising sun on certain and 'particular' days of the year. Here we present a second part of our project, considering a significant link between history, archaeoastronomy and Christian religious practices.

In the determination of the position of the sun, the switch from Julian to Gregorian calendar has been taken into account, because of the Reform of Calendar. In fact, during the year 1545 AD, the date of vernal equinox had been regressed from the 21st March (date of vernal equinox at the time of the Council of Nicaea, 325 AD) to March 11th (10 days earlier), and in 1582 a papal decree had been published in order to return the equinox on its proper date (Grumel, 1958:175; Ziggelaar, 1983:201-202; Aveni, 2002:101-102). Therefore the 5th of October 1582 was followed by October 15, just to readjust the error of the 10 days accumulated during the past 11 centuries, because of the incomplete calculations of the Julian calendar (Aveni, 2002:102; Ziggelaar, 1983:201-202). In Greece, the Gregorian Calendar has been accepted since 1924, when 5th of March was followed by March 18th (Gingerich, 1983:276-277; Potamianos, 2000;156).

Thus dates after the year 1582 must be corrected as follows: 10 days added for 1582 to 1699, 11 days added for 1700 to 1799, 12 days for 1800 to 1899, and from 1900 to 1924 we must add 13 days (Parise, 1982).

For centuries earlier than 1582, appropriate corrections were applied in certain Byzantine churches, bearing in mind the change of 0.75 days per century starting from 325 AD the date of fixing Greek Christian Easter.

Our software provides Gregorian dates, thus for comparison with Julian calendar a subtraction of some days is applied to the computed dates and the present day saint's celebration.

The aim of the present paper is to investigate if the day of sunrise coincides with the deity's name day in several Byzantine churches from Greece. The idea is to monitor the passage of time in terms of the shifting position of sunrise among the details of the mountainous horizon. The positive case implies that the architectural drawing of the church was intentionally constructed towards the particular horizon point where sun rises at the celebration day of the Saint of the church. Other due east orientations not related with sunrise at the saint's name-day but with equinoxes and summer solstice are discussed.

It should be mentioned that, at least for Rhodes most churches have changed original, but unknown yet, Saints' name (Elias Kollias, Rhodes, personal

communication). In fact initial Saint Name attribution has been removed and forgotten from later Ottoman occupation and transformation to mosques or other public buildings. Our work may contribute to the identification of first Saint's attribution of a church.

Measured Churches

Our work concerns the possible astronomical alignments of 21 churches ranging from 6th to 18th centuries (15 from Rhodes and 6 from other parts of Greece). These include:

Our Lady of the Castle, Medieval City of Rhodes, 11^{th} cent., St Nicolas or St, Bernardine, Medieval City of Rhodes, 14^{th} cent., St Mark, Medieval City of Rhodes, 14^{th} century, St Marina, Medieval City of Rhodes, c. 14^{th} – 15^{th} cent., Our Lady of the Burgh, Medieval City of Rhodes, c. 14^{th} – 15^{th} cent., Sts Theodore, Medieval City of Rhodes, c. 14^{th} – 15^{th} cent., St Catherine, (Ilk-Bihram), Medieval City of Rhodes, c. 14^{th} – 15^{th} cent., Our Lady of the Victory, Medieval City of Rhodes, 15^{th} cent., St, Panteleimon, Medieval City of Rhodes, 15^{th} cent., Holy Apostles, Medieval City of Rhodes, 15^{th} cent., St George, Medieval City of Rhodes, 15^{th} cent., St Paraskeve, (Takkeji-Mesjid), Medieval City of Rhodes, 15^{th} cent., Holy Trinity, (Dolapli Medjid), Medieval City of Rhodes, end of 15^{th}- beginnings of 16th cent., St Athanasios, Medieval City of Rhodes, beginnings of 16^{th}, Our Lady of Filerimo, 14^{th} cent., St Mamas, Menetes, Karpathos Island, 11^{th} or 12^{th} cent., St Paul, Pyrgiotissa of Herakleion, Crete Island, early 14^{th} cent., St George Galatas, Pyrgiotissa, Herakleion, Crete Island, early 14^{th} cent., St Spyridon, Mani, Peloponesse, 18^{th} cent., St Christophoros, Phokis, 6^{th} – 7^{th} cent., St Theodora, Arta, Epirus, 13^{th} cent.

Measurements and methods

In all occasions, orientation measurements included azimuth (Az) and angular altitude of the skyline (AAS), were made with a magnetic compass (Meridian, MG-3101) with attached clinometer. The magnetic compass and not a theodolite was the instrument of choice mainly for the reasons that M. Hoskin (2001:12) explained: it can be used in all weathers, and in all conditions. On the other hand, a possible error in measurement, not only systematic, concerns theodolite as well and not only a compass, as in some cases measurements on the same poles with two different theodolites, derived orientations differed by more than one degree (Hoskin, 2001:11)

The geographical latitude and elevation were measured by a portable GPS (Garmin GPS III). The magnetic declination correction was determined from magnetic variation maps of the Military Geographical Service (Athens) for the year 2000. No attempt was made to check for local magnetic anomalies, but based on geological maps the local environments were of limestone. The astronomical declination (δ) of a horizon point and the corresponding day of the year of sunrise were calculated using specially developed home-made software (STARDEC and SUNDAY) based upon appropriate formulas (Hawkins and Rosenthal 1967; Thom, 1967; Ruggles 1999:285, formulas A2.1, A5.1) (see, Liritzis and Vassiliou, 2002; Liritzis and Vassiliou, 2006 c). Magnetic correction due to present day geomagnetic declination at the sites is around +2.8° to +3.4°. Alignment was carried out along external walls and the main nave walls or the main apse is considered adequate to yield azimuth directions.

The AAS was considered in two cases, a) emergence of sun from the perceptible horizon, the intersection between extrapolated axis of altar towards east, and b) variable angular altitudes along the vertical projection of sun on to the intersected point of the horizon corresponding to the measured or an hypothetical azimuth ($A_{z,hypo}$) (Table 1).

Concerning the azimuth values Az, errors involved in compass were at the level of ±0.5 degrees with a subtracted systematic error of 3°, while for AAS angles errors are at a ±0.5° level Altitude of sun for given azimuths were calculated with software SkyMap Pro Version 10 (Marriott, 2003).

Results and Discussion

1) Our Lady of the Castle, Medieval City of Rhodes, 11th cent.

(Lat.= 36° 26' 57"N, Long.= 28° 13' 9"E, AzE = 92° ±0.5°, AAS=0° ±0.5°)

The church (Fig.1.a,b,c) belongs to the type of the inscribed cross-in-square and was the Greek Cathedral of Rhodes during the Byzantine period and the Latin Cathedral under the domination of Hospitaller Knights of the Order of Saint John at Rhodes (Kollias, 1998).

The dates derived from the eastern direction of the church found to be 4–7 October or 6 to 9 March (Gregorian calendar).

Regarding the dates of October, subtractacting approximately 5 or 6 days, for the 11th century, to meet the Julian calendar September 28 to October 2 is found, about 6 to 9 days after the autumnal equinox. Respectively for dates of March, we reach February 28 to 3 of March.

None of the above dates meet any important feast dedicated to Virgin Mary. Thus, under the assumption of zero AAS, it is possible that the orientation of the building was related to the autumnal equinox.

However, for a higher altitude (14°, 15° and 28°) and early morning hours (7.00-8.00 am) the three possible feasts of Virgin Mary, of 8th Sept, 25th March and 15th August, respectively, are met (Table 1).

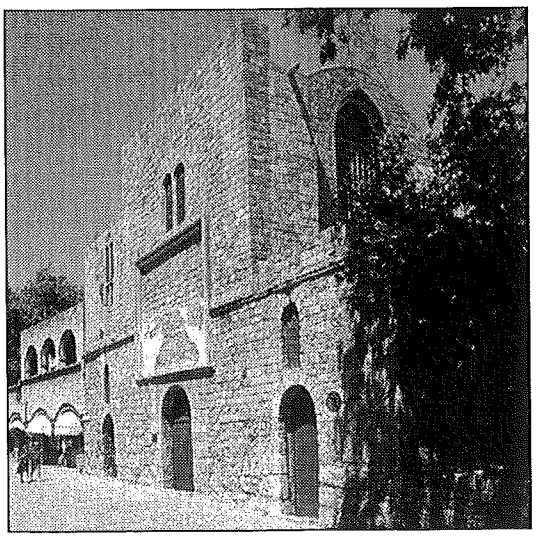

Fig. 1a: *Our Lady of the Castle from SW corner.*

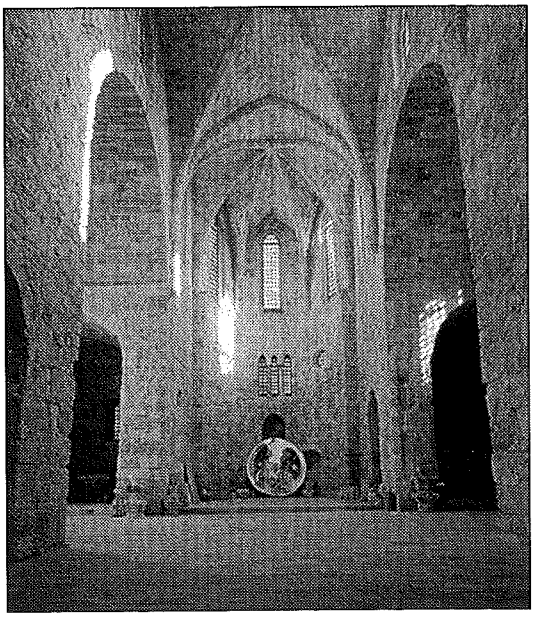

Fig. 1b: *Interior of the Church.*

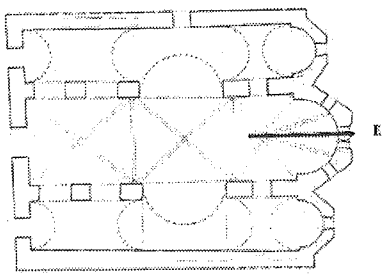

Fig. 1c: *Ground plan of the Church (Kollias, 1998): azimuth eastern direction is marked by arrow.*

2) St Nicolas or St Bernardine, Medieval City of Rhodes, 14th cent.

(Lat.= 36° 26' 29,1"N, Long.= 28° 13' 28,2"E, AzE = 92.5° ±0.5°, AAS=0° ±0.5°)

The little chapel of St Nicolas or St Bernardine is of western ribbed cross-vaulting type, and is built into the Katholikon of the Monastery of St Augustine (Fig.2). Formerly was known as St Bernard, or Abdul Djelil Mesjid (Dellas, 2000).

The dates derived from the eastern direction of the church found to be 5 to 8 of October or 5 to 8 of March (Gregorian calendar).

Regarding the dates of October, subtracting

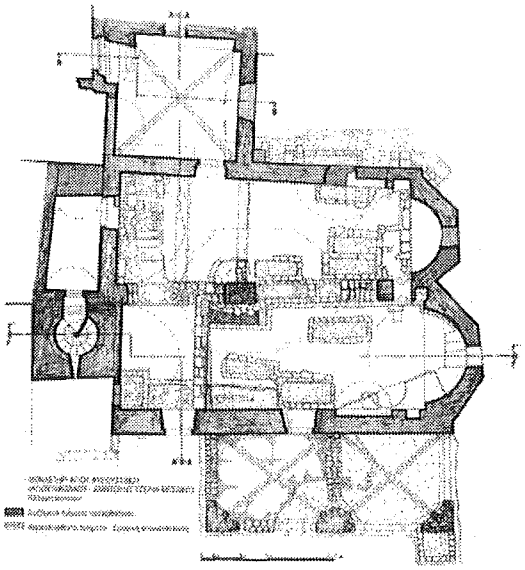

Fig. 2: *Ground plan of the Church of St. Nicolas or St Bernardine (Dellas, 2000): azimuth direction is marked by arrow*

approximately 8 days, for the 14th century, to meet the Julian calendar, the 27 to 30 of September is met, close to the autumnal equinox, and 25 to 28 of February respectively for dates of March.

With AAS=0°, the orientation of the church is not related to the Patron Saint, as the commemoration day of St Nicolas is celebrated by both Churches East and Latin on 6th of December (Grumel, 1958), and of St Bernardine on May 21 (Hampson, 1841-2).

However, for an AAS within the errors of the measurement (-0° 50' 59'') the day of 6th of December (St. Nicolas day) is met, but with adjustable azimuth to 118°, which certainly is an unacceptable case. However, St. Bernardine's day on 21st of May is met at AAS of 46° (c.9:00 am).

Following the first glittering the building followed the orientation of the church of Our Lady of the Castle, and more specifically 3 to 7 days after the autumnal equinox.

3) St Mark, Medieval City of Rhodes, 14th century

(Lat.=36° 26' 39.7" N, Long.=28° 13' 24.7" E, AzE =92° ±0.5°, AAS=0° ±0.5°)

The church of St Mark, known also as Satri Chelebi Mesjid is of free cruciform type, in which the dome is replaced by vaulted roof. (Orlandos, 1948; Kollias, 1998). The dates derived from the eastern direction of the church found to be 4 to 7 of October or 6 to 9 of March (Gregorian calendar).

Regarding the dates of October, subtracting approximately 8 days, for the 14th century, to meet the Julian calendar, the 26 to 29 of September is met, very close to the autumnal equinox. Respectively, for dates of March, we reach 26 of February to 1st of March.

The orientation of the church is not related to the Patron Saint feast day, which is celebrated by both Churches East and Latin on 25th of April (Grumel, 1958).

Although, it seems possible that the building followed the orientation of the church of Our Lady of the Castle about 3 to 6 days after the autumnal equinox, however, for AAS=34.5° the early morning sun glitters along the eastern axis of the altar on 25th of April i.e. the Saint Mark's Feast day.

4) St Marina, Medieval City of Rhodes, c. 14th – 15th cent.

(Lat.= 36° 26' 28.5"N, Long.= 28° 13' 45.3"E, AzE =92° ±0.5°, AAS=0° ±0.5°)

The dates derived from the eastern direction of the church found are 4 to 7 of October or 6 to 9 of March (Gregorian calendar).

Regarding the dates of October, subtracting approximately 8 or 9 days, for the 14th and 15th century respectively, to meet the Julian calendar, the 26 to 29 of September is met, very close to the autumnal equinox, and 26 of February to March 1 respectively for dates of March.

It is a small aisleless church, vaulted roofed, where the dedication name is given in documents of the Knights (Kollias, 1998), but it is not yet assigned with certainty to the existing building. In any case the orientation is not related to the Patron Saint feast day, which is celebrated by both Churches East and Latin on 17th of July (Grumel, 1958).

Here again, although the building seems either to have followed the orientation of the church of Our

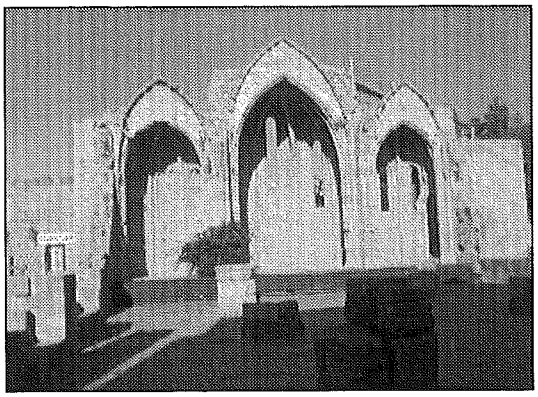

Fig.3a: *The remain apses of the Our Lady of the Burgh.*

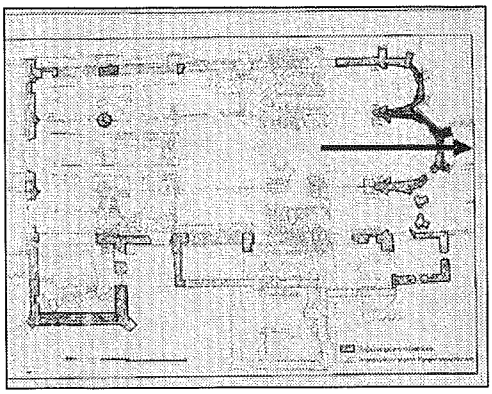

Fig.3b: *Ground plan of the Church (Dellas, 2000): azimuth direction is marked by arrow.*

Lady of the Castle, and more specifically 3 to 6 days after the autumnal equinox, or, for a higher solar altitude (42° ca. 8:30-9:00 in the morning) the Saint's Feast day of 17th July is met.

5) Our Lady of the Burgh, Medieval City of Rhodes, ca. 14th – 15th cent.

(Lat.= 36° 26' 57" N, Long.= 28° 13' 9"E, AzE =72° ±0.5°, AAS=0° ±0.5°)

The church of Our Lady of the Burgh (of the City), is of Western European type and preserves the three sanctuary apses (Fig.3ab) to their full height and most of the church and its chapels to a considerable height (Kollias,1998).

The dates derived from the eastern direction of the church found to be 22-25 of August or 17-20 of April (Gregorian calendar).

Regarding the dates of August, subtracting approximately 8 or 9 days, for the 14th and 15th century respectively, to meet the Julian calendar, the dates 13 to 17 of August are found, about 2 days before or after the Assumption, and April 8 to 12 respectively.

We suppose that the orientation of the church is related to the feast of the Assumption of Virgin Mary on August 15 (Grumel, 1958).

For a slight difference in AAS within the error of the measurement the 15th of August is found for first glittering of sunrays at 5:30 a.m.

6) Sts Theodore, Medieval City of Rhodes, ca. 14th – 15th cent.

(Lat.= 36° 26' 27.8"N, Long.= 28° 13' 39.8"E, AzE =102° ±0.5°, AAS=0° ±0.5°)

The church of Sts Theodore, known also as Hudai Mesjid, belongs to the type of aisleless building, with vaulted roof and dates circa the 14th or 15th cent. (Kollias, 1998). The dates derived from the eastern direction of the church found to be 26-29 of October or 12-15 of February (Gregorian calendar).

Regarding the dates of November, subtracting approximately 8 or 9 days, for the 14th and 15th century respectively, to meet the Julian calendar, the 17 to 21 of October is found. For dates of February, respectively, we get 3 to 7 of February.

Actually the commemoration day of Saints Theodores' is a movable feast, which is celebrated on the Saturday of the 7th week before the Easter Sunday (Grumel, 1958). There is also another important feast of St Theodore, which is celebrated on 8 February (Grumel, 1958).

We suppose that the church was aligned to meet the sunrise around the commemoration day of St. Theodore, which is met about or 1 to 5 days before the certain date. Indeed for a slightly higher altitude of 1° at c.7:00 a.m. the Patron's day of 8th of February is found.

7) St Catherine, (Ilk-Bihram), Medieval City of Rhodes, c. 14th – 15th cent.

(Lat.=36° 26' 45"N, Long.= 28° 13' 11" E, AzE =67° ±0.5°, AAS=0° ±0.5°)

The church of St Catherine (Fig.4.a,b,) was of the

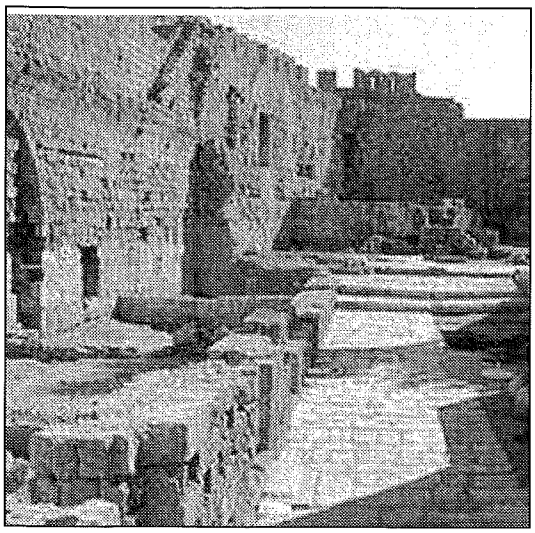

Fig.5a: *View of the Ruins of Our Lady of the Victory.*

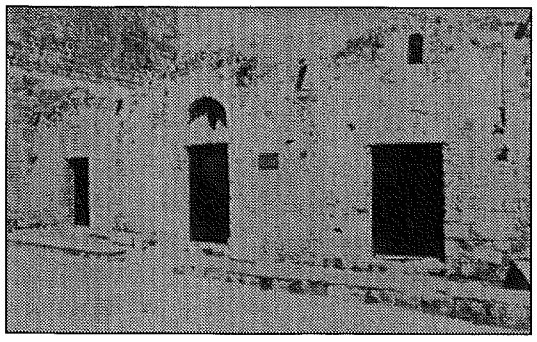

Fig.4a: *St Catherine's Church from SW.*

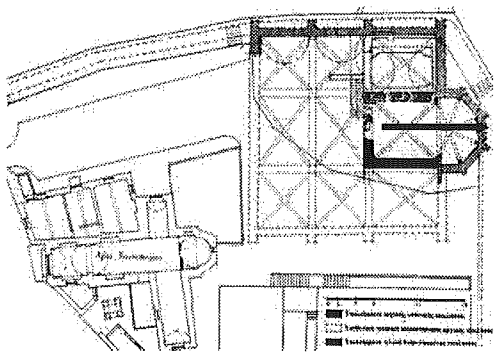

Fig.5b: *Ground plan of the church of Our Lady of the Victory (Dellas, 2000): azimuth direction is marked by arrow.*

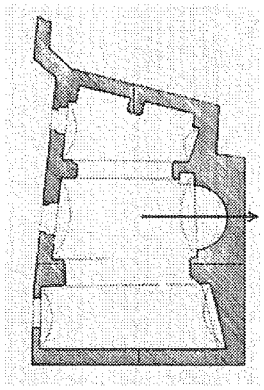

Fig.4b: *Ground plan of St Catherine's Church (Kollias, 1998); azimuth direction is marked by an arrow.*

type of three-aisled barrel-vaulted building and was built circa the end of 14th or the beginnings of 15th century (Kollias, 1998).

The dates derived from the eastern direction of the church found to be April 29 to May 2, or 10-13 of August (Gregorian calendar).

Regarding the dates of August, subtracting approximately 8 or 9 days, for the 14th and 15th century respectively, to meet the Julian calendar, the dates 20 to 14 of April are found. Respectively, for dates of August, the 1 to 5 of August is found, about 10 to 14 days before the Assumption of Virgin Mary.

The orientation of the building is not related to the commemoration day of St Catherine, which is celebrated by both Churches East and Latin on 25th of November (Grumel, 1958).

Taking into account that most churches at the Medieval City of Rhodes have changed original Saints' name, we could make the hypothesis that St Catherine's church was really dedicated to the Assumption of Virgin Mary on 15 August.

On the other hand, only at -0° 36' 52'' altitude but different azimuth of 117.5° St. Catherine's day of the 25th of November is met. But this reinforced azimuth is unacceptable, and we remain with former interpretation.

8) Our Lady of the Victory, Medieval City of Rhodes, 15th cent.

(Lat.= 36° 27' 3''N, Long.= 28° 14' 1''E, AzE =90° ±0.5°, AAS=0° ±0.5°)

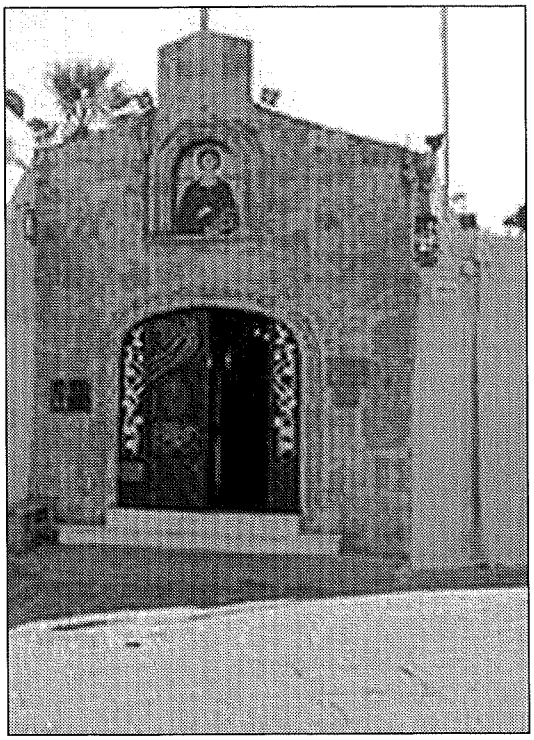

Fig.6a: *Entrance of St. Panteleimon's church.*

According to the tradition, the construction of this Latin church (Fig.5.a,b) begun in the latter part of 15th cent., when Grand Master was Pierre d'Aubusson (Bouhours, 1996) who honoured in this way the Virgin, because she had helped the Knights to defeat the Turks in the great siege of 1480. Today is a complete ruin and only a few traces of the cross-vaulting are left (Kollias, 1998).

The dates derived from the eastern direction of the church found to be September 30 to October 2, or 10 to 13 of March (Gregorian calendar).

Regarding the dates of October, subtracting approximately 9 days, for the 15th century, to meet the Julian calendar, we reach 21 to 23 of September. For dates of March, respectively, we reach 1 to 4 of March.

It is possible that the church was aligned to the sunrise around the 23rd of September, which coincides the important feast of the Conception of St John the Baptist and the autumnal equinox.

This aspect could be strengthened by Bouhours (1996), the biographer of d'Aubusson, who involved

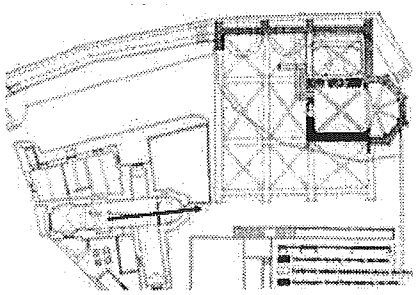

Fig.6b: *Ground plan of the church (Dellas, 2000): azimuth direction is marked by arrow.*

not only the help of the miracle-working icon of Virgin Mary, but also that of St John's, for the great victory against the Turks.

For higher AAS (9°, 14° and 23°) and early morning hours (6:30-7:30 am) the three possible feasts of Virgin Mary, of 8th Sept, 25th March and 15th August, respectively, are met.

9) St Panteleimon, Medieval City of Rhodes, 15th cent.

(Lat.= 36° 26' 27.5"N, Long.=28° 13' 47.1"E, AzE =95° ±0.5°, AAS=0° ±0.5°)

The church of St. Panteleimon, belongs to the type of free cruciform with dome, in which the east arm of the cross is short (Fig.6 a,b), while the other three relatively long and nearly equal (Kollias, 1998). According to Bouhours (1996), it had been constructed almost a little later of the church of Our Lady of the Victory by Grand Master d'Aubusson, because the date the Turks defeated, was on July 27, which coincides the commemoration day of St Panteleimon (Grumel, 1958).

The dates derived from the eastern direction of the church found to be 10-13 of October, or February 28 to March 2 (Gregorian calendar).

Regarding the dates of October, subtracting approximately 9 days, for the 15th century, to meet the Julian calendar, we reach 1 to 4 of October. Respectively, for dates of February, we reach 19 to 21 of February.

It is obvious that this way of sunrise the orientation is not related to Patron's Saint Day, but it seems very close to the day of Michelmas on September 29,

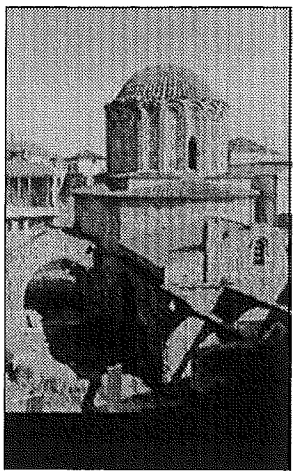

Fig.7a: *St Georges' Church.*

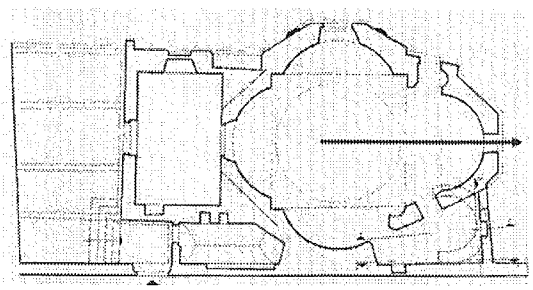

Fig.7.b: *Ground plan of St Georges'church (Kollias, 1998): azimuth direction is marked by arrow.*

and about 8 to 10 days after the autumnal equinox.

For higher altitude of 41° (c.8:45-9:00 am) St Panteleimon's day of 27th of July is found.

10) Holy Apostles, Medieval City of Rhodes, 15th cent.

(Lat.= 36° 26' 37.6" N, Long.= 28° 13' 27,9" E, AzE =96° ±0.5°, AAS=0° ±0.5°)

The Gothic type church of Holy Apostles is located very close to the ruins of the church of St John of the Collachium. The cross-vaulted apse of the church was recently discovered as it was concealed behind the oven of the old Muslim poorhouse. The name of the church is known by tradition, and is not yet possible to be assigned with certainty with the specific building (Kollias, 1998).

The dates derived from the eastern direction of the church found to be 13-15 of October, or 26-28 of February (Gregorian calendar).

Regarding the dates of October, subtracting approximately 9 days, for the 14th century, to meet the Julian calendar, we reach 4 to 6 of October. Respectively, for dates of February, we reach 17 to 19 of February.

Certainly the church is not aligned to meet the sunrise during the commemoration day of Holy Apostles, which is celebrated by both Churches Eastern and Latin, on June 30 (Hampson, 1841-2; Grumel, 1958). We suppose that the building followed the orientation of the previous churches at Rhodes, close to the autumnal equinox. For a higher AAS (51.5°) the Saints' Feast Day of 30th of June is found (Table 1).

11) St George, Medieval City of Rhodes, 15th cent.

(Lat.= 36° 26' 38.9" N, Long.= 28° 13' 22.7" E, AzE =94° ±0.5°, AAS=0° ±0.5°)

St Georges' church (Fig. 7a,b) is located at the Medieval City of Rhodes, was built circa the 15th century and is of the type quatrefoil with dome (Kollias, 1998).

The dates derived from the eastern direction of the church found to be 8 to 11 of October or 2 to 4 of March (Gregorian calendar).

Regarding the dates of October, subtracting approximately 9 days, for the 15th century, to meet the Julian calendar, the dates of September 29 to 2 of October are found. Respectively, for dates of February, we reach 21 to 23 of February.

Certainly the church of St. George is not aligned to meet the sunrise during the commemoration day of Saint, which is celebrated by both Churches Eastern and Latin, on April 23 (Grumel, 1958).

Although for AAS=0° the building followed the orientation of the previous churches at Rhodes, close to the autumnal equinox; once more for higher altitude of 36.5° i.e sunrise during liturgy, St George's day of 23rd of April is found.

12) St Paraskeve, (Takkeji-mesjid), Medieval City of Rhodes, 15th cent.

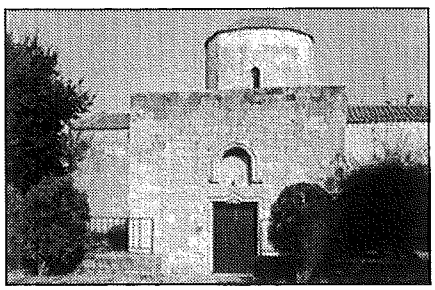

Fig.8: *St Paraskeve's Church.*

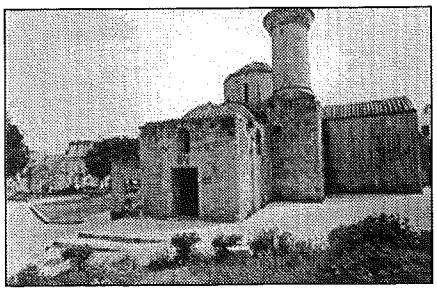

Fig.9a: *Church of Holy Trinity from SW.*

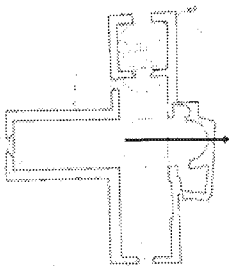

Fig.9b: *Ground plan of the Holy Trinity's church (Kollias, 1998): azimuth direction is marked by arrow.*

(Lat.= 36° 26' 35.8''N, Long.= 28° 13' 26.7''E, AzE =93.5° ±0.5°, AAS=0° ±0.5°)

The church of St Paraskeve (Fig. 8), belongs to the type of free cruciform with dome, and under the Ottoman occupation was a mosque (Kollias, 1998). The dates derived from the eastern direction of the church found to be 7-10 of October or 3-6 of March (Gregorian calendar).

Regarding the dates of October, subtracting approximately 9 days, for the 15th century, to meet the Julian calendar, the September 28 to October 1 is found. Respectively, for dates of March, the 22 to 25 of February is found.

Certainly the church of St. Paraskeve, is not aligned to meet the sunrise during the commemoration day of Saint, which is celebrated by both Churches Eastern and Latin, on July 26 (Grumel, 1958).

Apparently this as well building followed the orientation of the previous churches at Rhodes, about six to nine days after to the autumnal equinox. However, again here, for a higher altitude of the rising sun above horizon (39.5°) the Saint's Feast day of 26th July is found.

13) Holy Trinity, (Dolapli medjid), Medieval City of Rhodes, end of 15th- beginnings of 16th

(Lat.= 36° 26' 28.5'' N, Long.= 28° 13' 45.3''E, AzE =87° ±0.5°, AAS=0° ±0.5°)

The church of Holy Trinity (Fig.9 a,b), dates circa the late 15th or early 16th century and belongs to the type of free cruciform with dome building (Kollias, 1998).

The dates derived from the eastern direction of the church found to be September 24 to 26, or March 16 to 19 (Gregorian calendar).

Regarding the dates of September/October, subtracting approximately 9 or 10 days, respectively for the 15th and 16th century, to meet the Julian calendar, the period September 14 –17 is met, which is very close to the feast of the Conception of St. John the Baptist 23rd Sept. Respectively for dates of March, we reach 6 to 10 of March.

As the commemoration day of the Holy Trinity is celebrated 50 days after the Easter Sunday, and is the first Sunday after Pentecost (Grumel, 1958), the orientation of the building was not to face the sunrise during that certain date.

We suppose that the church was rather aligned to meet the sunrise during the feast of the Conception of St John the Baptist, which is also related to the autumnal equinox.

14) St Athanasios, Medieval City of Rhodes, beginnings of 16th cent.

(Lat.= 36° 26' 29.1'' N, Long.= 28° 13' 28.1'' E,

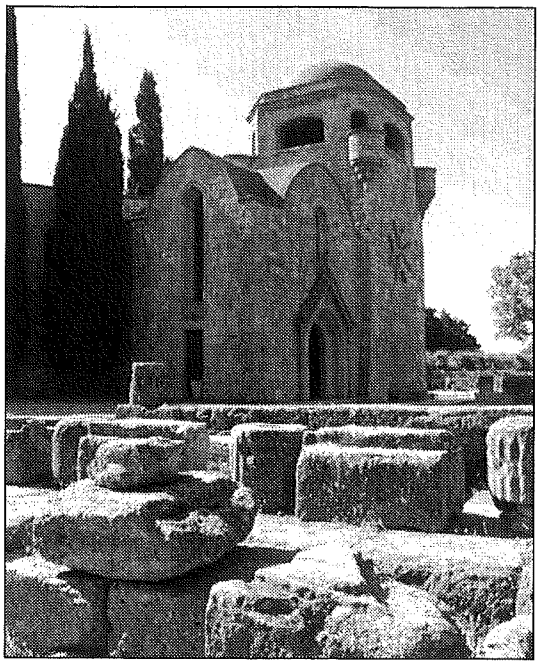

Fig.10a: *Church of Our Lady of Filerimo.*

AzE =92.5° ±0.5°, AAS=0° ±0.5°)

The church of St Athanasios belongs to the type of aisleless barrel-vaulted building, and is located very close to the wall of the Gate of St. Athanasios at the Medieval City of Rhodes (Kollias, 1998). The dates derived from the eastern direction of the church found to be 5 to 8 of October, or 5 to 8 of March (Gregorian calendar).

Regarding the dates of October, subtracting approximately 10 days, for the 16th century, to meet the Julian calendar, September 25 –28 is met, which is 2 to 5 days after the equinox. Respectively for dates of March, we reach 23 to 26 of February.

Certainly the church is not aligned to meet the sunrise during the commemoration day of Patron Saint, which is celebrated by Eastern Church on January 18th, and by Latin Church on May 2nd (Grumel, 1958).

We suppose that the building followed the orientation of the previous churches at Rhodes, and specifically two to five days after the autumnal equinox.

The Saint's Feast day of 18th of January is only met but with a different azimuth, an unacceptable possibility, thus we remain with earlier interpretation.

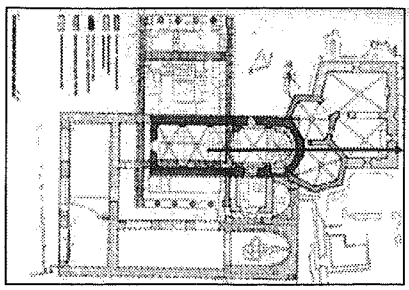

Fig.10b: *Ground plan of the Church.*

15) Our Lady of Filerimo, 14th cent.

(Lat.= 36° 26' 29.1'' N, Long.= 28° 13' 28.1'' E, AzE =92.5° ±0.5°, AAS=0° ±0.5°)

The dates derived from the eastern direction of the church found to be 5 to 8 of October or 5 to 8 of March (Gregorian calendar).

Regarding the dates of October, subtracting 8 days, for the 14th century, to meet the Julian calendar, September 27 –30 is met, about four to seven days after the equinox. Respectively for dates of March, we reach 25 to 28 of February.

The Church of Our Lady of Filerimo (Fig. 10 a,b) was re-built by the Hospitallers Knights, over the ruins of a pre-existed church dedicated to Virgin Mary, which was also built above the ruins of the ancient temple dedicated to Athena Polias of Ialyssos.

Certainly the Knights followed the direction of the pre-existed building, but the alignment does not seem to meet the sunrise at an important feast dedicated to Virgin Mary.

We could assume that the orientation of the church is related to the *"Festum Obdormitionis Virginis"*, Our Lady's Assumption, which is mentioned in ancient calendars of Church and was formerly celebrated on February 18, and much later was instituted to be celebrated on August 15 (Hampson, 1841-2).

On the other hand, on 29th of September was celebrated another important feast of the Latin Church: that of Michelmas dedicated to St. Michael Archangel. But some days earlier, on 23 of September is the important feast of the Conception of St John the Baptist, which also coincides to the autumnal equinox.

It seems most possible that the orientation is related to the autumnal equinox, and more specific or

Table 1: Fifteen Churches of Rhodes. Variable values of AAS and early morning hours with in situ measured azimuths (shown in text) and corresponding declination (δ), as well as, hypothetical azimuths ($A_{z,\ hypo}$) for respective AAS and δ, to meet the Patron Saint Feast Day,.

Church	Patron Saint/s Feast Day (Julian date)	Adjusted AAS & Az	Gregorian Date	δ
Our Lady of the Castle, Medieval City of Rhodes, 11th cent.	8 September (Birth of V. Mary) 25 March (Annunciation) 15 August (Assumption)	14° (c. 7:00-7:30 am) 15° (c.7:30-8:00 am) 28° (c.8:00 am)	13 September 31 March 20 August	4°33'1.41" ±0.39° 4°39'18.52" ±0.38° 12°11'24.38" ±0.36°
St Nicolas or St Bernardine, Medieval City of Rhodes, 14th cent.	6 December (St. Nicolas) 21 May (St. Bernardine)	If sun rises at an AAS: -0°50'59" (ca. 7:12'33" am) $A_{z,\ hypo}$=118° 44' 23", δ= -23° 18' 7.8" 46° (c.9:00 am)	30 May	21°40'4.62" ±0,3°
St Mark, Medieval City of Rhodes, 14th century	25 April	34.5° (8:00-8:15 am)	3-4 May	15°51'33.92" ±0.34°
St Marina, Medieval City of Rhodes, c. 14th – 15th cent.	17 July	42° (c.8:30-9:00am)	26 July	19°54'31.37" ±0.13°
Our Lady of the Burgh, Medieval City of Rhodes, c. 14th – 15th cent.	15 August (Assumption)	0° (ca. 5:30 am)	24 August	11° 17' 17.64" ±0.16°
St Theodores, Medieval City of Rhodes, c. 14th – 15th cent.	8 February	1° (c.7:00am)	17 February	-12°1'33.84" ±0.4°
St Catherine, (Ilk-Bihram), Medieval City of Rhodes, c. 14th – 15th cent.	25 November	If sun rises at an AAS: -0°36'52" (c. 7:3'46" am.), $Az,\ hypo$ =117.5° δ=-22° 13' 56.1"		
Our Lady of the Victory, Medieval City of Rhodes, 15th cent.	8 September (Birth of V.Mary) 25 March (Annunciation) 15 August (Assumption)	9° (ca. 6:30 am) 14° (ca. 7:30 am) 23° (ca. 7:30 am)	17 September 3 April 24-25 August	2°31'35.83" ±0.4° 5°30'50.81" ±0.39° 10°47'22.6" ±0.38°
St Panteleimon, Medieval City of Rhodes, 15th cent.	27 July	41° (c.8:45-9:00 am)	5 August	17°28'32.73" ±0.31°

Holy Apostles, Medieval City of Rhodes, 15th cent.	30 June	51.5° (ca 9:30 am)	9 July	22°29'33.61" ±0.27°
St George, Medieval City of Rhodes, 15th cent.	23 April	36.5° (ca 8:30 am)	3 May	15°37'19.34" ±0.33°
St Paraskevi, (Takeji_medjid), Medieval City of Rhodes, 15th cent.	26 July	39.5° (8:30-8:45 am)	4 August	17° 36' 39,74" ±0,32°
Holy Trinity, (Dolapli Medjid), Medieval City of Rhodes, end of 15th-beginning of 16th	Depends on Easter Date Proposed Feast Day: 23rd Sept., St John's conception			
St Athanasios, Medieval City of Rhodes, beginnings of 16th	18 January	If sun rises at an AAS: -0°45'56"(c. 7:14'46" am.), $A_{z,\,hypo}$ =112° 35' 24", δ=-18° 28' 38.6"		
Our Lady of Filerimo, 14th cent.	8 September (Birth of V.Mary) 25 March (Annunciation) 15 August (Assumption)	12° (c. 6:45-7:00 am) 16°(c. 7:15-7:30 am) 27.5°(c. 7:45-8:00 am)	17 September 4 April 24 August	2°20'51.3" ±0.39° 4°53'48.21" ±0.39° 11°13'45.26" ±0.36°

4 to 7 days after the equinox.

For higher altitudes the three important Feasts of Our Lady (8th Sept., 25th March and 15th August) are found (Table 1). (Dellas, 2000): azimuth direction is marked by arrow.

16) St Mamas, Menetes, Karpathos Island, 11th or 12th cent.

(Lat.= 35° 28' 50.4'' N, Long.= 27° 8' 49.9'' E, AzE =79° ±0.5°, AAS=30° ±0.5°)

The church of St Mamas is located at Menetes village, close to the Akropolis of Karpathos. It is a single-aisled domed building, of small dimensions, dating probably on the 11th or 12th cent. (Moutsopoulos, 1978). The dates derived from the eastern direction of the church found to be July 4 to 12, or May 31 to June 7 (Gregorian calendar).

Regarding the dates of July, subtracting 6 or 7 days, respectively for the 11th or 12th century, to meet the Julian calendar, June 27 to July 6 is reached. Respectively, for dates of May, we reach May 24 to June 1.

The church is not aligned to meet the sunrise during the commemoration day of Patron Saint of the sheperds, which is celebrated by Eastern Church on September 2 (Grumel, 1958).

We assume that the orientation was not made by intention but randomly.

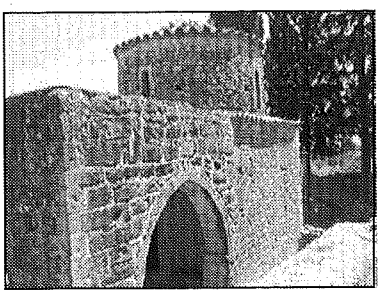

Fig.11a: *Church of St Paul from SW.*

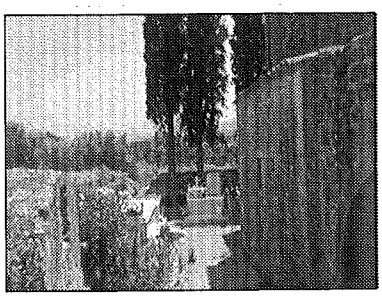

Fig.11b: *Eastern horizon of the church from NW.*

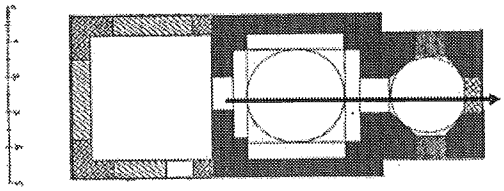

Fig.11c: *Ground plan of the church (Gerola,1993).*

17) St Paul, Pyrgiotissa of Herakleion, Crete Island, early 14th cent.

(Lat.= 35° 3' 0'' N, Long.= 24° 0' 49'' E, AzE =115° ±0.5°, AAS=5° ±0.5°)

The small sinlge-aisled church (Fig.11a,b,c) is located at the village of St Ioannis, about 1 km southern of Phaistos archaeological place.

According to the founding inscription, the church was probably dedicated to St Paul (the part of the name of Paul has been destroyed, but it is known by tradition) and it was rebuilt by a priest named Peter, when emperor of Byzantium was Andronicus Palaiologus about 1304 BC, above the foundation of a preexisted building perhaps an early Christian Bapteste-rion (Psilakis, 2002; Gerola, 1993; Spanakis, 1993; Xanthoudides, 1904).

The dates derived from the eastern direction of the church found to be 18 – 23 November or 18 – 23 January (Gregorian calendar).

Regarding the dates of November, subtracting approximately 8 days, for the 14th century, to meet the Julian calendar, we reach 10 to 15 of November and for dates of January, we reach 10 to 15 of January.

As the commemoration day of Apostles Peter and Paul is celebrated by both Churches Eastern and Latin, on June 29 (Grumel, 1958:326), it is obvious that the building was not aligned to meet that date.

The Latin Church has instituted, since the 12th century, an important feast of the Conversion of St Paul to the Christianity, which is celebrated on January 15th, a similar day found above for the orientation, but it does not seem to be accepted by the Eastern Church (Hampson, 1841-2).

We must notice here that during the years of the rebuilt of the church, the area was under the Venetian Domination, and perhaps influenced of the ecclesiastical customs.

On the other hand, on January 16th the Eastern Orthodox Church commemorates the Veneration of the Precious Chains of the Holy and All-Glorious Apostle Peter.

As the name of dedication is not preserved in the inscription, the church could be dedicated to Apostle Peter. This aspect could be strengthened by the fact that Xanthoudides (1904) described: "*that, according to the inscriptions found in Cretan churches, it was a common practice for the priests to name the church after their first name*".

18) St George Galatas, Hagia Triada, Pyrgiotissa, Herakleion, Crete Island, early 14th cent.

(Lat.= 35° 2' 0'' N, Long.= 24° 0' 47'' E, AzE =77° ±0.5°, AAS=11.5° ±0.5°)

The small church of St George (Fig.12) is located at the southern edge of the Hagia Triada archaeological place, near Phaistos and was built in the beginnings of 14th century, between 1302 and 1317 AD (Xanthoudides, 1904). It is single-aisled and tiled-roofed chapel, which preserves frescos and built-in iconostasis (Gerola, 1993; Spanakis, 1993).

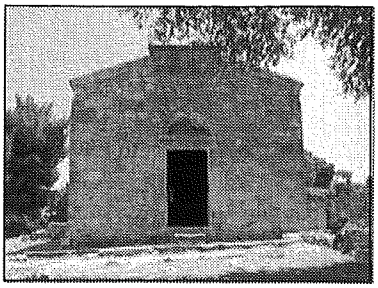

Fig.12: *Entrance of the Church of St. George Galatas.*

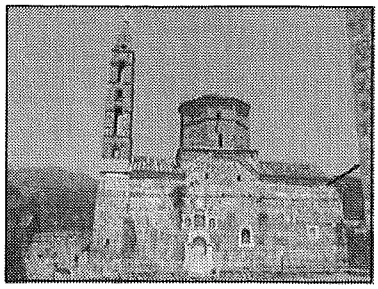

Fig.13a: *Entrance of St Spyridon' Church.*

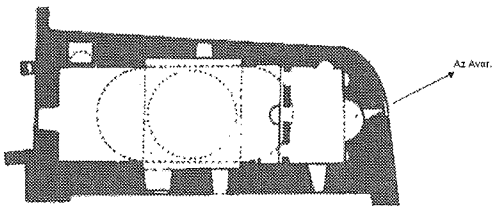

Fig.13b: *Ground plan of the Church (Michailidis et al,1989).*

The dates derived from the eastern direction of the church found to be 12– 15 August or 27 – 30 April (Gregorian calendar).

Regarding the dates of August, subtracting approximately 8 days, for the 14th century, to meet the Julian calendar, we reach 4 to 7 of August. Respectively, for dates of April, we reach 19 to 22 of April.

We suppose that the church of St George was aligned to meet the sunrise during the feast of the Saint, which is on April 23rd (Grumel, 1958), but is always celebrated after the Easter Sunday.

19) St Spyridon, Mani, Peloponesse, 18th cent.

(Lat.=36° 53' 30'' N, Long.= 22° 14' 30'' E, AzE =90° ±0.5°, AAS=14° ±0.5°)

The church of St Spyridon (Fig. 13a,b) is located at the northeastern corner of the fortified settlement of Kardamyli, near the gate of the Castle. It is a single-aisled with large dimensions, barrel-vaulted domed basilica, which dates in the first half of the 18th century (Michailidis and Christophidou, 1982).

The dates derived from the eastern direction of the church found to be 6 – 9 September or 2 – 5 April (Gregorian calendar).

Regarding the dates of September, subtracting approximately 11 days, for the 18th century, to meet the Julian calendar, we reach 26 to 29 of August. Respectively, for dates of April, the period 22 to 25 of March is met.

Certainly the church is not aligned to the commemoration day of St Spyridon, which is celebrated on December 12 (Grumel, 1958).

The date that the church seems to be aligned is possibly that of March 24 or 25, which coincides to the important feast for Christianity the Annunciation of Mother Mary, and is also related to the vernal equinox.

20) St Christophore, Phokis, 6th – 7th cent.

(Lat.= 38° 37' 45,2'' N, Long.= 22° 31' 11,1'' E, AzE =109° ±0.5°, AAS=20.5° ±0.5°)

The ruins of St Christophore's church (Fig.14), are located at the region Polydroson or Souvala, Phokis, very close to the springs of Kiphissos River. The church probably belonged to the type of three-aisled basilica and its dedication is known by tradition, and not based on evidence (Lazaridis, 1966).

The dates derived from the eastern direction of the church found to be September 30 to October 3, or 10 to 13 of March (Gregorian calendar).

Regarding the dates of October, subtracting approximately 2 or 3 days, for the 6th and 7th century respectively, to meet the Julian calendar, we reach September 27 to October 1. Respectively, for dates of March, we reach 7 to 11 of March.

Certainly the church is not aligned to meet the commemoration day of the (ambiguous) Patron Saint, which is celebrated by the Eastern Church on May 9th (Grumel, 1958). We suppose that the ori-

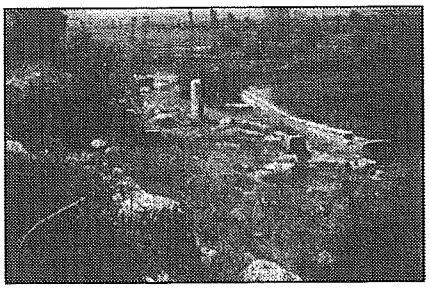

Fig.14: Ruins of the church of St Christophore (Lazaridis, 1966).

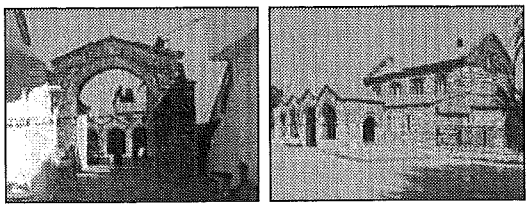

Fig.15: Church of St. Theodora (entrance and view from Southwest Corner).

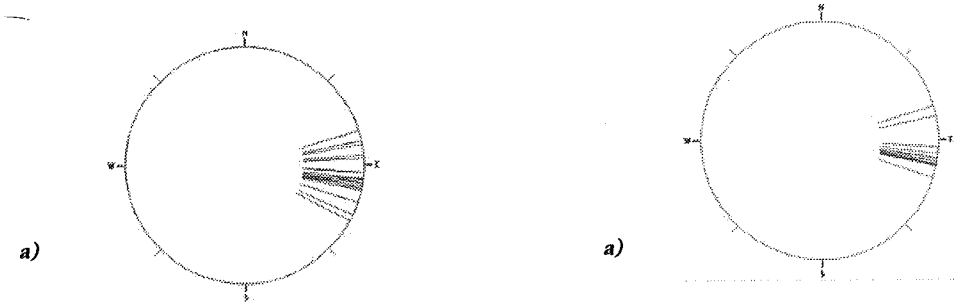

Fig.16: Distribution of all churches' azimuths highlighting the eastern range of all of them and those from Rhodes alone. a) Azimuth distribution of all Churches presented in this paper. b) Azimuth distribution of Churches located at Rhodes.

entation is related to the autumnal equinox and more specifically 4 to 8 days after the equinox.

21) St Theodora, Arta, Epirus, 13th cent.

(Lat.= 39° 9' 45,8" N, Long.= 20° 59' 1,5" E, AzE =81° ±0.5°, AAS=6° ±0.5°)

The church of St Theodora (Fig.15), was the Catholicon of a monastery dedicated primarily to St George, and had been founded by Theodora, wife of the ruler of Arta and Byzantine Emperor, Michael II Komnenos Doukas, and (Moutsopoulos, 2002; Papadopoulou, 2002). According to St. Theodora's vita, she entered monastic life after being widowed and was the only woman that became Saint during the thirteen century (Talbot, 1996). After her death, the church was dedicated to St Theodora.

The dates derived from the eastern direction of the church found to be August 30 to September 2, or 9 to 12 of April (Gregorian calendar).

Regarding the dates of September, subtracting approximately 7 days, for the 13th century, to meet the Julian calendar, we reach August 23 to 26. Respectively, for dates of April, we reach 2 to 5 of April.

The alignment of the building does not meet the sunrise during the commemoration day of St George's (on 23 April) or St Theodora's, which is on February 11th according to Grumel (1958) or on March 11th (Talbot, 1996; Eustratiades, 1935).

It seems possible that the orientation is related to the great feast for Christianity, the Annunciation, which is celebrated on 25th of March, and more specifically about 7 to 10 days after the certain feast.

Conclusion

For sunrise **exactly on the perceptible horizon** the results indicated that, out of 21 churches: 13 are aligned near the autumnal equinox, 3 have relation with the feast of Patron Saint, 4 are related to other important feast of Christianity as Annunciation (25 March), Conception of St John the Baptist (23 September), Michelmas (29 September) or Assumption of

Virgin Mary (15 August), and 1 orientated randomly.

For the 15 Churches of Rhodes **an adjustable value of AAS** (Table 1) indicated that sun's position along the eastern extrapolated axis of altar was in early morning (6:30-9:30 am) and at angular altitudes +9 to 51.5° above horizon. For such an early morning sunrise most orientations could be possible to meet Saint's name day.

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