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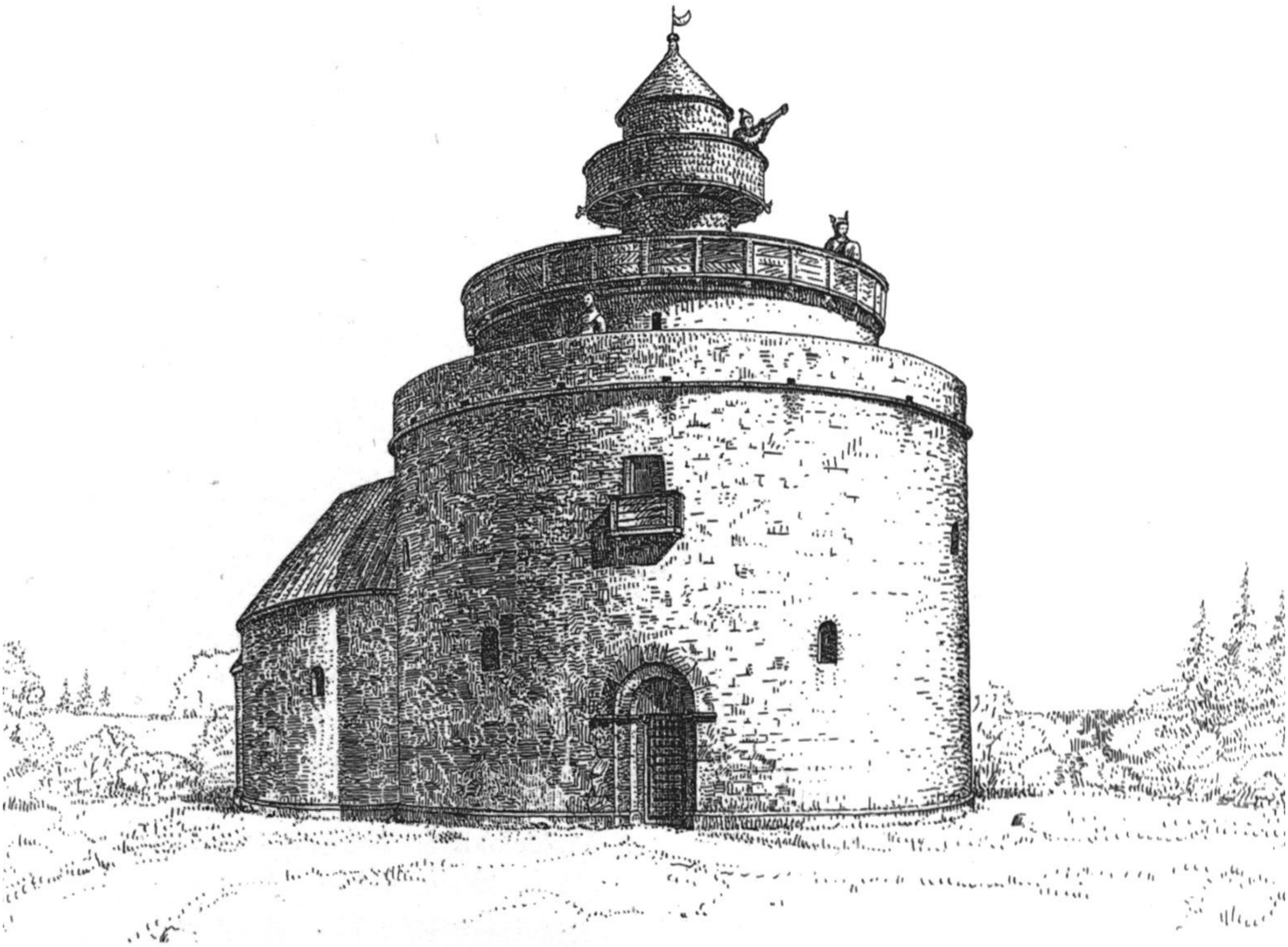
The Bornholm Mystery

- a case study research into the island's medieval churches

by Erling Haagensen



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This is a follow-up to the article "Medieval Round Churches and the Shape of the World" (Haagensen & Lind 2015). Case Study Research (Yin 2018) has been used as a method, which makes it possible to test the hypothesis presented in the article. In addition, the archaeological and historical data of the article are further substantiated. It should be emphasized that this is still a preliminary study, which indicates opportunities for more exhaustive research, but at the same time it is important to highlight the possible very comprehensive historical perspectives that may result from such research.

Abstract:

Location: Bornholm (a Danish island in the Baltic Sea between Sweden and Poland)

Purpose:

To challenge the current hypothesis: that the island's four round churches are designed for defense - and replace it with the hypothesis that the purpose was to gain knowledge about both the universe and the shape of the Earth - and at the same time perform practical experiments to develop new techniques for map drawing.

Method:

The first part is a case study research based on existing measurements and on observations in situ.

The second part is a case study research based on a hypothesis about the function of the churches as astronomical observatories (Haagensen & Lind 2015):

Using a table of coordinates for fix points and the Danish Geodata Agency's program KMSTrans 2, the churches relative positions in the landscape are analyzed and their positions are compared with a plane geometric model, which is assumed to be the model for the churches' location.

The method for measuring the length of a parallel, previously described (Haagensen & Lind 2015), is tested using the KMSTrans 2 program.

The third part is a presentation of historical data selected to support a hypothesis that it was Christian intellectuals within the Order of the Knights' Templar, in collaboration with Muslim intellectuals on the Iberian Peninsula, who is responsible for this project on Bornholm, and that the project was orchestrated by the Order of the Knights Templar.

Result:

When the positions of the churches in the landscape are compared with a plane geometry assumed to be the model, an apparent systematics emerges in the discrepancies between the model and the location of the churches.

This systematics seems to relate to *the orientation of the geometry in relation to the geographical north*. If this systematics is assumed to have been deliberate, all angles between the churches in the landscape become accurate within one hundredth of a degree.

Using the method, based on measurements of the meridian convergence as described in *Medieval round Churches and the Shape of the Earth*, it is confirmed that the Bornholm landscape geometry makes it possible to calculate both the length of the earth's parallels and the length of the earth's meridian.

The northernmost point in the geometry is C on Christiansø. The southernmost of Bornholm's medieval churches is Povlsker. The distance on the meridian between the parallel through C and the parallel through Povlsker reveals an exact geometric relationship, which indicates that the landscape geometry also has been used to measure the size of the Earth using the traditional Eratosthenes method.

Main conclusion:

The analysis of the location of the churches and their interiors shows very clearly that the churches could not have had anything at all to do with defense. The light openings in Østerlars Church's third floor seem to make the church a perfectly accurate calendar and a perfectly accurate sundial. This could mean that the movements of the sun throughout the year were so accurately mapped in relation to sidereal time that a conclusion based on these data would be controversial in relation to the dogmatic worldview of the Catholic Church.

The geometric relationship between C and Povlsker indicates that the geometry was also used in the traditional way to measure the size of the Earth (Eratosthenes' method). It is thus confirmed that the measurements which could be made from the churches, could lead to the conclusion that the Earth is spherical.

An apparently systematic deviation in the angular accuracy within the geometry, which seems to be connected to the orientation of the plane geometry in relation to the geographical north, leads to the hypothesis that a technique for map drawing, based on projection, was tested - and that developing this technique is the explanation behind the accuracy we find in the so-called Portolan Charts.

Selected historical data are found to support - but do not prove - the hypothesis that the experiments on Bornholm were carried out by the Order of the Knights Templar - thus also support that the Order of the Knights Templar could be behind the construction of the Portolan Charts.

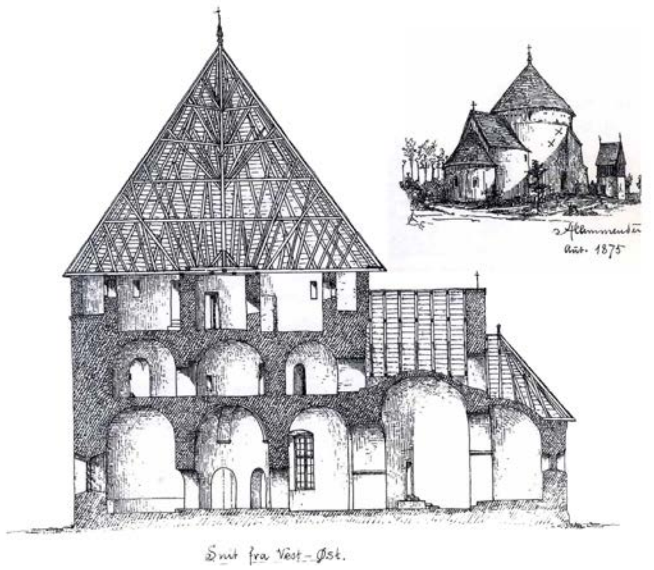


Figure 1: Profile of Østerlars from Holm 1878.

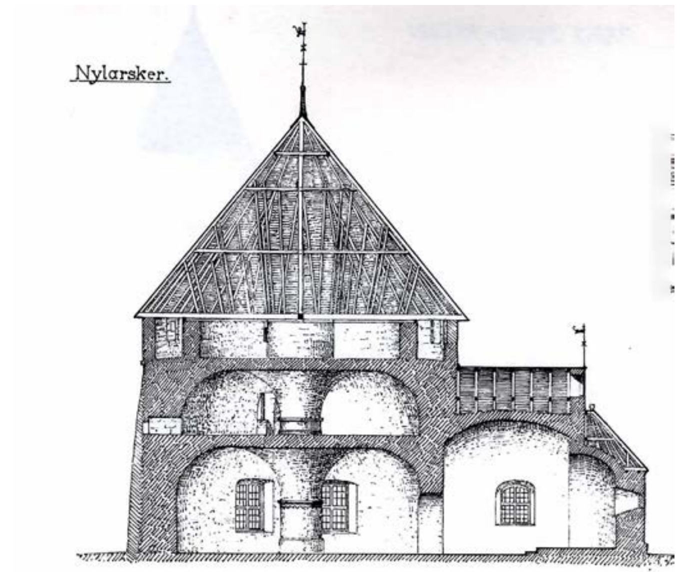


Figure 2: Profile of Nylars from Holm 1878.

Introduction:

15 medieval churches on the small island of Bornholm nestle over a secret. There are no written sources to indicate who built them, when they were erected, or what the purpose was of several extraordinary architectural details in the churches that, as we shall see, clearly had no religious purpose.

It is not unique to lack written sources to shed light on who was responsible for the original construction of a medieval church. Even though we are in a period where we have written sources, the building of a church need not always to have been considered so significant as to have written and filed the information.

What is special about the churches on Bornholm, however, is that common features in their unusual architecture and common features in several peculiarly secular details show us, that the churches must be built over a shorter number of years as a coherent project in a pre-assembled plan for new churches on Bornholm.

Thus, in a period with written sources, it is a mystery why no written sources exist for such a comprehensive and expensive project.

Who planned it and where did the money come from?

There is another considerable medieval building project on Bornholm, where there is a similar lack of sources to elucidate who was responsible for the construction. This applies to the Hammershus fortress.

Hammershus was in the Middle Ages Northern Europe's largest fortress. Analyzes show that, with its size, it required a staff of about 1,000 soldiers to defend the stronghold.[1]

First, it seems illogical to build a fortification of these dimensions – at this time larger than any of the medieval castles built by the Scandinavian kings - on a remote island. The construction has required both many workers and costed a considerable amount. Therefore, again, it is a mystery why we have no written sources about who built the fortress, who paid for it or what the purpose was with a fortress of this size on this remote island.

This lack of source material for as many as two extraordinarily large and probably reasonably contemporary construction projects on the little island is remarkable and therefore it is a coincidence that still lacks sufficient attention.

The question is, however, whether the lack of written sources for both projects can be explained by a connection between the two construction projects, which leads to a political desire to deliberately remove all traces of this connection. This will be discussed later.

The 15 medieval churches are themselves mysterious.

There is a consensus that they are contemporaries. Four of them are round, which is an unusual concentration of round churches. Their architecture is also unconventional with three stocks, and vaults supported by only one central pillar, going through all three stocks (drawing figure 1 and 2).

The additional 11 conventional churches are in fact also unconventional due to their contemporaries' strong western towers, built in Romanesque architecture on four floors and with massive vaults. (drawing figure 3 and 4)

Only three round churches have been preserved in the rest of Denmark (Thorsager, Bjernede and Horne) and they are all on two floors.

This means that all eight round churches have a room above the downstairs church room. We will subsequently support the hypothesis that this additional church room on the second floor has had the same purpose and the same function in all eight round churches.

The four Bornholm round churches, however, are distinguished by being on three floors – although one, the probably most recently built, Nyker (New Church), was only prepared for the third floor.

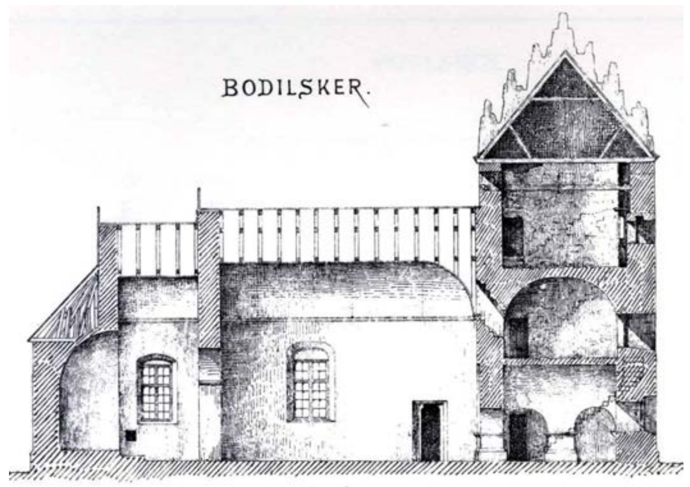


Figure 3: Profile Bodilsker from Holm 1878.

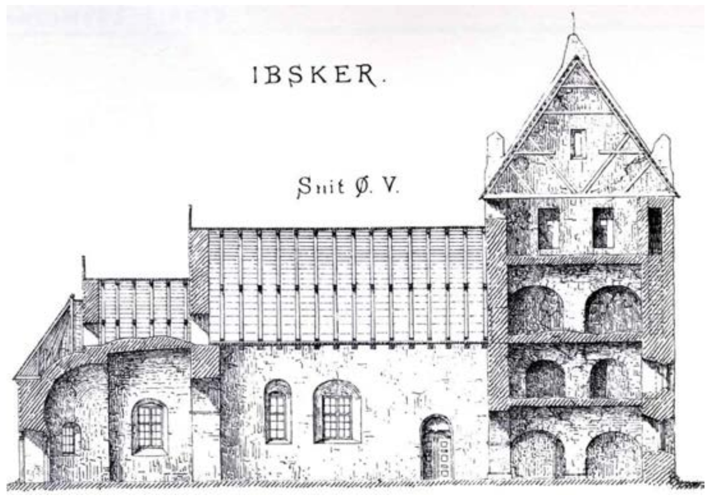


Figure 4: Profile Ibsker from Holm 1878.

Prevailing hypothesis

The prevailing hypothesis among historians is that their additional floors should be explained by having served as defense works.

The defense hypothesis has, however, been met with criticism.

First: The topographical selection of the churches' location is not where one would choose a place for a defense structure: "*With regard to local conditions, all old castles are built in hilly terrain. Nothing had been easier than finding suitable sites for the construction of a fortification on top of rocks or other natural protection. . . The round churches, on the other hand, are all built on unprotected land, two of them on the friendliest and most accommodating plains, the other two also in easily accessible places, though the landscape far and wide around them is intensely hilly* "(Friis 1856), see Figures 5,6,7 and 8.

Second: Expected necessary arrangements for defense are missing, for instance: "*. . . a building from the Middle Ages - before the invention of firearms - which is not designed for vertical defense from the parapet, and above all, from above the entrance, is not from the outset built for defense, although in eyes of present days it may seem suited for this due to its thick walls*" (Blom 1895 in his description of Østerlars).

Further: There are no historical documents confirming defense purposes, and no arrowheads or other archaeological evidence of battle has been found in or around the churches.

In fact: *Only the need for an explanation of the purpose of a third floor - combined with an interpretation of a single architectural detail in Østerlars and Nylars - leads to the idea of a defense purpose*.

This single architectural detail is a small path, originally open to the sky, surrounding the third floor of both Østerlars and Nylars. Because this detail is so crucial to the defense hypothesis, we shall in the following analyze this in more detail:

The floor of the path rests on the thick outer wall to the lower floors and was shielded outwards through a low, thin parapet. In both churches, the path today has been enclosed behind the present conical roof of the churches (see Figures 1 and 2), but it was originally open to the sky (see Figures 9 and 10). The interpretation of this detail is that the path has served as an open area for archers, thus it is not only the strongest, but in fact the only argument that the building has had a defensive purpose. But when we in the following compare the design with a logical design for a defense purpose, we see that it could never have been intended for defense.

1: To be able to function as a defense structure it is essential for a parapet to be furnished with battlements, but apparently none of the round churches were originally furnished with battlements on top of their exceptionally low parapet.

Nylars has additions to the original parapet that are interpreted as battlements: "*The ca. 75 cm thick parapet was originally only approx. 90 cm high, but was early equipped with battlements, of which 10 are preserved ... difficult to get around is that the*

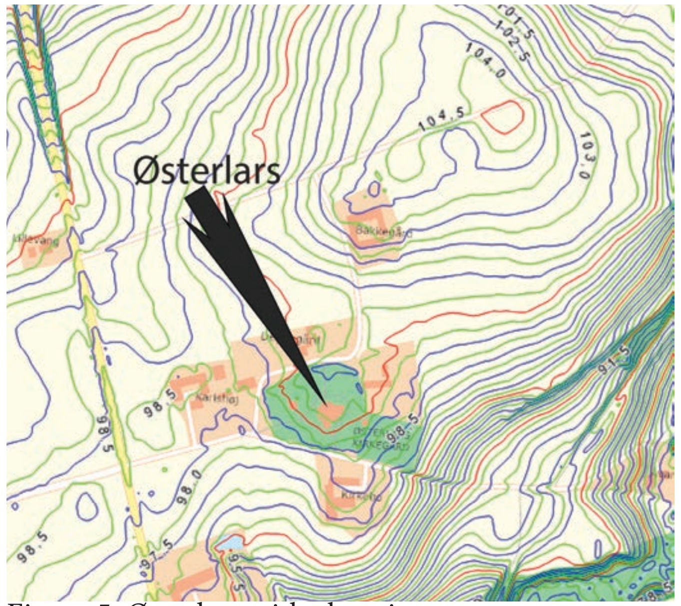


Figure 5: Østerlars with elevation curves.

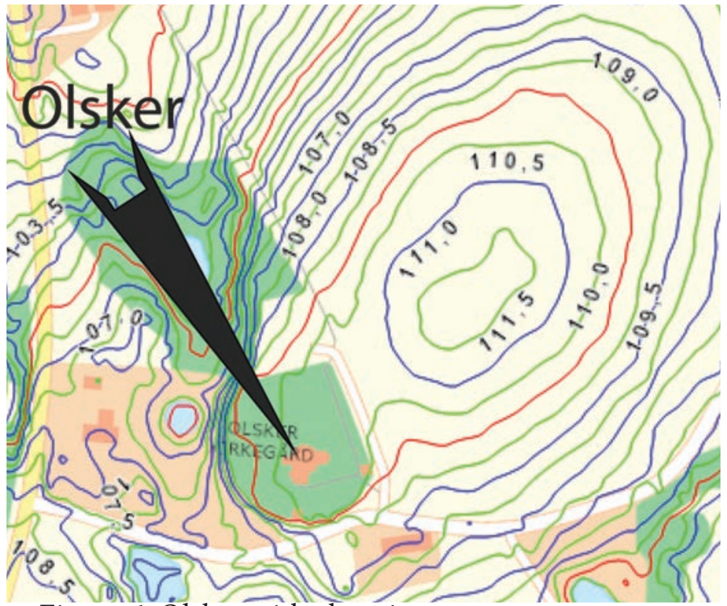


Figure 6: Olsker with elevation curves.

Figure 7: Nykirke with elevation curves.

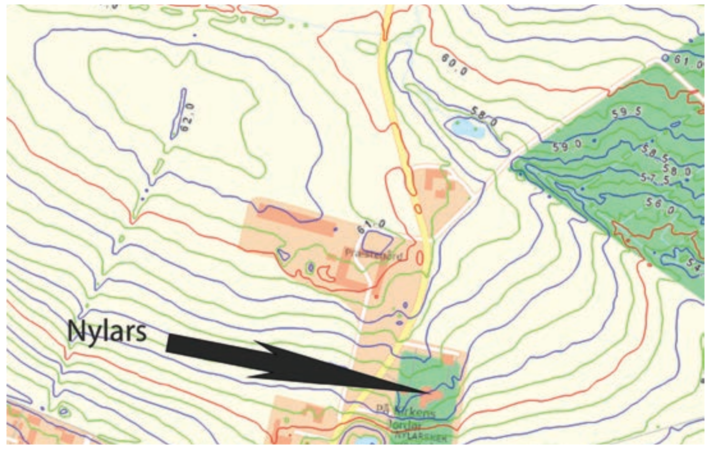


Figure 8: Nylars with elevation curves.

mortar in the first phase of the oldest parapet is smoothed over the upper edge of the wall in such a way that there can be no doubt, that the battlements, as old as they are, should nevertheless be secondary". (Norn et al. 1954. p 258).

Thus, there was no battlements on the parapet wall originally, which is strange. Why build a defense reliant on battlements and not apply them from the beginning? The question is, if the later added wall fragments really were meant to be battlements. They are about 120 cm high, which means that their peak is (90 + 120) cm = 2.10 meters above floor level, which is exceptionally high for such protection.

The possibility exists that these wall fragments were built to support the roof as the church got its current roof covering the previously open parapet walk. The reason why it might be decided from the beginning to let the roof rest on wall sections instead of on a solid wall, could be a consideration for the roof woodwork. A completely enclosed roof tends to create moisture and rot.

The open space between the wall fractions, hitherto interpreted as embrasures, was later walled up with boulders, and in this walled up section: "*the mortar is fresh and not weathered. The open space must therefore have been walled up very late, possibly only at the same time or even after the church was given the current large conical roof, which is pulled beyond the parapet walk*" (Norn et al. 1954, p. 258). The authors thus support the possibility that the space was walled up after the church got its conical roof.

When the first conical roof was laid is unknown.

The roof's load-bearing beams are laid from the central pillar out to the ring wall like struts from an umbrella. Remarkably, this construction follows the pattern that two beams rest on the original masonry wall on top of the parapet wall - interpreted as battlements - while only one beam then rests on the new masonry in the space between the "battlements", and so on.

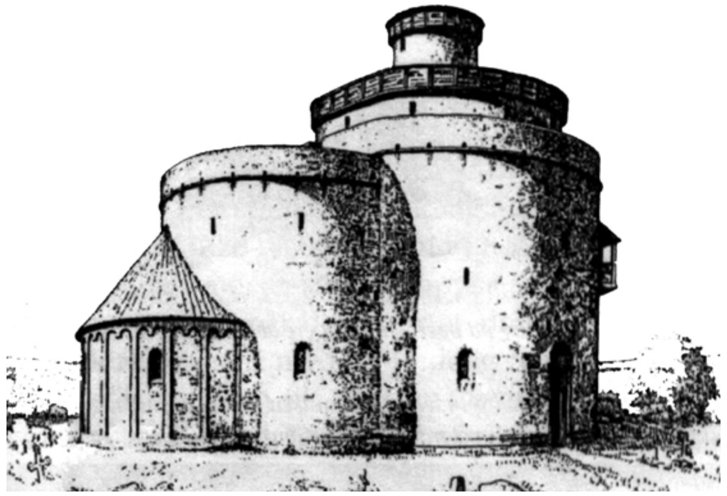


Figure 9: Danish National Museum, reconstruction of Østerlars (Charles Christensen).


Figure 10: Danish National Museum, reconstruction of Nylars (Charles Christensen).


Figure 11: Two beams rest on the solid wall fractions, while one beam rests on the new wall in the spaces, but as can be seen, these beams have previously rested on a beam that bridged the gap.


Figure 12: Olsker Church.

There is still an example where you can see that the beams resting on the new masonry originally rested on a wooden bar (se figure 11), which means the roof must have been laid before the space between the original wall fractions was bricked up. Taken together, these details suggest that the old wall fractions were not intended as battlements, but were erected as supports for the conical roof, which explain more logically their height and why they are secondary to the original parapet masonry.

Olsker is the only one of the four Bornholm round churches that clearly shows that it is designed to be both a church and a defense. But it is also clear that the church is designed for defense at a time when using rifles and cannons and therefore it cannot be the original church that has had these functions.

The church's third floor shows nine openings in the masonry, which today are closed with gates (see figure 12)

The Swedish historian Hugo Frölén claims in 1911 that 12 of our preserved round churches in Scandinavia have devices that prove that they were intended for defense. (Frölén 1911). In Olsker, these devices are the nine openings, which Frölén shows in an illustration how they can work for that purpose (see figure 13)

First, it is logical that a gate with that width is unsuitable for archers. It also looks as if Frölén has drawn a defender with a rifle. But such a gate is neither logically intended for guns. But the gates are logical for defense in connection with cannons.

When we look at the floor behind these gates, the original floor has been dug for a grave that fits a small cannon. (see figure 14)

Why? We do not know. Perhaps it may have to do

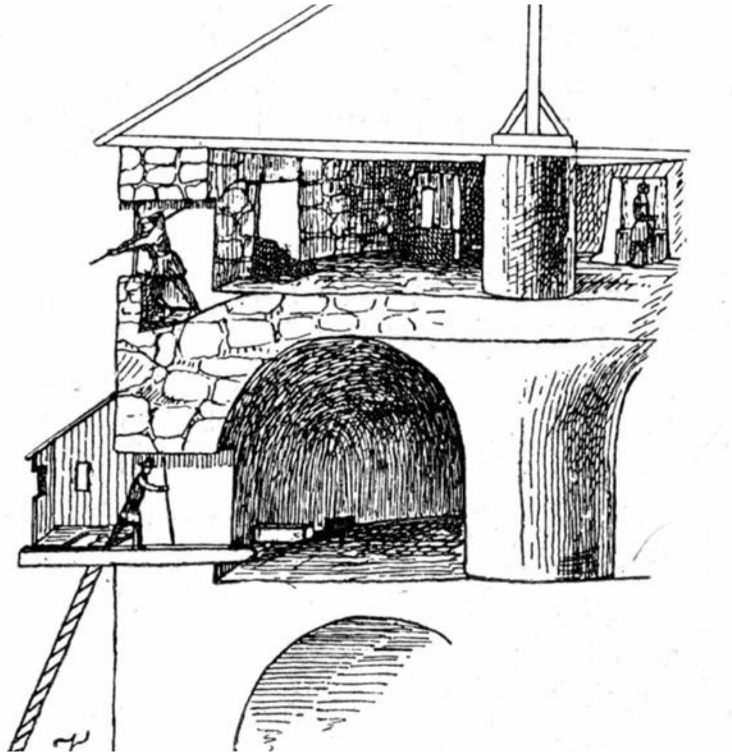


Figure 13: Illustration from Frölén.

Figure 14: Example of excavations in the floor behind the church's gates. It is evident that the excavations are secondary.

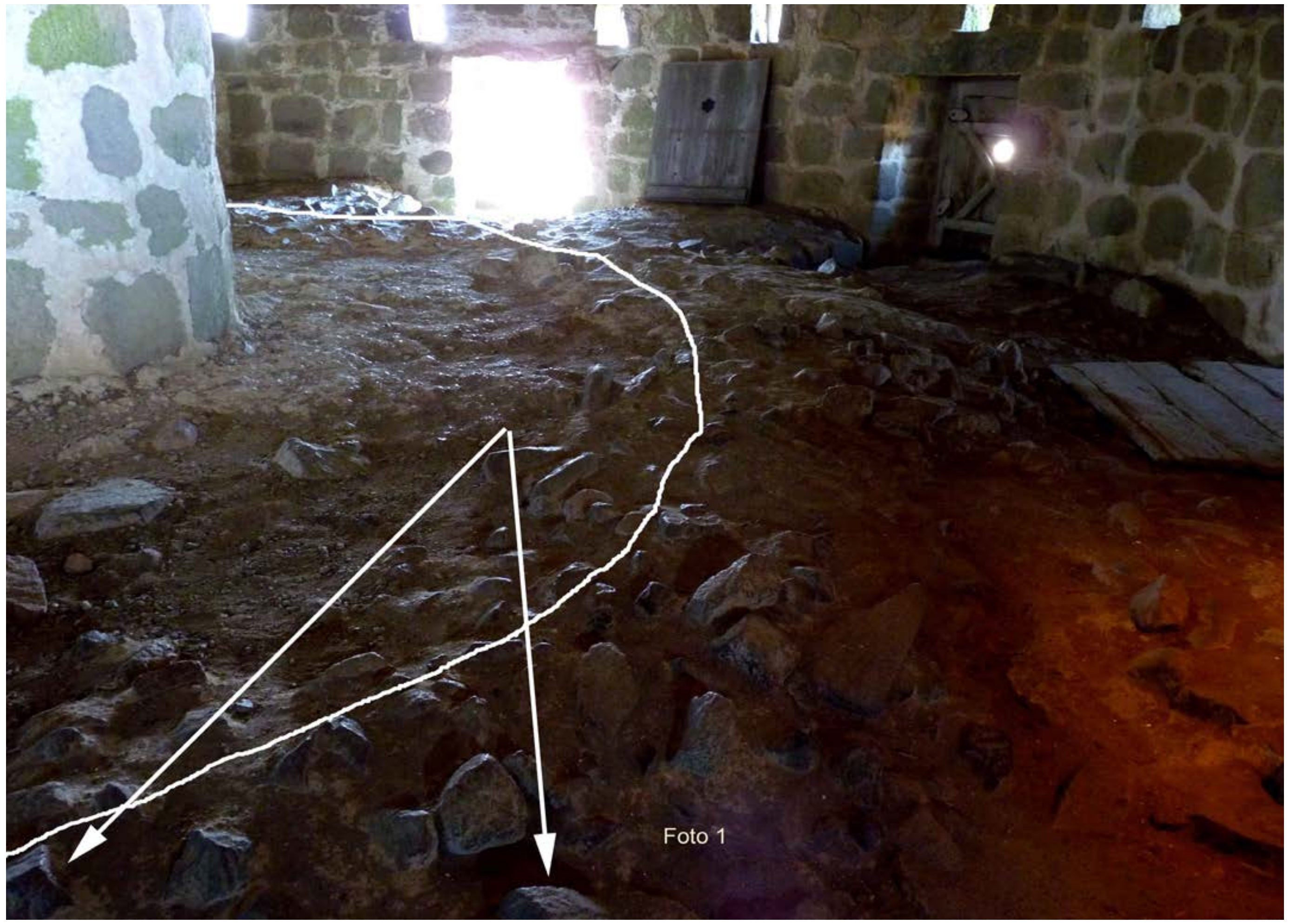


Figure 15: Third floor in Olsker.

with the fact that Bornholm in 1525 became surrendered to the free Hanseatic city of Lübeck for a period of 50 years.

The taxes and duties which normally belong to the Danish king, now belonged to Lübeck›s dispossessor at Hammershus, thereby the king thus paid off on a debt to Lübeck of 158,019 Lybs mark.

The church revenue, the so-called tithes, was not covered by this agreement and would still be paid to the church in kind, since Bornholm in 1525 was still Catholic. But because Hammershus with its large magazines no longer belonged to the archbishop, the Church was forced to find a new storage for these tithes. Olsker's second floor could have been used for the storage of the Church's kind until they perhaps should be shipped to the archbishopric in Lund. This could explain why the third floor of Olsker was equipped with cannons, in which case the cannons were meant as a deterrent rather than a functional defense. The cannons also explain the gallery of wood that originally was in front of the gates (Norn et al. 1954, p. 349). From the gallery one could charge the cannons.

Incidentally, it is noteworthy that the floor on this level is filled with stones, several of which are seen to have been worked. The stones are laid as if they came from a broken ring wall, and in that case Olsker's third floor was originally built in the same way as Nylars and Østerlars with an outside walkway resting on the underlying ring wall (see figure 15)

Nyker: The church shows several signs that a third floor was prepared, and which must be assumed to have had the same original purpose as the third floor in Østerlars, Olsker and Nyker.

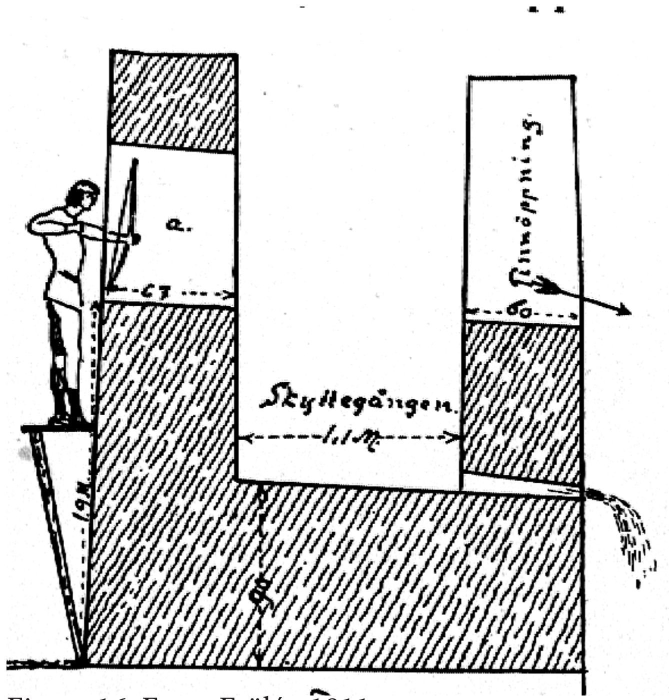


Figure 16: From Frölén 1911.

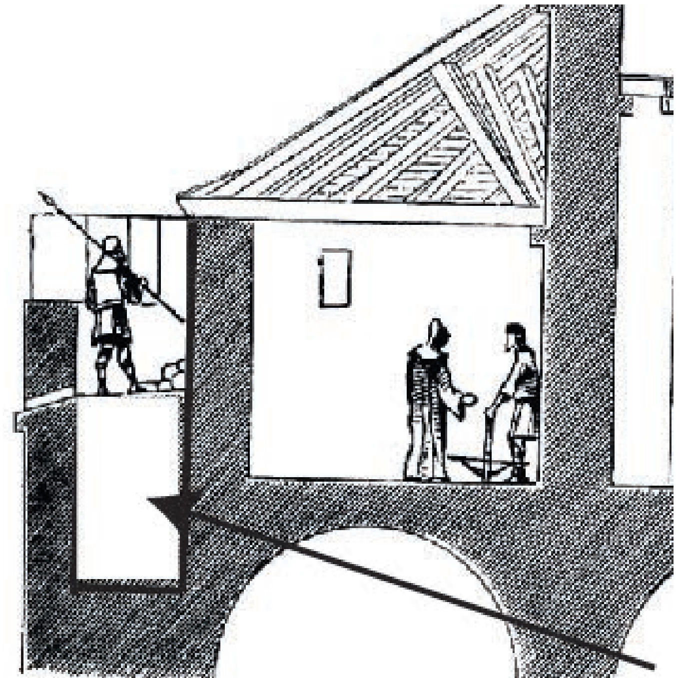


Figure 17: For a defense purposes, it would be logical to lower the floor in the parapet walk as suggested here (inserted in illustration from Laske 1902)

Østerlars: Under the later constructed conical roof, the church's originally open parapet has been preserved, and this makes it possible to see details. As we shall see, these details show us that the purpose of this device could not possibly have had anything to do with defense.

First: The parapet wall is only about 80 cm high and has never been equipped with battlements. "*There can be no doubt that the lower part of the outside wall of the parapet walk (in Østerlars) during a long period stood as a barely one meter high parapet, apparently without battlements, which completely corresponds to the condition in Nylars;*" (Norn et al. 1954. p 408.)

It seems logical that if one were to defend the church from this outdoor walkway, the parapet would have been provided with battlements.

Secondly: The wall behind the outdoor walkway in Østerlars has openings that at first glance may look like arrow slits, but they are placed so low to the originally only 80 cm high outer wall in the parapet that this wall prevents the view from these openings to an enemy , which comes within a distance of 90 meters from the church. "*From the slits you have probably been able to see over the parapet and been able to fire at an enemy being further than 90 meter from the church, but you would not have been able to see him when he had approached a bit closer.*" (Norn et al. 1954, p 410.)

Third: The floor of the parapet walk is placed one meter higher than the floor behind the rotunda. It is a construction that is completely illogical if the purpose is to have archers in the parapet walk and archers inside behind the rotunda that shoot out through arrow slits in the rotunda. Frölén, who insists that Østerlars' third floor is built for defense, imagines that the archers inside have stood on wooden pedestals, as can be seen from figure 16. There is no trace in the wall that might confirm the existence of such construction.

As mentioned, the floor of the parapet walks rests on the wide outer wall of the lower floors. As can be seen from the figure 17, one could instead have lowered the floor in the parapet walk with 2 meters so that it lay one meter *under* the floor in the rotunda. From a defense point of view, it would have been logical, as the archers in the rotunda could then shoot over the head of the archers in the parapet walk, and the archers of the rotunda would at the same time have a view of the enemy nearer the church wall. When this solution is not chosen, there must have been a special motive for the decor we see - and this motif could have nothing to do with defense.

In summary: The defense hypothesis is unrealistic.

Figure 18: Picture of the rotunda next to opening 2, photographed at sunrise summer solstice. It is seen that the light spot has the same size and shape as aperture 2 which demonstrates that the hole opening in aperture 2 points with great accuracy towards this sunrise.

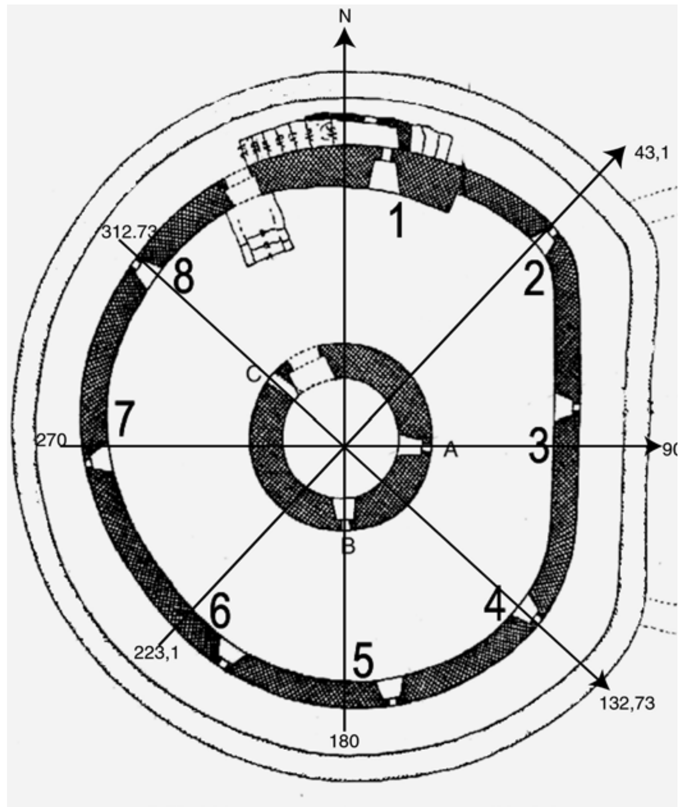


Figure 19: Light openings in the rotunda and in the hollow central pillar on the third floor in Østerlars.

However, there must have been a purpose to this third floor of the church, and the arrangements we see must be logical in relation to this purpose.

It turns out that the eight light openings in the rotunda on this floor can bring us on the trail of this purpose.

Observed from aperture 2, the aperture points in the direction of the first glimpse of the sun at sunrise midsummer, see figure 18.

The plan in figure 19 is from a survey from the National Museum of Denmark and shows how the eight light openings are distributed in the rotunda.

In the drawing, I have numbered the openings in the rotunda with numbers 1 to 8 in a direction from the north and clockwise. Three light openings in the wall of the hollow center pillar are marked with the letters A, B, and C.

Based on an azimuth of 43.1 degree to the sunrise of the summer solstice seen from Østerlars[2], it shows how the distribution of the seven openings apparently corresponds to: #2: summer solstice sunrise; #3 equinox sunrise; #4 winter solstice sunrise; #5 south, #6 winter solstice sunset, #7 equinox sunset and #8: summer solstice sunset. The opening #1 is special, because it is placed lower than the other seven and gives a view to the sky towards north.

When a star - viewed one night and seen at one position in the sky – are seen from the same location at the same position the following night, it defines the time it takes for the celestial sphere (in fact the Earth) to make a complete cycle.

Continuous nocturnal observations of the northern hemisphere of the celestial sky each night make it possible to determine, what is called sidereal time, which determines time in relation to a complete cycle of the celestial sphere.

A manuscript from 1299 describes the use of an instrument called "sphaera horarum noctis" or "astrolabium nocturnum", with which it is possible at night to calculate the full-time from the location of certain stars. (Lull 1299)

Based on the following overall picture of astronomical measurements that seem to have been possible to perform here in Østerlars, it seems reasonable to assume that light aperture 1 was once arranged with instruments to make accurate observations of the stars on the celestial sphere and their circular movement around a center, the so-called celestial pole, and thus continuously keeping track of the sidereal time.

It should be emphasized that the proposed directions of the light apertures in the drawing of Figure 19 are for an apparent purpose. From the sharp, vertical edges of the light openings, it seems important to measure the direction of the light rays that barely form a luminous line. Subsequent accurate measurements and astronomical calculations will be able to debunk or confirm whether the openings have had such an astronomical purpose.

It must also be emphasized that the directions can additionally be important for observations of the moon's movements. The maximum declination of the moon is only 5.3^0 greater than that of the sun. Therefore, it is even possible to use these devices to make comparative observations of the movements of the sun and the moon.

The drawings on Figure 19 are not accurate; for instance, it is not apparent, how #3, #5 and #8 correspond to openings A, B, and C in the hollow central pillar (see Figure 20). As mentioned, the outer wall is today raised and thus covers a view of the sun from the parapet walk, but there is a hatch in the outer wall opposite opening # 2, which has made it possible to see the sunrise as Figure 18 shows.

Similarly, it would then have been possible for a sunbeam to penetrate from the outside through opening # 5 and further through opening B into the dark interior of the hollow middle column. The same correspondence is between # 3 and A and between # 8 and C.[3]

These openings are carefully shaped with straight and sharp vertical sides, facilitating precise observation. As the sun moves across the sky, its light from a certain direction will be trapped by one of these light openings, and due to the opening's sharp and parallel edges, the light beam will first manifest itself as an exceedingly small strip of light that will point to a very precise direction to the sun.

Because the sun rises higher and higher above the

Figure 20: Opening 5 connected to opening A.

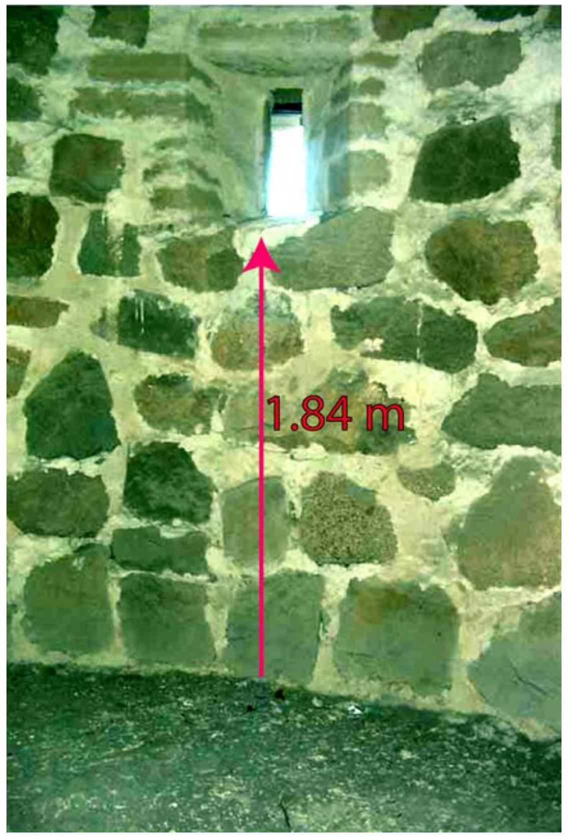


Figure 21: It looks as if the aperture was made by breaking a hole in the original wall.

Figure 22: From the inside of the hollow pillar at the third floor.

horizon from sunrise until it reaches its maximum in the south, it will be necessary to place secondary light apertures lower than the primary apertures to capture the same sunbeam as the sun moves. That is, the openings in the hollow center pillar must thus be placed lower than the openings in the rotunda. We arrive thus at a now logical explanation for the fact that the floor in the rotunda behind the parapet walk is one meter lower the floor in the parapet walk, see figure 21.

And further:

In the hollow center pillar, there are three light openings, A, B and C, as shown in Figure 19. The space inside the pillar is so small that there can hardly be more than three people in it at the same time. Yet the two apertures, A and B, are unusually carefully designed - in the same way as the outside apertures, with vertical, sharp, and parallel edges, see Figure 22 - and like explained in Figures 21 - it looks as if the aperture was made by breaking a hole in the original wall. These opening sits only about a meter above the floor. Logic would tell us that such a careful way of making a light-opening so low above the floor in such a small room must have had a special purpose - which could have nothing to do with defense.

Figure 21 and Figure 22 appears to present archaeological evidence that the purpose for the parapet walk was to make it possible for initial astronomical observations outside the wall to determine where the light openings should be placed in the rotunda. As can be seen from Figure 21, the wall of the rotunda has been demolished and replaced with limestone in an unusually large area around the light opening. This also applies to the other light openings. This seems to suggest that the rotunda was

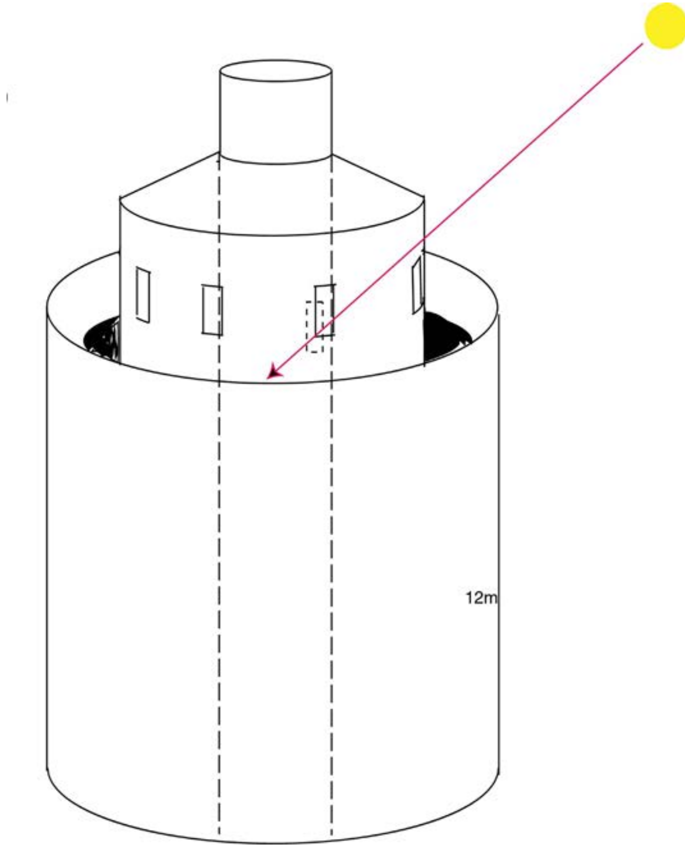


Figure 23: Schematic representation of the function of the light openings.

originally constructed as an unbroken wall all the way around and then cut open, where astronomical measurements from the outside parapet have indicated the locations of the openings.

These openings have made it possible to determine with great accuracy the movements of the sun day by day, not only through a single year, but also to determine if it is the same movement year after year, see Figure 23.

The light openings 1 - 7 and the light openings A, B and C indicate that Østerlars has been able to function as an advanced sundial, where you could with great accuracy determine the sun's declination and its ascension. You could thus define the exact time of the day, the exact length of the year and divide the year accurately in seasons.

The sun in the church

This combination of church and astronomical measurements is not unique for Østerlars. Many reliable historical sources describe the following:

The Italian astrologer, astronomer, mathematician, and cosmographer Paolo dal Pozzo Toscanelli (1397-1482) constructed in 1468 a so-called gnomon (a gnomon is the part of a sundial that casts a shadow) in the Cathedral of Santa Maria del Fiore in Florence.

The same system is utilized by the Italian priest, mathematician, and astronomer Egnatio Dante (1536-1586) in 1574 in Santa Maria Novella church in Florence.

In 1576 Dante moves to the University of Bologna, where he continues his astronomical studies, and he makes a similar hole in the wall of the university church, Basilica of San Petronio, to catch the sunlight and bring it down to a scale on the church floor like Toscanellli's construction in Florence.

In 1655 Giovanni Cassini becomes responsible for ensuring that Dante's solar observatory in the Basilica of San Petronio is retained after a conversion of the church. Cassini transfers Dante's opening to the new church wall, but he moves it higher up, so that he can make an even more accurate scale on the church floor.

He says he will use the observatory to measure the exact time it takes the sun to go once around the celestial sphere. But Cassini conceals his true aim out of consideration for the Church.

His real motive is to observe the sun so precisely that it can confirm or refute the theory put forward by the German mathematician and astronomer Johannes Kepler in favor of the heliocentric system. Kepler had announced his thesis about the planets' elliptical orbits around the sun in 1609 and Cassini found he could test the hypothesis through the facilities in the church.

It had to result in the sun and the earth being closer to each other part of the year and further apart another part of the year. It should be possible to measure by studying the magnitude of the sun's projected face. For the experiment to succeed, Cassini could tolerate measurement errors no greater than 0.3 inches in the Sun's projected face, which ranged from 5 to 33 inches wide, depending on the time of year. No telescope of the day could achieve that precision. The experiment was run around 1655, and after much trial and error, succeeded. "Cassini and his Jesuit allies", Dr. Heilbron writes, "confirmed Kepler's version of the Copernican theory". (Heilbrun, 1999).

A study of the shape of the sun's analemma, which is described in the following and could be plotted from Østerlars, would probably have led to the same conclusion.

Thus, the unique of Østerlars is not its combination of church and astronomical observatory but the fact, that it is some 4 - 500 years prior to other Christian churches with the same purpose.

If subsequent accurate measurements of the church and astronomical calculations can confirm this hypothesis about the astronomical use of the light openings, we are faced with a possible explanation why there are no written sources for the Bornholm medieval churches.

Because: In that case, it cannot be the local population on Bornholm who has been responsible for the construction. The knowledge necessary to devise and carry out the experiment, which the archaeological details may possibly confirm, is certainly available at this point in history. But it is highly unlikely that the necessary knowledge was present in the local population on Bornholm or for that matter could have been present in Denmark at all at that time. Nor can it be the Catholic Church itself that has overseen the project. The Church would not be motivated to conduct empirical studies that could disprove or confirm the Church's own dogmas.

We shall later discuss who it may have been.

Cassini's example illustrates that observations based on the special mechanisms of Østerlars church may have led to a knowledge of the (apparent) movements of the sun, which as early as the thirteenth century, like Copernicus and Kepler in the sixteenth century, raise doubts about the dogmatic worldview of the Catholic Church.

When one has the opportunity for such accurate observations of the sun's movements, as in Østerlars, and continuously compares the observations of the sun's movement with sidereal time, it is inevitable that one will discover that either the celestial sphere moves at different speeds in different periods during a year - or it is the sun, which moves faster in certain periods of the year and slower in other specific periods.[4]

To determine if it is the stars that change speed, or if it is the sun that does it, you can use a water clock or an hourglass, with which you can determine that there are no variations in sidereal time. An instrument such as the previously described Astrolabium Nocturnum may also be used.

The solstices and equinoxes divide the year up into four approximately equal parts. The light apertures in Østerlars appear to have been created to determine these four parts - and when observations of the sun's movements are compared with sidereal time, it will be revealed that the sun changes speed in its orbit these four times every year.

If the position of the sun in the sky, as viewed from a fixed position on earth like Østerlars, at noon (12 o'clock) every day for an entire year, the resulting curve resembles a figure-eight with the lower lobe much larger than the upper lobe, a so-called analemma.

This figure reveals an important information about the suns (the Earth's) movement:

1: If the sun were supposed to move in a perfectly circular orbit and with no axial tilt, the sun would always appear at the same point in the sky at the same time of day throughout the year, and the analemma would not be a figure 8, but a dot (and there would be no difference between summer and winter).

2: If the sun were supposed to move in a perfectly circular orbit, but with a significant axial slope - consistent with the worldview of the Catholic Church - the analemma would be shaped like the number 8 *with upper and lower lobes equal in size*.

But, as mentioned above, plotted from Østerlars' church, the resulting analemma would appear with the lover lobe much larger than the upper lobe, which is due to the elliptical orbit of the Earth around the sun. (See https://en.wikipedia.org/wiki/Analemma).

Such a discovery must necessarily lead to considerations that call into question the Catholic Church's description of the universe as perfectly circular motions around a motionless globe.

Observations in Østerlars would therefore be as dangerous to the Catholic Church as the conclusions in favor of heliocentrism that Copernicus puts forward some 400 years later. The difference is that in Copernicus' time, the art of printing was invented. Copernicus made sure that his manuscript was printed, and therefore the church could not prevent knowledge of Copernicus' hypothesis from spreading - even though the Catholic Church tried with all its power to stop this spread. But it was much easier for the church in the 13th century to destroy a limited number of handwritten documents and thus prevent knowledge of the results of the observations in Østerlars - observations that, like Copernicus, Galilei, and Kepler, would question the church's dogmatic geocentric worldview.

But we are left with another important question that lacks a logical answer:

If the hypothesis of Østerlars as an astronomical observatory can be confirmed - then the one planned and the two existing third floors in the three other round churches on Bornholm must necessarily also be interpreted from an astronomical purpose. So, what is the logical explanation for the need for not just one, but four astronomical observatories on such a small island?

A possible answer to this question has emerged in the article "Medieval Round Churches and the Shape of the Earth" (Haagensen & Lind 2015).

The article demonstrates how there appears to be a geometry that dictates the relative location of the four round churches. The article describes further what the purpose of this appears to be and how it can provide an explanation for a need for more than one astronomical observatory on the island.

Here follows first a summary of the geometry on which the article is based, then a description of triangulation and its history. Then follows a quote that is the very core of the article.

Based on this, the folowing case study research is centered on the practical connection between the Bornholm landscape geometry and the article's proposed method for measuring the shape and size of the Earth:

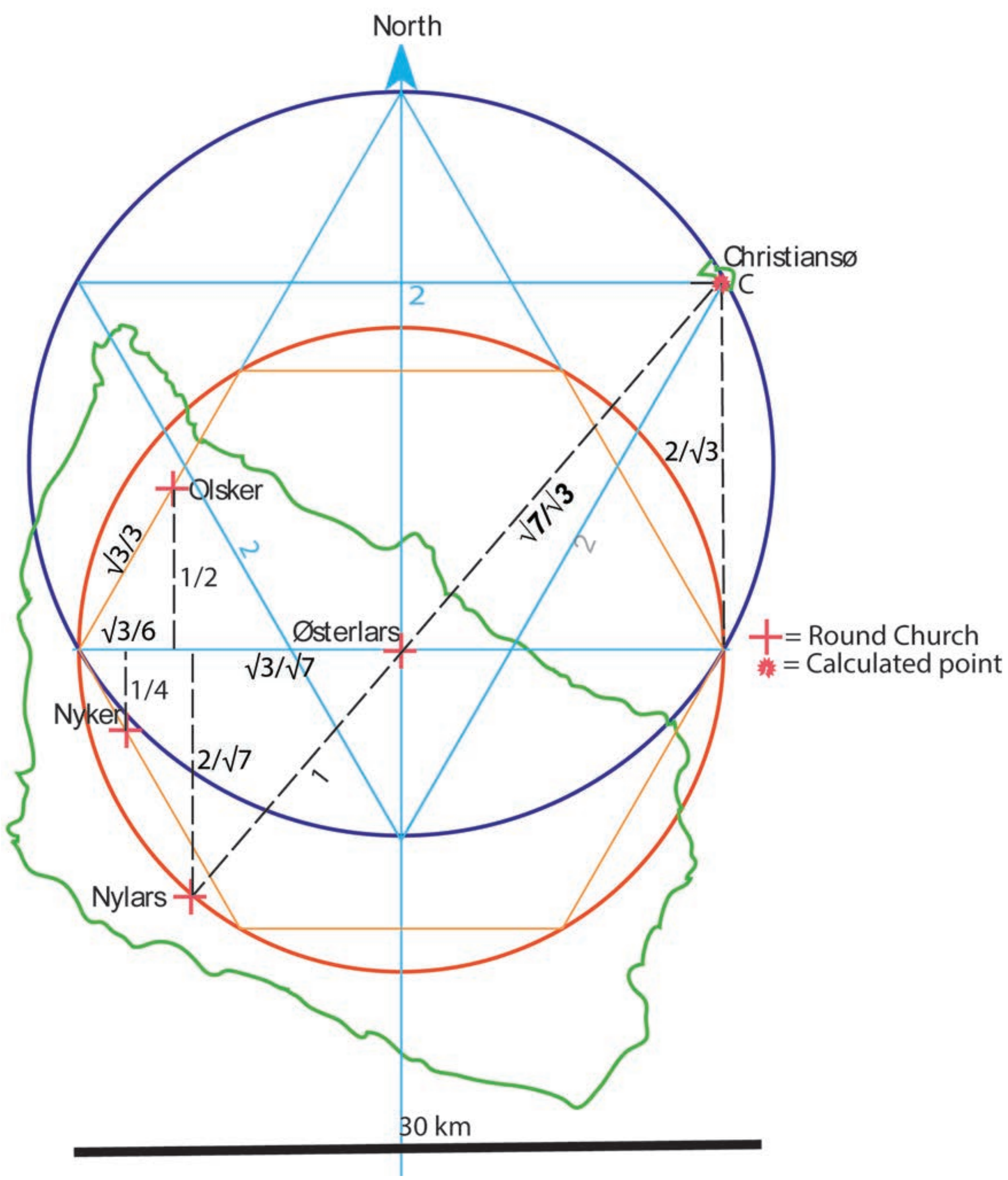


Figure 24: An illustration of the geometry that connects the four Bornholm round churches. The distance between Østerlars and Nylars is selected as the unit (1) of the geometry. The geometry is here oriented in relation to true north, based on Østerlars. A diameter (=2) east-west through Østerlars is the baseline in an equilateral triangle that defines the location of point C (on Christiansø).

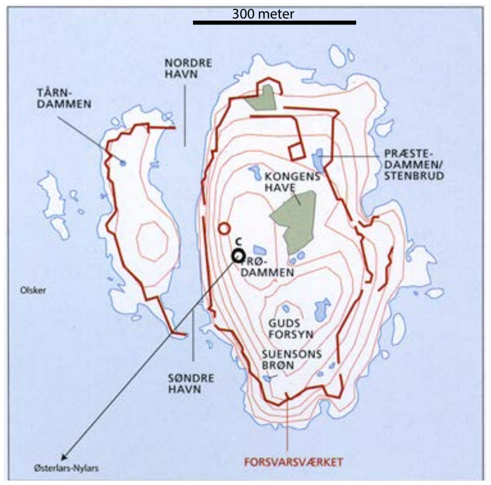


Figure 25: The location of point C on Christiansø.

The geometry, that dictates the four round churches location, is associated with a target C on Christiansø, see figure 24.

The location of C can be calculated from an extension of a line through Nylars and Østerlars in the distance from Østerlars = (Østerlars-Nylars) * √7/√3 .

This calculation places C at a point in the middle of the profile that Christiansø forms seen from Østerlars (see figure 25). From this point there is an unobstructed view to the entire Bornholm northeast coastline and to practically all localities in the landscape on the north-east side of a ridge that extends in the middle down through Bornholm and divides the island in a north-east and a south-vest segment (see Figure 27) – and to the horizon towards north, east, and south.

The spot that meets the criteria according to the calculations thus also meets the criteria for a point in the landscape that is exceptionally suitable for establishing a triangulation network. This means that the preliminary hypothesis that C is deliberately intended to be included in the geometry is supported when, based on Nylars and Østerlars, C's location on Christiansø is calculated.

From *Haagensen & Lind 2015*:

"We can compare the actual location of each of the four round churches in the landscape with its hypothetical location, calculated from the geometry (in Figure 24), suitably scaled. The basis for the calculations is the set of coordinates of the centers of the rotundas of the round churches. These coordinates have been measured and published by the Danish Geodata Agency (GST); they are shown in Table 1. With these coordinates it is possible to calculate any distance between the churches and the bearing of the lines connecting the churches. Lines between locations in the landscape in this study— unless otherwise stated— will always be a segment of a geodesic between the locations, which is in practice the same as a sightline, the shortest distance between two points in the landscape."

Then follows a description of the method used to calculate how precisely the churches are in accordance with the geometry in Figure 24, and the conclusion is: "*The average error in the church locations is less than 18 m. The largest error is for Olsker, 30.167 m.* "

Triangulation

The only technique that can be used to lay out a geometry in the landscape with that accuracy is triangulation. The earliest use of this technique in Europe is attributed to the Dutch astronomer and mathematician Willebrord Snell (1580-1626) who in 1615 measured the size of the Earth using this technique (Snellius 1617).

But knowledge of triangulation was already introduced into medieval Spain through Arabic treatises on the astrolabe by for instance the Spanish-Arab astronomer Ibn al-Saffar (d. 1035), born I Cordoba. (Hill 1984, 119 -122).

Also, the Arab astronomer and mathematician Abu Rayhan Biruni (973 - 1048) introduced triangulation techniques to measure the size of the Earth and the distances between various places.[5]

Therefore, although the earliest known example of the use of triangulation in Europe seems to be from 1615, the technique was in use as early as the 11th century, and at that time the technique was known by intellectuals on the Iberian Peninsula.

The use of a triangulation network is particularly advantageous in connection with the so-called astrogeodetic method for measuring the size of the earth. This method was first described and used by Eratosthenes (ca. 284 - 192 B.C.E).

A spherical Earth is described more than three hundred years B.C.E., in Hellenistic astronomy. Several early Greek astronomers estimated its size, but by using the astrogeodetic method Eratosthenes was first to perform accurate calculations of the meridian curvature.

The (Eratosthenes') method: One selects two points on the same meridian (that is, two points located on the same north-south line). Using astronomical measurements from each point, one can determine how many degrees of the meridian that separate the two points, and by measuring the distance between the points, for instance by using a triangulation network, one can calculate the complete circumference of a meridian, i.e. the circumference of the earth in the direction North-South.

As is the case with triangulation networks, medieval Europe was aware of Eratosthenes' method before the middle of the 12th century. The method was taught in at least one of the many Catholic cathedral schools in the early twelfth century.

Practica Geometriae is a collection of seven Latin manuscripts attributed to Hugo of St. Victoire

(1095–1141), principal of the convent school in St. Victoire near Paris; this is widely accepted. (Homann 1991).

The manuscripts provide a good insight into what was being taught at this time. They refer to Eratosthenes and describe his method and describe the necessary preconditions for triangulation.

The general curiosity of the intellectual elite in Greece and later in the Arabic caliphate stimulated numerous measurements of the meridian curvature as soon as they get knowledge of Eratosthenes' astrogeodetic method.

But even though this technique was taught in Christian Europe as early as the middle of the 12th century, four hundred years were to elapse - according to our historical sources - before the astrogeodetic method was first used in practice - and by an amateur!

This amateur is the French doctor, Jean Francois Fernel, who, out of curiosity, made his own private experiment, published in 1528 (Fernelli 1528). Then another hundred years passed without further such measurements until the Dutch astronomer and mathematician Willebrord Snellius in 1615 used Eratosthenes' method. (Snellius 1617).

This is strange because the question of the Earth's shape and size had always been of great scientific interest, and especially in the thirteenth century there should be a growing also economic interest. At that time Christian Europe was experiencing an explosive growth in trade, which included trade in goods from India and China (Reyerson 1982). New types of merchant ships to transport goods were being developed, but trade with the Far East still went over land, requiring risky journeys of thousands of miles. A desire to find new ways of shipping merchandise is thus strongly motivated by economic interest, for instance the ability to reach India by sailing west was economically as interesting in the late 1100s as in the late 1400s. Such a desire motivates one to know the size and shape of the Earth.

The many measurements of the Earth's size prior to the 1100s were of its circumference

around the poles—that is, south–north, assuming the meridians are perfect circles. But to

sail from Europe to India one must sail east - west.

Therefore, the desire to know the curvature of the Earth must have motivated the intellectual elite out of purely commercial interests. They knew for certain that the Earth is round. But nobody knew for sure whether it is spherical. If not

spherical, the sailing time to India might be longer or shorter than anticipated. What is the

shape of the Earth? The layout of Bornholm's round churches can serve to answer that very question

The following is a quote from the article "Medieval Round Churches and the Shape of the Earth" (Haagensen & Lind 2015), which describes a method for measuring the circumference of the earth by calculating the length of parallels. This method will be referred to as *the Bornholm Method:*

THE SHAPE OF THE EARTH

"With two observatories located at different longitude and latitude it is possible to determine if the Earth geoid is locally spherical. In Figure 26, the two points A and C lie on a surface of revolution S. On S, let B be a point north of A and west of C, while D is a point east of A and south of B. ABCD is an isosceles trapezoid; the plane ABCD intersects the axis of revolution in point N. The shape of the trapezoid is determined by measuring the angles NAC at A and NCA at C, from which follows the angle v ANC at N, called the meridian convergence. The meridian convergence is greater when ABCD is nearer the pole than the equator. Thus, a northern location is favorable for a test of the hypothesis that the Earth is spherical. Let u denote the latitude of A. The length of the latitude circle around the Earth through A and D, and hence the length to sail or walk all the way around the Earth at that latitude, equals 2r, where r is its radius. Since r AN sin u, the length of the latitude circle through AD equals (2/v) AD sin u.

Also, by the astrogeodetic method the difference in latitude between A and C is determined, from which the local curvature radius R of the meridian follows, also in proportion to the trapezoid. If the length of the latitude circle is what one would expect on a sphere of radius R, then the Earth is locally spherical, and it makes sense to believe that it is a sphere. Thus, with two observatories the practical question of the Earth's circumference around that latitude can be answered, while the scientific hypothesis of a spherical Earth can be either rejected or given empirical support. With four observatories you have six combinations of A and C. This yields a better

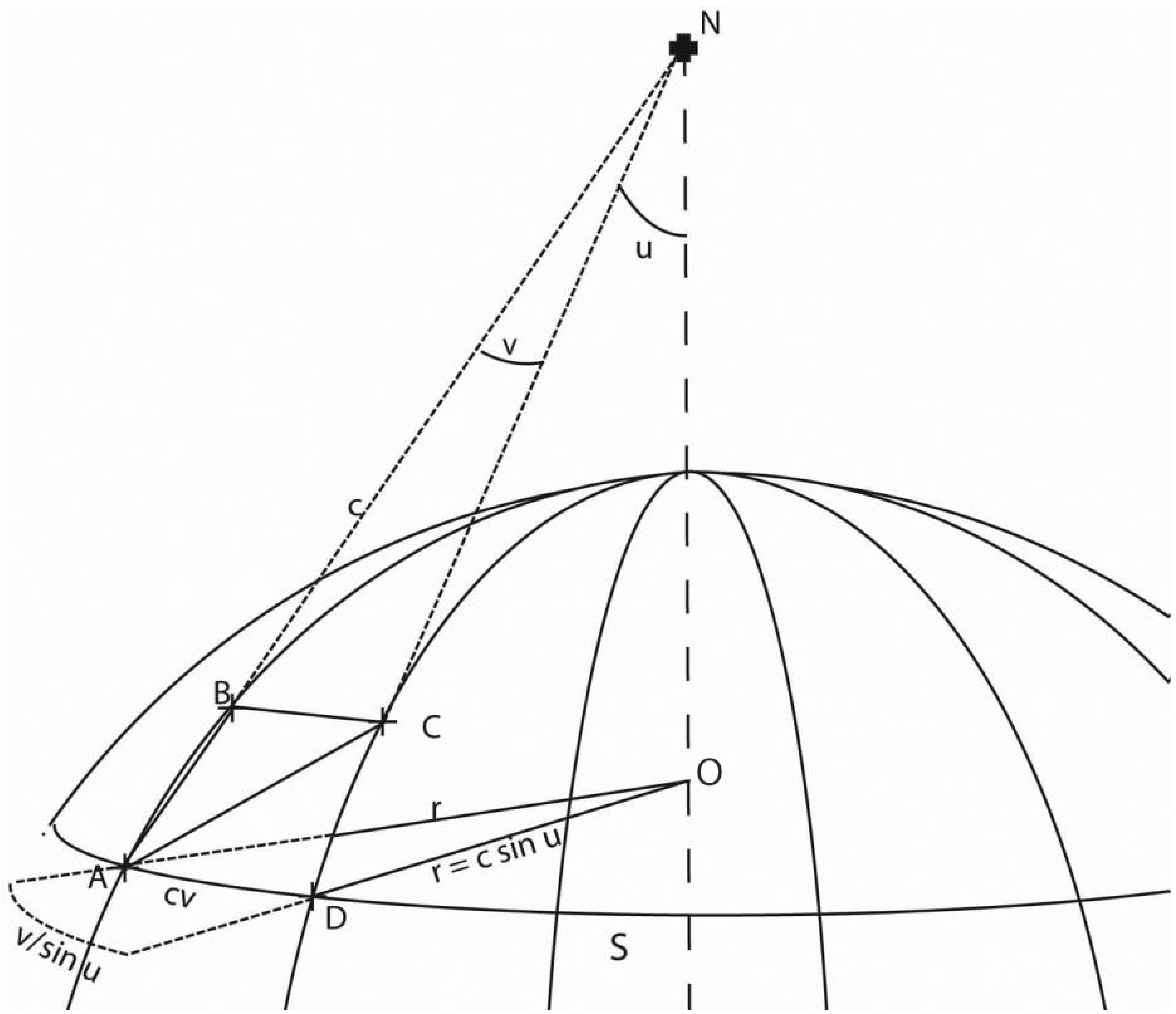


Figure 26: Points A, B, C, D, and N lie on the same horizontal plane tangential to the globe at point A, which is also the point of view of an observer.

estimate of the curvatures plus an estimate of their accuracy. Also, repeated measurement from any pair of fixed observatories (e.g., Nylars and Østerlars) and averaging improves the accuracy. Measurement of the meridian convergence—in contrast to a determination of latitude—is independent of an exactly determined angle between the horizon (or zenith) and the celestial pole. You only need to measure the angle from a sighted point in the landscape to a plumb line aligned with the celestial pole—thus making only a horizontal measurement, which can be performed far more simply and with better accuracy than measurements of latitude.

CONCLUSIONS

The four round churches on Bornholm may have served multiple purposes, not including defense but almost certainly including astronomy. The topography is ideal for triangulation. The island's northern position makes it ideal for terrestrial measurements to comparethe principal curvatures of the Earth locally. Angles in the landscape could be measuredin the Middle Ages with an accuracy of about 1 minute of a degree, sufficient to support or refute the hypothesis that the Earth is spherical; in the event, such measurements would support that hypothesis. Further, by measuring the distance between two points in the geometry—for example, from Østerlars to Nyker—the length of the parallel circle, and hence the sailing distance west to the Orient, could be estimated. The archaeological evidence indicates that a reasonably accurate determination of the Earth's shape and size could be made.

The crucial innovation is that with pairs of observatories these calculations allow both north–south and east–west curvature measurements—unlike the *conventional calculation*

with the astrogeodetic method—and thus allow for the insight that the Earth must indeed be spherical."

Thus, according to the article, *the Bornholm Method* is the background for the geometry that exists between the round churches.

This hypothesis will be tested in this article by performing the proposed method based on the data available.

But before this test, we present a proposal for how the lay out of the geometry in the landscape could conceivably be carried out in practice:

Prior to the presentation of the observatory hypothesis, an account is given of how the location of other of the 15 medieval churches also appears to be determined by the geometric pattern shown in Figure 24 (Haagensen 1993).

As we shall see, the accuracy of the geometry indicates that it is the distinctive west tower of these churches that is included as the geometric point. This provides the basis for setting up the following hypothesis about how the geometry in Figure 24 could have been measured and laid out in the landscape using a triangulation network. This turns out to lead to a surprising discovery regarding the possible accuracy of the geometry:

In this context it is important to realize the island's special topography.

A ridge runs down through the middle of Bornholm, approximately parallel to the island's long, straight coastline to true northeast (see figure 27). Its peak is around the middle of the island, the highest part being between 160 and 165 meters above sea level.

First logical consideration:

Just as it is logical for topographical reasons to select point C on Christiansø as a starting point for a triangulation network, it would be logical to select one or more of the high spots on this ridge with a clear sight to C on Christiansø, as additional geometrical points in the first layout of a triangulation network.

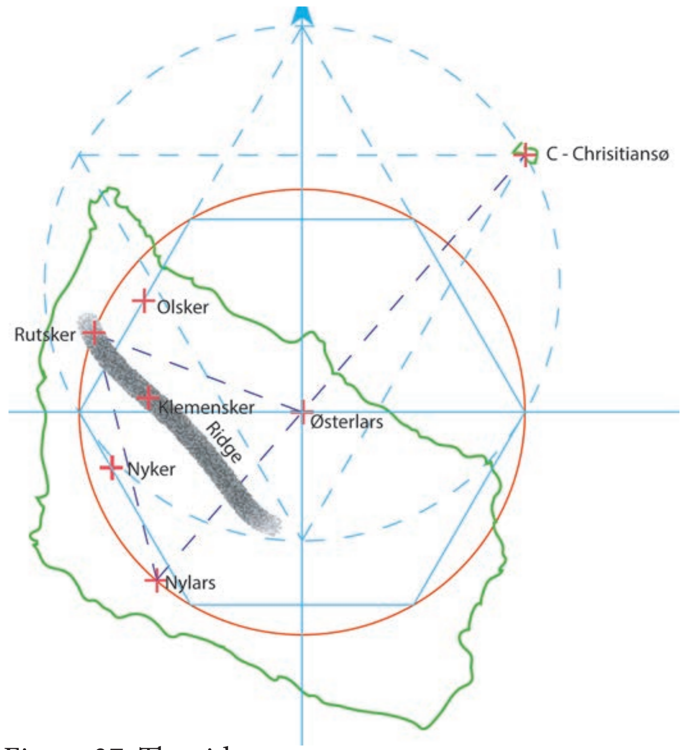


Figure 27: The ridge.

Second logical consideration:

It is noteworthy that on an island with an unusually hilly terrain, only two of the island's 15 medieval churches are located on a definite peak in the landscape.

These two churches, Rutsker and Klemensker, are in turn located on the mentioned ridge.

Both churches are also included in the geometry depicted in Figure 24 in the following way:

Rutsker*:*

Rutsker lie on the perimeter of the main circle in the geometry, defined by having the island's largest round church, Østerlars, as the center, and with a radius defined by the distance Østerlars-Nylars. Thus, both Rutsker and Nylars lies on the perimeter, see Figure 27.

Using coordinates from the Danish Geodata Agency (GST) (see Table 1), the distances Østerlars-Nylars and Østerlars-Rutsker are calculated in Table 2.[6]

Table 2 also makes it possible to calculate with what accuracy the angle Østerlars-Nylars-Rutsker is identical to the angle Østerlars-Rutsker-Nylars. It shows that the two angles are equal except for 0.001 degree. This accuracy is surprising. The accuracy is so great that it is possible to determine which part of Rutsker church best meets the criteria of the suggested geometry. *We can state that it is the church's remarkable west tower that is designated by the geometry.*

Considerations in relation to the rival hypothesis: coincidence.

We have no other examples of a medieval landscape geometry with this accuracy.

The rival hypothesis is that the landscape geometry presented here is not deliberately constructed but arises because of coincidences.

This view has been advocated by professor of medieval archeology at Lund University, Jes Wienberg.

His argument is that the fifteen Romanesque parish churches on Bornholm can be connected by 15 * (15-1)/ 2 = 1051 lines, further that the formula for the number of possible triangles between n number of points is n * (n-1) * (n -2)/ (3 x 2 x 1). The number of triangles between the fifteen medieval churches on Bornholm will therefore be 455 and the number of possible angles between the churches are 1365. If Christiansø is considered, the number of angles will be 1680.

Based on this number of combination possibilities, Wienberg's view is that the geometry between the churches, shown in Figure 24, is a result of coincidences. (Wienberg 2001).[7]

He supports this through the view that a study and construction of this geometry could not be carried out at this time in history. "*How to measure the distances with the necessary precision?*" (Wienberg 2002).

The following case research study will provide an answer to Wienberg's questions.

Wienberg is right so far that according to our present historical knowledge, the accuracy found ought to be a coincidence.

But Wienberg's argument does not rule out that the geometry may be conscious. Thus, if not coincidentally, and since the towers of Bornholm's medieval churches are already particularly remarkable, it may support a logical assumption that the towers had a function in connection with the construction of the triangulation network. Therefore, it is worth to conduct a case study to investigate whether there are other examples from the location of the medieval church towers, that show *a similar exact agreement* with the hypothetical geometry.

When based on the location of Østerlars and Nylars, a similar example is found with the angle Nylars-Østerlars-Olsker. Line 2 in table A shows the magnitude of the current angle and demonstrate a deviation of 0.0016 dg from the theoretical. Thus, in relation to the theoretical, this is an accuracy completely like Rutsker.

A third example shows how a similar accuracy is associated with the tower of the former Vestermarie church, also distinguished by being a prediction, which subsequently turns out to be verifiable.

The supposed intention of the location of the tower in the old Vestermarie Church relates to the geometry as follows (see figure 28):

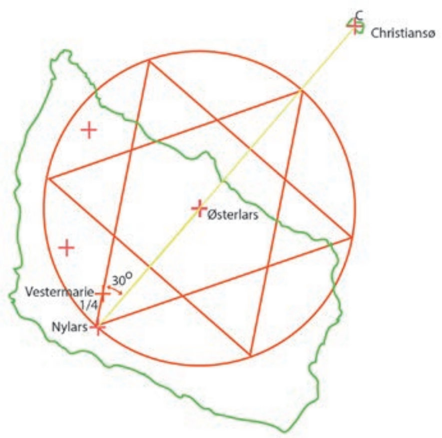


Figure 28: Vestermarie church's location in the geometry.

The tower is supposed to have to be placed on a line to Nylars, so that a 30-degree angle is formed Vestermarie-Nylars-Østerlars. The intention seems further to place the tower at a distance from Nylars equal to a quarter of the distance between Nylars and Østerlars.

Vestermarie church tower, to which the coordinates in table 1 are calculated, is not the original medieval church tower. In the last decades of the 19th century, four of the original medieval Bornholm churches were demolished and replaced by new churches: Klemensker, Rø, Vestermarie and Østermarie.

Vestermarie was the second of the four churches to be "sacrificed" in the name of the great religious revivals in the 19th century. The new Vestermarie church from 1885 was designed by the architect Mathias Bidstrup, who also designed the new church of Rø. This is interesting in connection with an estimate of the original position of the old church in Rø as discussed later.

It can be proved that Bidstrup built the new Vestermarie church as an extension to the west of the old church after the demolition of the tower of the old church, but before the old church's eastern nave and chancel were demolished, so services could

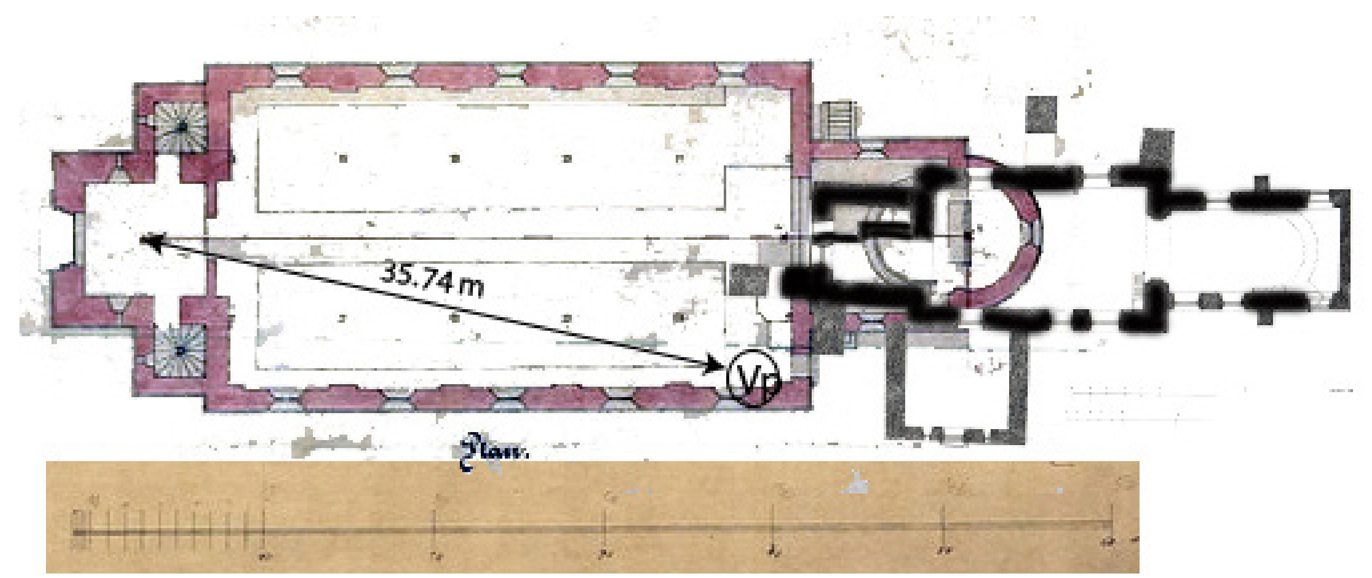
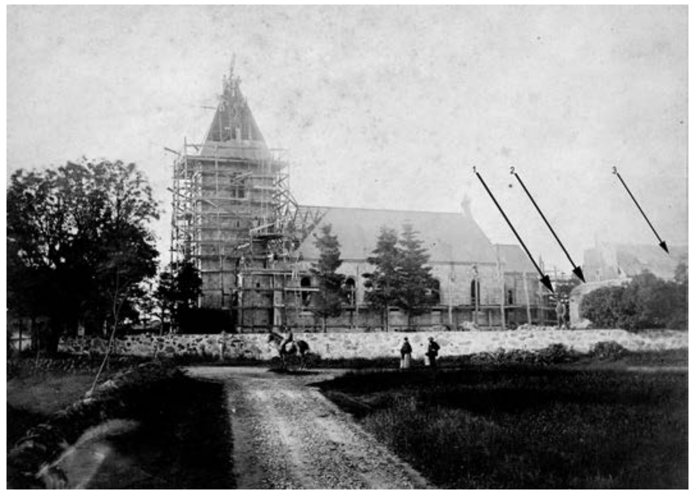
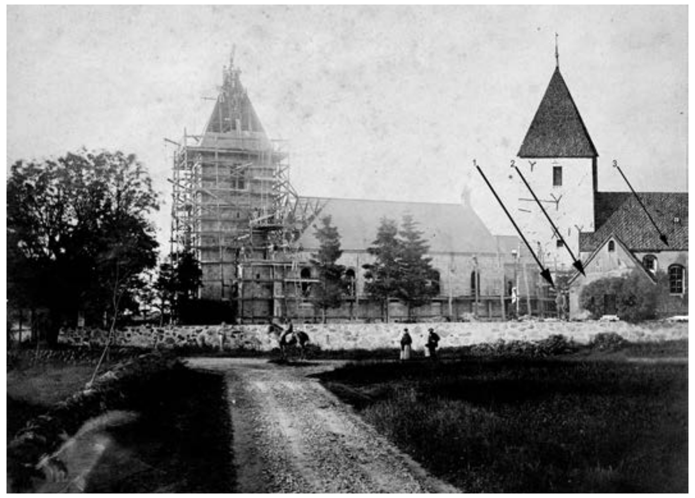


Figure 29: Vp is the calculated location of the old tower of Vestermarie, based upon the location of Østerlars and Nylars and the geometry in Figure 28.



A photo taken during the construction of the new church. Arrow 2 points to the remains of the old church's porch. Arrow 3 points to the roof of the old church choir, which is still used during construction. (Haagensen 2007)



Here, the old church is inserted in the photo which thus shows how the old church was in relation to the new church. (Haagensen 2007).

be performed during the construction period. The evidence is in the form of a well:

"An old well is in the cellar under the cancel of the new church. Since the new church is situated further to the west, the well may have been in the medieval church's tower. Dalby Church in Scania, Sweden, also has a well under its west tower". (Old Churches of Bornholm 1999, description 20). This location of the old tower can also be verified through an analysis of photographs taken during the construction of the new church (Haagensen 2007. 168-172).

The theoretical point that meets the conditions is illustrated in Figure 29. The figure shows the location of the new church and the location of the old church. It is seen how the geometry with great accuracy designates the tower of the old church.[8]

These three examples of what we might call extremely accurate angles calls for a different study of the accuracy of all angles between the four round churches and C on Christiansø - *a study that is not based on simple plane geometry* because:

A significant question

Comparing the angles in Figure 24 with angles in a corresponding plane geometry rises questions.

If the purpose of the geometry in the landscape is to create conditions for a measurement of the length of a parallel, as demonstrated in Figure 26, the geometry should be based on parallels and meridians as seen with the parallelogram ABCD in Figure 26.

A study of all the angles between the four round churches and point C on Christiansø is portrayed in Appendix A with the corresponding Table A.

In Figure 2A in appendix A, all angles in Figure 24 are numbered, and Table A shows in column B the results of a plane geometric calculation of all angles.

But if the intention has been that Olsker should lie on a parallel north of Østerlars, so that the distance between the parallel through Østerlars and the parallel through Olsker - measured on the meridian - corresponds to half the circle radius Østerlars-Nylars - as displayed by Figure 24 - then the plane-geometrically calculated theoretical angle Østerlars-C-Olsker (angle 3 in Table A, column B) is incorrectly calculated and should be 0.0707.. dg *larger* due to the socalled *meridian convergence*, which is explained below.

The difference between a plane geometry and a geometry in the landscape that follows parallels and meridians, respectively, also relates to the geometry's orientation towards true north, because all straight lines in a landscape have a different angle to true north at each point on the line, unless the line itself is part of the meridian. This means, that while in a plane geometry all lines are oriented in relation to a flat Cartesian coordinate system, the orientation towards true north of a (sight)line in a landscape depends on the directions of the meridians crossing the line, see figure 26.

This means that if you want to define a line in the landscape that should have a certain angle to true north, then you must *select a certain point on the line* where you want the line's angle to true north to be accurate - and in all other points on the line the angle to true north will then become inaccurate compared to a plane geometry.

An example is the straight line Nylars over Østerlars to point C on Christiansø. In the plane geometry in Figure 24, the line as such has a defined theoretical angle to true north (to the y-axis of a coordinate system), but in the landscape, there will only be *one point* on such a sight line, where this theoretical angle to true north is fulfilled - all other points on the line will have "an inaccurate" angle to true north, the "inaccuracy" increasing with the points distance from the point with the accurate angle.

This variation in a (sight)line's direction towards North is a result of the so-called *meridian convergence* (described as angle *v* in Figure 26).

This means that if we assume that the purpose of the geometry is connected to the hypothesis described in *Medieval Round Churches and the Shape of the Earth,* a calculation of the angles in a coresponding hypothetical geometry should consider the meridian convergence and can therefore not be expected to have the plane geometric angles calculated *in Table A, Colum B*.

Therefore, to investigate the accuracy of the landscape geometry the following method has been used in this case study:

Compare the actual existing angles between the four round churches and C on Christiansø with a plane geometric calculation of the corresponding hypothetical angles in Figure 24 ***and note the size of each angle's actual deviation from a calculated plane geometric angle.***

The geometry in Figure 24 consists of 23 angles between the churches plus one angle to true north, but *it is defined by only six angles plus the angle to true north*, see Table A and Figure 2A in Appendix A.

The described method has revealed a remarkable regularity in the deviations of the angles from their theoretical model. The reason apparently has to do with the meridian convergence along the line from Nylars over Østerlars to C:

There is a free sight from Østerlars to C and free sight to the horizon towards north both from C and from Østerlars.

The geometry dictates the distance from Østerlars to C = (see Figure 24).

After measuring the line's angle to true north both in C and in Østerlars, it is possible *to calculate* the meridian convergence, *mc*, between C and Østerlars.

The meridian convergence between two locations with the same distance between them on any great circle (sight line) that differs from a meridian, decreases with a decreasing latitude for the sites and increases with an increasing latitude for the sites, which we can expect would have been known for the intellectuals of the 13th century. But within a (for this study) insignificant inaccuracy, a meridian convergence v = 0.06 degree between any two points on the line Nyalrs-C can be calculated to be equal to the unit of geometry (= the distance

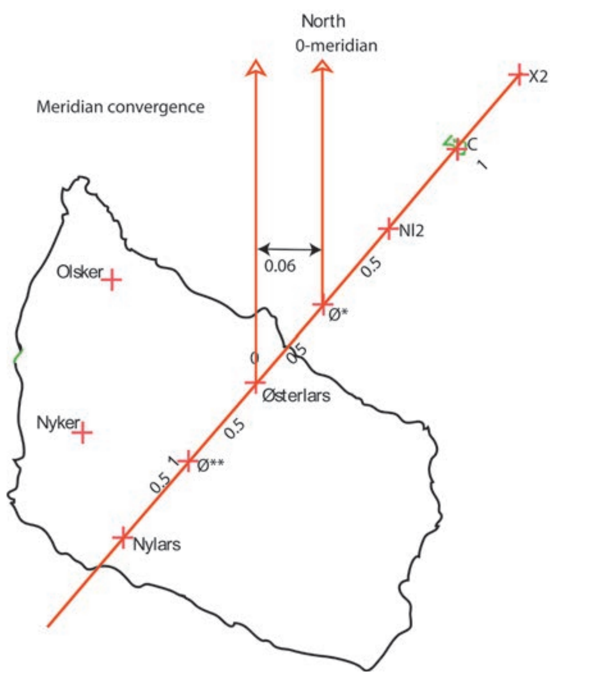


Figure 30: The line Nylars-Østerlars-C has its theoretically accurate angle to north (see Figure 24) - not in Østerlars, but at the point Ø*, which is at 1/2 (* Østerlars-Nylars) from Østerlars and has the meridian convergence 0.06 degrees between Østerlars and Ø *.

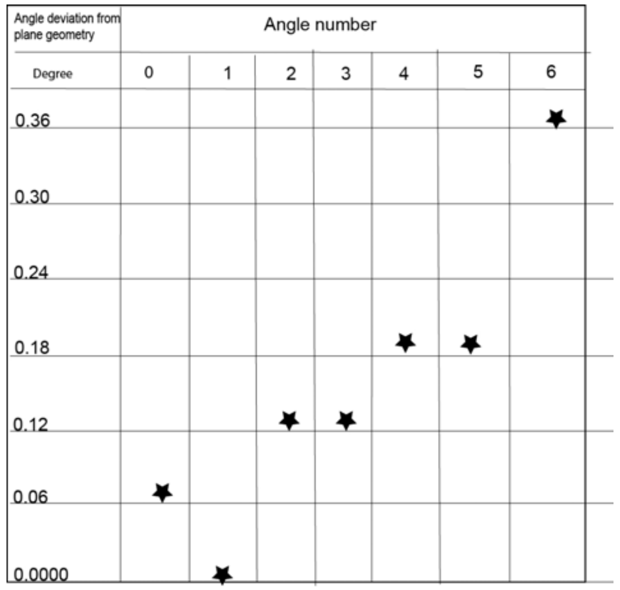


Figure 31: The table shows how the deviations from the theoretically accurate angle are distributed for the six angles (1-6) that define the geometry - as well as the angle to true north in Østerlars (angle 0), defining the geometry's orientation.
It is noteworthy that a single angle is accurate within 0.01 degrees while all other angles within the same degree of accuracy have a deviation of either 0.06 degrees or a product of 0.06 degrees.

Østerlars-Nylars) multiplied by 0.5. (See Figure 30)

By use of Table 2 we can in this case study *calculate* what would be the result of *measuring* the angles in situ to true north both in C and in Østerlars.

We do not know with what accuracy the medieval constructors on Bornholm were able to measure angles, and we do not know their capability to calculate sides and angles in triangles using trigonometric formulas, but we know that Abu'l-Wafa (940 – 998) devised a new method of calculating sine tables. His trigonometric tables are accurate to 8 decimal places (converted to decimal notation). (O'Connor & Robertson 1999).

One must thus assume that at this point of history one could calculate triangles and their angles with far greater accuracy than the accuracy, with which one could measure angles between points in the landscape.

The calculations in this case study are partly ordinary trigonometric triangular calculations and partly calculations performed by the program KMSTrans, based on the coordinates given in Table 1. These calculations include up to eight decimal places – which makes it possible to compare the archeological findings (the coordinates in table 1) with its theoretical counterpart without speculating in advance as to what accuracy is expected.

Today, the meridian convergence, *mc*, between Østerlars and C would be measured to (Table 2) (221.01769 – 180 – 40.83219) degree = 0.1855 degree. This is very close to 11' = 0.18333.. dg.

If the constructors of those days could measure angles with an accuracy down to 1 minute – which is sustained in this research – they would have measured the meridian convergence between Østerlars and C as 11 minutes = 0.18333… dg

On the line Østerlars to C, a distance d = 1 between two locations on the line would thus produce an equivalent calculated meridian convergence, *m*, of (0.1833 * √3/√7) dg = 0.12.. degree - and the corresponding distance d = ½ would produce a meridian convergence of (m/2 = *v*) = 0.06 degree, see Figure 30..

Column F in table A is displaying the deviation between the real angles displayed in Table A column E and the equivalent hypothetical angle in column B,

Here we first notice that one angle (angle (1)) is equal to its theoretical equivalent *within two decimals places.* Then we notice that the other of the 6 angles that define the geometry, all have remarkably larger deviations, but - *all these deviations are in turn very close to a product of (v = m / 2 =) 0.06 degrees, close that is, with an accuracy well within 0.01 degree*. This also applies to the angle (0), Nord-Østerlars-C, see Table A and Figure 31.

Could it be a deliberate, systematic deviation? In which case there ought to be a purpose to such a system.

Thus, let us first look at whether there could be a logical reason why the line Nylars-Østerlars-C should be predetermined to have an angle to true north in Østerlars, wich should not be the plane geometric angle shown in Figure 24, *but the plane geometric angle minus 0.06 degree.*

This would imply that the line Nylars-Østerlars-C's orientation to true north is not determined by the meridian through Østerlars, as anticipated in Figure 24, but is determined by the meridian through a point (Ø *) at the distance d = ½ (half distance Østerlars-Nylars) from Østerlars towards C. See Figure 30.

Østerlars is the center of the geometry as illustrated in Figure 24. Østerlars is also the largest of the four round churches. It seems logical that the meridian through Østerlars would have been carefully chosen as the main meridian, the *Map North.*

Could there be any reasonable purpose to instead orient the line Nylars-Østerlars-C after a meridian through Ø* - and thus make this meridian the main meridian of the geometry, the *Map North*?

Such a resonable purpose surprisingly proves to be present, as we shall see.

But before we get to that, we need to look at a proposal for how the triangulation network could have been measured and laid out in the landscape, in other words, which points in the landscape were probably used as starting points for the construction of the geometry - and which stretch was measured as the basis for the measurement of the entire triangulation? These are key questions for an understanding of the geometry and its construction.

First triangulation

As previously mentioned, two of the Bornholm medieval churches stand out because they are the only ones of the 15 churches that are located on a clear peak in the landscape, and in addition, both are located on Bornholm's ridge, which divides Bornholm into two halves.

Rutsker, whose relation to the geometry is described above, are the highest situated of the Bornholm medieval churches, and at the same time the one (of the two) that most clearly lies on a noticeable hilltop. It is located at elevation 129 meter, and with its 12-meter-high tower plus roof, it allows you to observe the surroundings from a position more than 140 meters above sea level, which gives an unobstructed view to Christiansø as well as a clear view to, for example, Olsker on the north side and to Knudsker on the south side of the ridge.

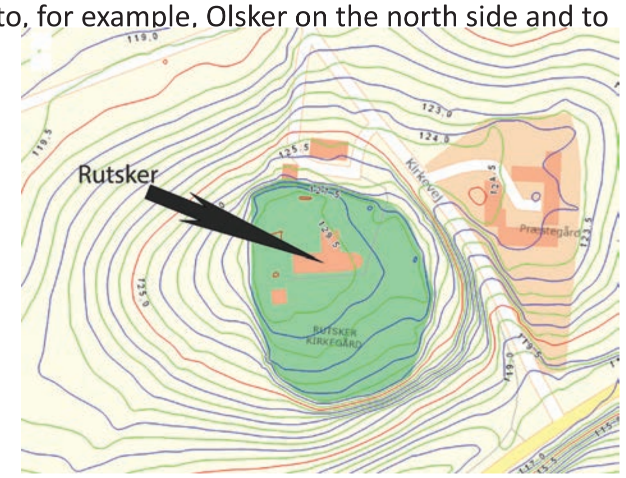


Figure 32: Rutsker with elevation curves.

Klemensker also marks a high spot in the landscape but is not like Rutsker the highest spot in the surroundings, and thus not deliberately chosen to precisely meet this criterion, which supports the following hypothesis of the procedure in the establishment of the geometry.

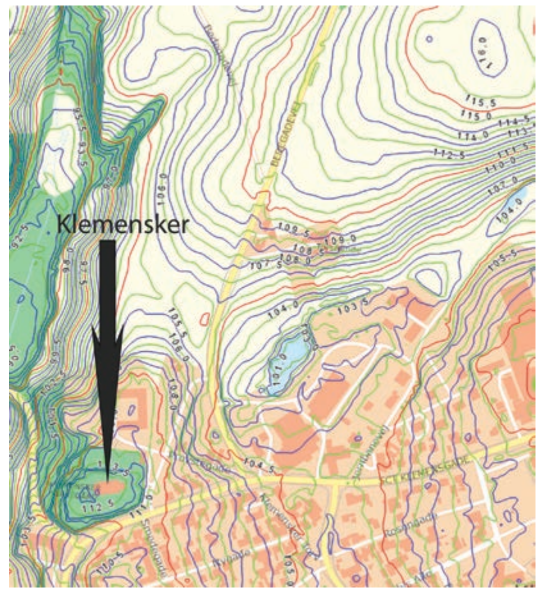


Figure 33: Klemensker with elevation curves.

Klemensker's relationship to the geometry is one of the most notable in this landscape geometry.

A guess is that it has been discovered through observations along the line Rutsker-P1 (see below) how the hill on which Klemensker lies could be fitted into the geometry in the following extremely remarkable way:

Based on Østerlars, the island's largest round church, as the center, and Østerlars-Nylars as the radius of what we define as the unit circle, Klemensker lies on a circle, inscribed in the square, inscribed in the unit circle. The church is further located so that

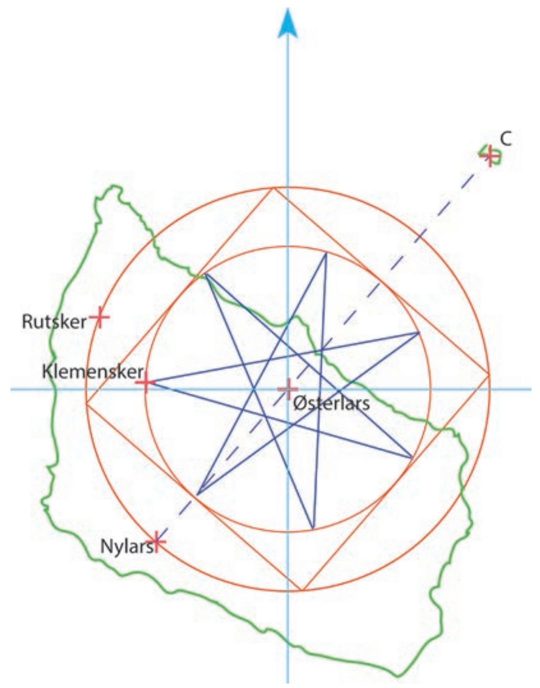


Figure 34: Klemensker church's location in the geometry.

it is designated by the tip of a heptagon oriented by the line Nylars-Østerlars-C and inscribed in this circle, see figure 34.

Unfortunately, it is not immediately possible to judge the accuracy of the location of the church tower in relation to the theoretical geometry, because the church - as mentioned earlier - is not the original.

As we shall see, the location of the original church tower is important for a calculation of the proposed first triangulation, and therefore the following calculated angles in the proposed first triangulation rest on a qualified estimate of the location of the original church tower in Klemensker.

Rutsker and P1

The top of the mentioned ridge, which divides Bornholm into two parts, has been named Rytterknægten. A tower called Kongemindet has been built on Rytterknægten in memory of a visit by the Danish king Christian VII in 1851.

Rytterknægten reaches a height of 162 meter above sea level.

North, south and west of this point there are within about 100 meters distance several other peaks that reach over 160 meters above sea level (see point P1 in Figure 38). The height difference between these peaks is on average between one and two meters.

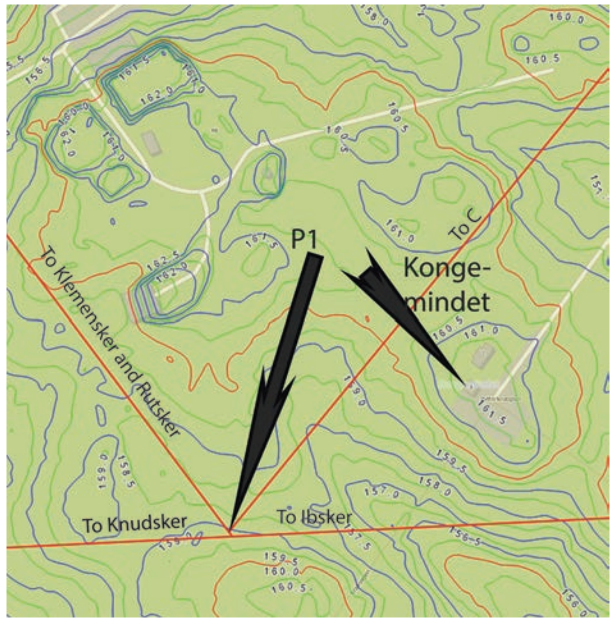


Figure 38: P1 designates a point that is the intersection of two lines: a line through the church towers of Rutsker and Klemensker and a line through the church towers of Knudsker and Ibsker.

It would therefore be natural if one of these hilltops – considering the point's views - would be used as a base point for establishing the geometry – just as natural as point C on Christiansø.

It is previously described how one of these points, (P1), seems to be included in the geometry as a point designated as a cross between the extension of a line between the towers of Rutsker and Klemensker and a line between the towers of Knudsker and Ibsker (Haagensen 1993).This previous calculation of P1 have used coordinates for the current church tower in Klemensker, but since this church tower is not the original, and as the geometry has proven to be able to designate with high accuracy the location of the church tower in Rutsker and the location of the original church tower in Vestermarie, it could be worth to calculate a possible accurate location of the old church tower in Klemensker, based on the geometry in Figure 34, and from this calculate a possible more accurate location of P1. Therefore, a calculation now follows of the location of the old church towers in Klemensker and Rø, calculated on the basis of the location of Østerlars and Nylars and the geometry depicted in Figure 34.

Intermezzo: Calculating old towers in Klemensker and Rø

Just as we did in Vestermarie we use the geometry to designate the hypothetical location of the original Klemensker tower, Kp.

Calculated coordinates to Kp (Klemensker theoretical) through KMSTrans, see figure 34). Through KMSTrans we find coordinates to Kp:

<u>55.174989238 dg N; 14.802714570 dg E</u>

Kp reveals to be located 18.51 meters from the current church tower. We know, however, from drawings, that the present church is about 10 meters longer than the old church. In 1888 the new church was Denmark's largest country church seating 1,000 people (Old Churches 1999). Since the present church still has the old crypt under its chancel[9], the old tower must have been about 10 meters further to the east. Old maps show that the old church also seems to have turned more in a south-easterly/north-westerly direction, so this indicates overall that the tower of the old church with reasonable accuracy is designated by the coordinates of Kp. See figures 35 and 36.

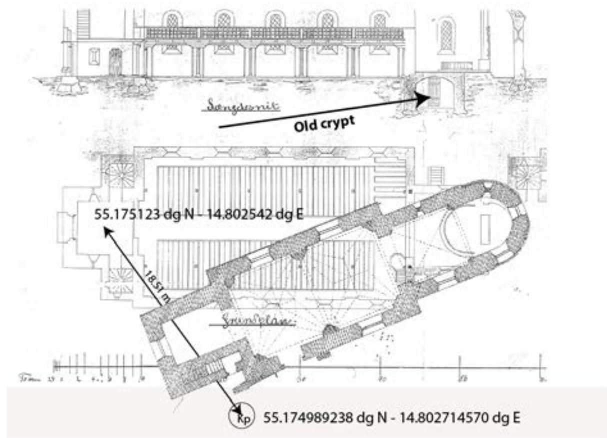


Figure 35: Drawing of the old church's floor plan is laid over drawing of the new church with the right size ratio and with coincident apse. At the same time, the old church is turned in a northwest-southeast direction, like what is shown in Figure 36. Kp marks the point determined by the position of Nylars and Østerlars in relation to the geometry in Figure 34.

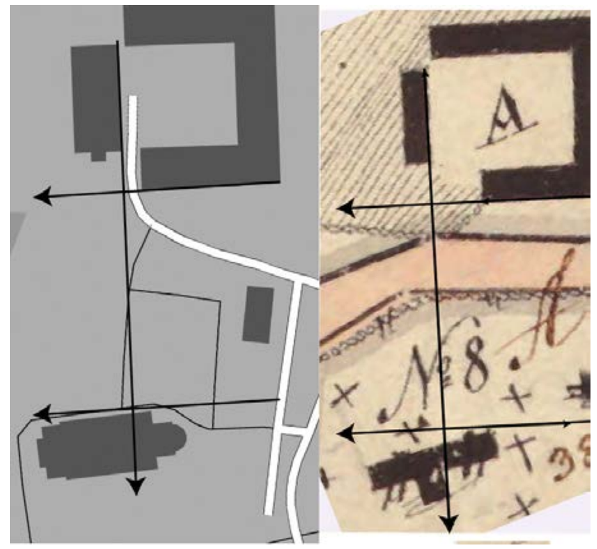


Figure 36: To the right Klemensker old church on land map april 23 1859, on the left a contemporary land map. The rectory, which is seen north of the church, has the same orientation today as in the late 1800s and is therefore used as a reference to the church's orientation. This indicates that the old church was turned more in a southwest-northeast direction.

This opens the opportunity that eventually archaeological traces of the old tower <u>may prove or disprove</u> the accuracy of the geometry.

Rø

Since the location of the old tower in Rø church also seems indicated by the geometry, we use the opportunity of calculating the location of the old church tower in Rø:

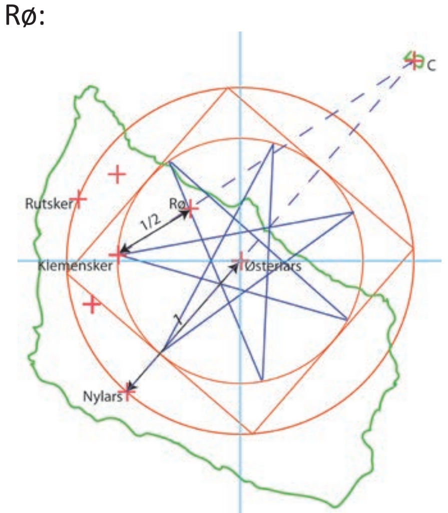


Figure 37A: Rø church's location in the geometry. Rø is on a line from Klemensker to C on Christiansø - so that the distance from Klemensker to Rø is half the distance between Østerlars and Nylars

In relation to Klemenskers' tower, the tower in Rø is found on a line from Klemensker to C on Christiansø at ½ (* Østerlars-Nylars) from Klemenskers tower, see figure 34.

A calculation with KmsTrans gives the following coordinates for Rp:

55.210592941 dg N - 14.896487542 dg E.

From Rø to Rp: 24.55 m in the direction of 96.002 dg.

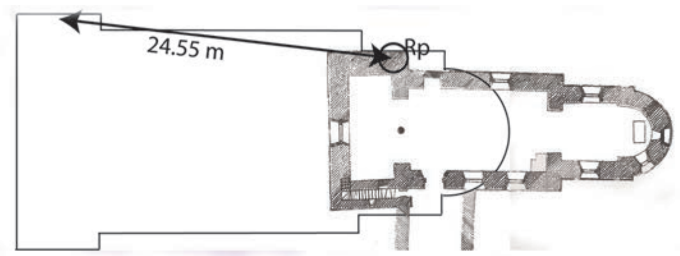


Figure 37B: Drawing of the old church's floor plan is laid over drawing of the new church with the right size ratio. Rp marks the point determined by the position of Nylars, Østerlars, and C in relation to the geometry in Figure 37A.

This is illustrated in Figures 37A and 37B. It indicates that the new church in Rø have been built to the west in extension of the old church. This corresponds to the relationship between the new and the old church in Vestermarie, supported by the fact that it was the same architect, Mathias Bidstrup, who was responsible for the construction of both the new churches.

This opens a similar possibility that archaeological traces of the original tower will be able to prove or disprove the accuracy of the geometry.

Continuation:

Calculation of P1:

Based on the locations of the church towers in Rutsker and (the above calculated location of the tower in) Klemensker (now Kp) and the locations of the towers of Knudsker and Ibsker, the location of P1 is:

55.110983928 dg N; 14.886315585 dg E [10]

P1 is located at an altitude of 159 meters above sea level. It is therefore not the highest point on Bornholm. There is another hilltop nearby that rises about one and a half meters higher but will not cover for the prospect of the horizon for a person standing up. The subsequent calculation shows that P1 together with Rutsker and C form an isosceles triangle. This triangle must be assumed to have had priority over a location on the hilltop itself. The view from P1 to C, to Rutsker, to Knudsker and to Ibsker - and probably several other of the medieval churches - might further support the point's significance for triangulation.[11]

-

By calculating the angles Rutsker-P1-C and P1-Rutsker C we discover that triangle P1-Rutsker-C is an isosceles triangle.[12]

Angles Rutsker-C-P1: 27.827994 dg;

C-P1-Rutsker: 76.086041 dg

C-Rutsker-P1: 76.086266 dg

(Average: 76.0861535; = 76 dg 5 min 10 sec = 76.086111.. dg –; difference 0.00004 dg)

This means that the isosceles triangle Rutsker-C-P1 has an angle accuracy better than one thousandth of a degree.

Figure 39: By measuring the distance P1-Po in the right-angled triangle P1-Po-C, the sides of the isosceles triangle P1-C-Rutsker can be calculated. From P1 to C: 30,148,02 m. From Rutsker to C: 30,147.99 m (Table 2).

From P1 towards Rutsker, the ridge forms a generally slight descent, during periods of small, fairly flat hills - with one or two slightly more marked exceptions - but largely a smooth line until shortly before the line hits Klemensker. This straight and even part of the line extends past a point Po, where the line P1-Po forms a right angle with the line Po – C, see Figure 39.

This means that it is possible to establish the location of Po through bearings to P1, Rutsker, and C on Christiansø. It would have been possible to measure the distance from P1 to Po with, for example, chains or rods - and from this it is possible to calculate the length of the sides in the triangle Rutsker-C-P1.

Applying the Bornholm Method.

Triangle P1-Rutsker-C will be a sufficient starting point for measuring the size of the earth by applying the Bornholm Method described in connection with Figure 26.
Note that Rutsker is the westernmost of the Bornholm medieval churches and C is the easternmost point in the geometry.

In addition to knowing the calculated distance Rutsker-C, one must measure Rutsker's latitude, u, measure the angles North-Rutsker-C and North-C-Rutsker and calculate the meridian convergence (v) between Rutsker and C.

Again, we do not know with what accuracy this data could be measured and calculated at that time. With today's instruments and by following the *Bornholm Method,* we get the following result:

Latitude for Rutsker (table 1)(angle u): 55.215238 dg N, distance Rutsker-C (table 2): 30147.99 m, angel north-Rutsker-C: 67.03404 dg, meridian convergence Rutsker-C (table 2)(angle v): (247.39339 – 180 - 67,03404) dg = 0.35935 dg

Let A in figure 26 represent Rutsker and C represent C on Christiansø, see Figure 40.

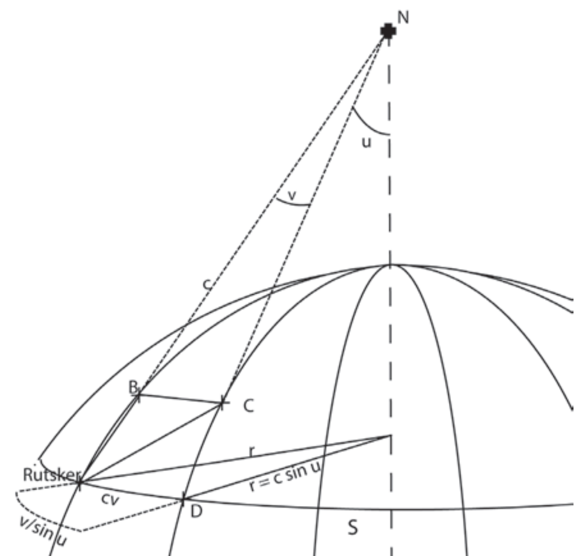


Figure 40: From figure 26: A is replaced with the tower of Rutsker church and C with C on Christiansø.

Following the described method: Calculating triangle Rutsker-N-C gives us N-Rutsker = c = 4437600 m, r (= radius in the parallel through Rutsker) = 3644605.154 m. Circumference of the parallel through Rutsker: 22899729.56 m.

If the earth is a perfect sphere and has this circumference of a parallel at the latitude of Rutsker, the circumference of the earth will be [22899697.17 / cos (55.215238)] m = 40140094.35 m; 40,140 km

Three other approaches

Described in note[13]

These calculations demonstrate that it is possible to calculate triangles in the landscape, where the two sides follow a parallel and a meridian, respectively.

A discussion of the purpose

Let's look at what may be a rationale why the geometry P1-Rutsker-C is expanded to the geometry illustrated in figure 24:

First it is assumed that because the meridian convergence between Rutsker and C is measured close to 0.36 degrees - that is, one thousandth of a circle – it has inspired to lay out a sight line through C which would cover a meridian convergence of 0.36 dg. Then it seems to have been decided to divide this line into 3 units, corresponding to a meridian convergence 1/3 of 36 dg = 0.12 dg for each unit, see figure 30.

It seems reasonable that this new line through C as far as possible is constructed to go across Bornholm down the middle of the island - as opposed to the line Rutsker-C – because this would lay as much as possible of the line on land and make it possible to build observatories on this line, not only with a maximum achievable distance between them, *but with a preferred unit distance,* which would provide the optimal conditions for measuring different latitude and corresponding meridian convergences on this new line. This seems to be the reason for choosing the line that becomes Nylars-Østerlars-C, which the geometry is subsequently built on.

Calculation of Østerlars:

Østerlars› position in the landscape - which is assumed to be the basis for the rest of the landscape geometry – can be calculated from triangle Rutsker-P1-C in the following way (see figure 41):

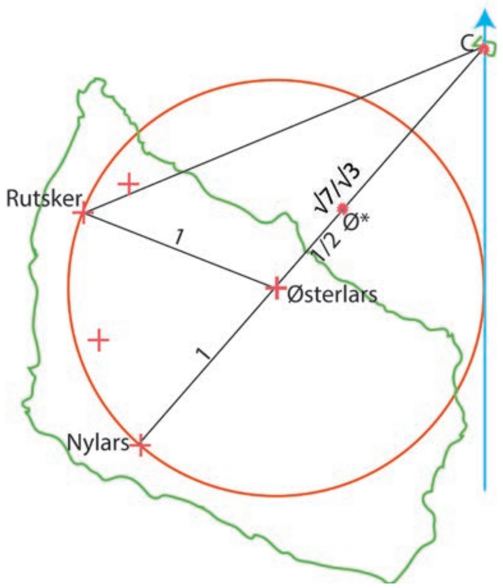


Figure 41: The distance Rutsker-C is known. The desired inclination to the north of the line Østerlars-C is calculated from the angle of the line to the north at point C. Thus, the angle of Rutsker-C-Østerlars can be calculated. Since Østerlars-C and Østerlars-Rutsker are also known, the angle Rutsker-Østerlars-C can be calculated and thus Østerlars' location can be determined.

As mentioned, it is assumed that the prerequisite for the geometry is that a line through C should be three units long, where each unit corresponds to a meridian convergence of 0.12 degrees, thus a total meridian convergence between the endpoints of the line corresponding to the meridian convergence Rutsker-C = 0.36 dg.

A proposed method:

Through various measurements to C from points along Bornholm's northeast coast, a point Ø1 is found, where the angle N-Ø1-C is equal to the plane geometric angle North-Østerlars-C in figure 24.[14] At the same time it is found, that the meridian convergence between Ø1 and C is 11' (as discussed earlier).

It is assumed that this led to the decision to define the geometry from a line Østerlars-C based on the following two requirements:

1: Since 11' divided by the geometric distance Østerlars-C in figure 24 is 0.12 dg (0.120012.. dg), a decision that the distance Østerlars-C should be the geometrical distance in figure 24 would result in the desired meridian convergence of 0.12 degrees for the unit = 1.

2: The line Østerlars-C is further defined on the basis that the line must have an angle to true north equal to the plane geometrical angle North-Østerlars-C in Figure 24.

These two requirements are related to the fact that the distance thus chosen Østerlars-C is then geometrically related to the direction of the line Østerlars-C towards true north. This creates the conditions for generating a relatively simple geometry based on Pythagoras' theorem, which at the same time proves to be able to also fulfill the previously mentioned desires for a line through C, which is subsequently achieved as the geometry shown in Figure 24.

The above anticipate that angles could be measured with an accuracy around two correct decimals. (The meridian convergence between Østerlars and C is 0.1855 dg (se table 2), compared to 11' = 0.183333..). This is the only place in this study with an anticipation about the available accuracy. As it will appear, there seems to be good evidence for this anticipation.

In the above and onwards, all other calculations are based on the accuracy that can be achieved with today's measurements.

This method forms a basis that makes it possible to make an objective comparison between the archaeological traces in the landscape and the theoretical expectations of the hypothesis. However, this study goes no further than an attempt to substantiate the hypothesis of Bornholm's round churches' function as observatories in the geo-astronomical experiment described.

This study cannot conclude what might have been the result of measuring the Earth with the method described. The purpose of this study is to make it probable that such a result could be achieved.

The question of whether the archaeological traces can document an accuracy, with which one was able to measure and calculate distances and angles, requires a closer analysis of the data presented, which is not included in this study.

This then forms the basis of the hypothesis that a meridian convergence of 0 dg 7 min 12 sec (0.12 degree) has dictated the structure of the geometry.

To sum up:

It is assumed that a decision to define the distance Østerlars-C forms the basis for the calculation of the geometry shown in Figure 24. The decision on this defined distance is logically related to the fact that the distance is geometrically related to the line Østerlars-C's direction to true north. This creates the conditions for generating a relatively simple geometry based on Pythagoras' theorem, which at the same time proves to be able to satisfy the above mention desired conditions for a line through Østerlars and C, and which is subsequently realized as the geometry shown in Figure 24.

This awareness of the possibility to create a line through C, which will satisfy the above mention desired conditions, can necessarily only be obtained through prior extensive surveying, which would display that a three units long line through C can be determined not only through the location of C and Østerlars but at the same time can be predetermined to have its starting point on the west side of the island, where Nylars is later located - which creates the conditions for the geometry displayed in Figure 24.

As the meridian convergence decreases with decreasing latitude and increases with increasing latitude, it is logical to calculate a center, Ø*, - 1.5 units from each end of the predetermined 3-units long line - as the point where the line should have its theoretically accurate angle to true north.

Østerlars-Nylars is predetermined to have a distance 1, Ø* is thus a fictitious point (located in the sea) 0.5 units from the center of the geometry (Østerlars) in the direction of C.

Ø*›s position on the line C-Østerlars is calculated so that the meridian through Ø* becomes the *Map North* and defines the direction of the line Nylars-Østerlars-C.

Against this background, we can determinate the location of Østerlars and Ø* in relation to Rutsker and C and calculate the unit length 1, see Appendix C.

Thus, if the circumference of the Earth around the poles is known, it can be compared with the results from the calculations with the *Bornholm Method* to estimate, if the earth is spherical.

The polar circumference of the Earth was at this period known with a reasonable accuracy.

In the mid-12th century notes attributed to Hugh of St. Victor, he describes the astrogeodetic method of Eratosthenes. (Hohman 1991, p. 27).

The method of Eratosthenes is thus well known among the scholars of the Catholic Church as early as the middle of the 12th century.

Hugh describes the method as it is known from Cleomedes, but he adds a description of how, to achieve greater accuracy, one can replace measurements for the sun with measurements for the celestial pole.

Since this is of great importance for achieving the accuracy that is apparently reflected in the geometry on Bornholm, we will subsequently discuss how to determine the celestial pole.

Probably in year 820 AD, the astronomers of Caliph Al-Ma'mun determined the equatorial Earth's circumference being 20400 miles. One degree of the meridian arc measured thus 56 2/3 Arabian miles, which is equal to 111.8 km. ((Sparavigna 2014).

Through the *Compendium on the Science of Stars*, written by Al-Farghani (Alfraganus), and translated in Latin by John of Seville and Gherardo da Cremona (Campani, 1910), a value of Earth's circumference was well known in Western Europe during the Middle Ages (Angelitti 1905) (Nallino 1892-1893, 1-41).

Povlsker

But it seems that on Bornholm they did not want to settle for a measurement of the meridian performed by others and elsewhere.

The location of Povlsker shows that the geometry using the *Bornholm Method* was supplemented by a measurement with Eratosthenes' method, as Povlsker, the southernmost of the Bornholm medieval churches, is placed on a parallel that has an an accurate and simple geometric distance from the parallel through C on Christiansø, the northernmost point in the geometry, see figure 44.

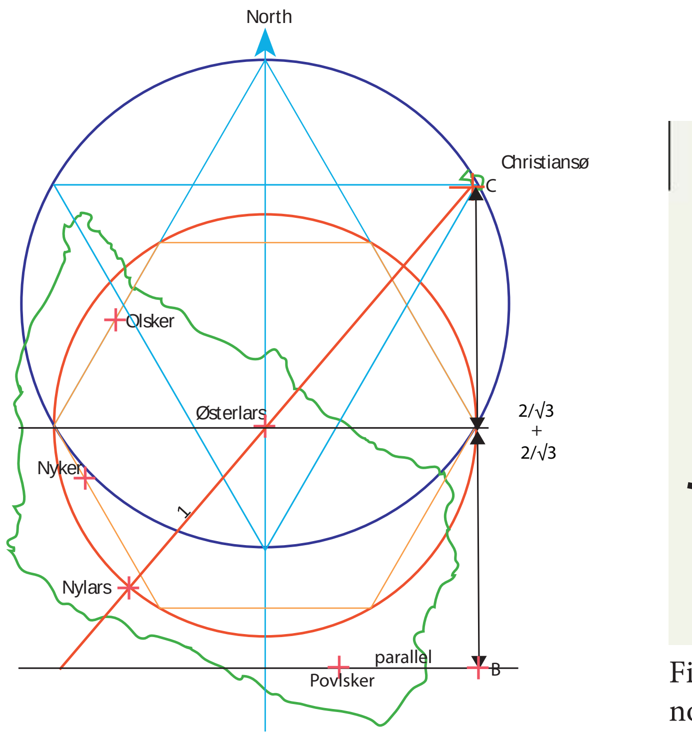


Figure 44: The location of Pv can be calculated with relation to C and Østerlars:
In triangle Østerlars-C-B we know the sides Østerlars-C and C-B. The angle Østerlars-C-B can be measured with relation to true north.
Angle Pv-B-C is (90-0.12/2) dg. Thus, in triangle B-Østerlars-Pv we know the sides B-Østerlars and B-Pv and we can calculate angle Pv-B-Østerlars. In triangle B-C-Pv we know the sides C-B and B-Pv and the angle Pv-B-C. From this, we can calculate distance and bearings from Pv to Østerlars and from Pv to C.

Povlsker, for good reasons, cannot be placed directly on the meridian through C, as the meridian runs east of Bornholm.

In Figure 44, B is the point on the meridian through C, located (* 14335.505) m south of C.

KSMTrans gives coordinates to B:

55.022738087 N; 15.1872222000

From the coordinates of Povlsker (table 1), it can be calculated that the parallel through B goes through the south-western corner oof Povlsker church, see figure 45, which means that the church lies with great accuracy on the same parallel as B.

The question is whether the geometry also dictates where on this parallel the church is intended to be located?

This study does not have an answer to that question, but there is a remarkable detail:

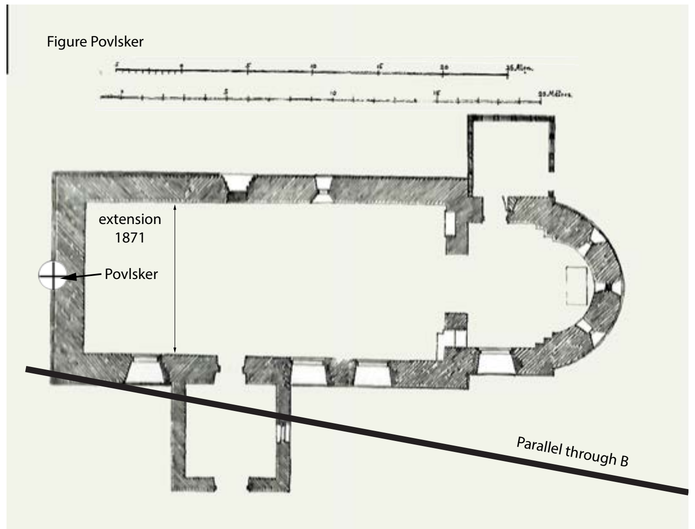


Fig. 45. The parallel through B intersects the northwest corner of the church. Povlsker is the only of the 15 medieval churches who does not have the characteristic west tower. But 25 meters east-southeast of the church stands a 6-meter-high granite tower on two floors, where the lower floor was originally a gate passage. The ground plan of the tower is a square measuring 5.30 meters. (Norn et al. 1954, 533) The parallel through B also intersects the southwest corner of this tower, see Figure 46.

Fig. 46

As described in figure 30 the geometry is assumed to be built around a unit on the line Østerlars-C with a meridian convergence of 0.12 degrees. On the line Nylars-Østerlars-C, the meridian convergence is closest to 0.12 dg between Nylars and Østerlars, where the true meridian convergence is 0.12038 dg (calculated from Table 2)

It turns out that the meridian convergence between Povlsker and C is 0.12007 dg (calculated from Tabel 2). The difference from 0.12 dg is a meridian convergence of 0.00007 dg which correspond to approximately 4.5 meter on the parallel through Povlsker.

Could this be intended? It is remarkable, but this study is not able to say if this is a cooincidence - if intended, this study is not able to explain, how this could be achived.

Purpose:

Povlsker's location is assumed to be a marking in the landscape of a specific point included in the geometry in Figure 24, but at the same time a point determined by the desire to use the geometry for a traditional measurement of the size of the Earth, the well-known so-called Eratosthenes Method.

Povlsker can with certainty be determined as the youngest of the Bornholm medieval churches.[15]

As previously mentioned, Nykirke was intended for a third floor, which never managed to be completed. This leads to the hypothesis that the overall project had to be abandoned before it was completed.

If the builder was the Order of the Knights Templar, as is argued for later, the construction may have been interrupted in connection with the order's arrest in 1307 and dissolution in 1312.

True north

The accuracy of the layout of the geometry in the landscape and the accuracy of the calculations made possible by the geometry are crucial depending on the accuracy with which the position of the celestial pole could be determined.

As mentioned earlier, it is not part of this study to answer the question of what accuracy can be deduced from the data presented.

Others have previously given various suggestions on how to determine the location of the celestial pole. An example is Kate Spence, who describes a method she calls *the Simultaneous Transit Method,* which she believes could have been used as early as ancient Egypt more than 3,000 years ago. (Spence 2000). The method requires that the location of the celestial pole be initially determined through careful observations, for example from an observatory, after which the direction to true north from outside the observatory can be determined quite simply by means of a plumb line through a selected pair of stars. If a similar technique were used on Bornholm, it could simplify the measurements of the meridian convergence.

Portolane Charts

"The only available technique to map a significant portion of the earth's surface is to begin by establishing a geometric framework. This is the quintessence of geodesy; it is why geodesy developed as an applied, mathematics-based science in the 18th century. In those days' geodesy, together with astronomy, formed the vanguard of science." (Nicolai 2016)

This is a quote from dr. phil. Roel Nicholai. He made a study of the so-called Portolan Charts, which is a special type of map of the Mediterranean area, of which the earliest, we know of, is from the end of the 13th century.

These maps look like a modern map and are therefore different from any other maps drawn at that time, which is an enigma for both historians and geodesists. The maps have a network of lines. The lines are assembled at nodes at different longitudes. The nodes are places where the direction to true north is "adjusted". In the later Portolan Charts, a compass rose has been inserted in these nodes. It is this technique that makes the maps look like a modern map. As Nicolai says: "the overall shape of the coastlines is closely related to that on a modern map based on the Mercator projection". (Nicolai 2015).

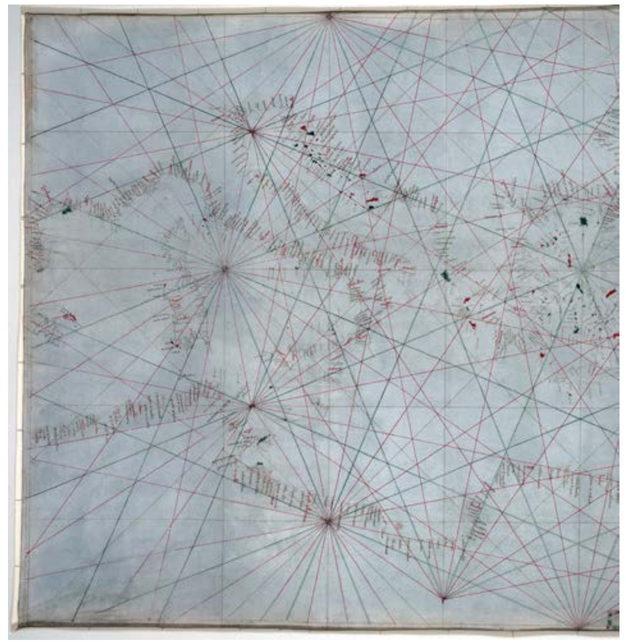


Figure 47: The oldest original cartographic artifact in the Library of Congress: a portolan nautical chart of the Mediterranean Sea. Second quarter of the 14th century. Italy is seen in the middle of the map.

Roel Nicholai continues: "*The science of geodesy had yet to be invented when the portolan charts first came into use, and the geodetic technique of triangulation, which was used in the eighteenth century to construct the geometric framework of the first scientifically produced topographical map, now known as the Cassini map of France, was still more than three centuries away. The hypothesis of portolan charts' medieval origin requires a convincing explanation for the gap that exists between the state of medieval science and technology (as far as this is known), on the one hand, and the requirements for scientific mapping of the large area portrayed by portolan charts, on the other..*" (Nicolai 2015)

This case study of the archaeological testimonies that relate to the geometry of Bornholm apparently shows that those who made this geometry adjusted it according to certain meridians (see table A, Figure 30, and Figure 48) and thus there seems to be a correlation between the geometry on Bornholm and the geometry that formed the basis of the Portolan Charts.[16]

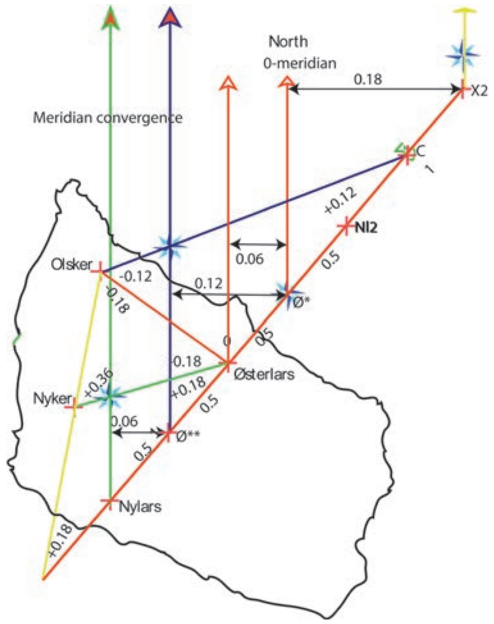


Figure 48: If the line from Nylars through Østerlars to C and X2, and the line Østerlars-Olsker, both are assumed to be oriented based on a meridian through Ø *, if the line C-Olsker is assumed to be oriented based on a meridian through Ø **, if the line Østerlars-Nyker is assumed to be oriented based on a meridian through Nylars, and if the line Nyker-Olsker is assumed to be oriented based on a meridian through X2, then the geometry on Bornholm will show an accuracy in relation to the theoretical assumptions that for all angles is better than 0.01 degrees. See Table A and Figure 30.

Bornholm is thus a testimony that "somebody" at this time of history seems to have had the necessary knowledge and technique behind the Portolan Charts.

Who made it?

This study is now supplemented by several well-known historical facts that might support the hypothesis that the design of this geometry and the setup of this empirical experiment may be the result of collaboration between certain members of the Knights Templar and one or more Muslim scientists from the Iberian Peninsula.

First, when we look more closely on the Order of the Knights Templar, a general interest from the Order into the island of Bornholm appears. The Order is from the beginning intricately connected to Burgundy. The founding knights were all Burgundy noblemen. The Order's affiliation to Burgundy becomes clear when the first Grand Master, Huges de Payenne, nine years after founding the Order, travels back to Burgundy and turns to Bernhard of Clairvaux, abbot in the Cistercian monastery Clairvaux and an outstanding member of the Burgundy nobility, closely related to the duke of Burgundy.

After this visit' Bernhard arranges the Council of Troyes 1128, after which pope Honorius II recognizes the Order – and Bernhard writes the Order's rules and regulations, closely following the Rules of St. Benedict as reformed by the Cistercians, an order also recently (1198) established by the Burgundians. The strong connection between Templars and Cistercians is well-known and important.

In the opinion of leading historians, Burgundy has a history connected to Bornholm.: "All in all …the traditional identification of Bornholm with the prehistoric wanderings of the Burgundians is entirely credible: by no means proven, but more than a mere possibility" (Davis 2011, p. 30 – see also Guichard 1965)

Today Bornholm belongs to Denmark. The earliest historical sources connecting Bornholm to Denmark is from around 1070[17], but the island has a much longer history as an independent kingdom going back to at least 880 AD.[18]

Many archaeological finds on the island points to the existence of a king and his court. The location of these finds indicates the king's palace was once situated at a site called "Sorte Muld". The finds include more than 2.500 tiny gold figures, so called "guldgubber" from around 500 AD. Many of the figures depicts Merovingian kings.

The island has many grave chambers of a type, which in Central Europe was reserved for the Merovingian aristocracy: "Developments on Bornholm during the period from the 6th to the 8th century show a similarity to the Merovingian area in several details that can hardly be interpreted as merely copying a burial custom". (Jørgensen, 1992 – off print p. 125.)

The Merovingian dynasty was founded in 492 AD through the marriage of the Frankish king Clovis I and the Burgundian princess Clotilde, daughter of King Childeric II of Burgundy.

Based on the above, it is possible that the Burgundian aristocracy, which gave birth to both the Cistercian Order and the Knights Templar, could still in the 12th century have had some family-related interest on the island of Bornholm.

This in turn might catch light on a certain gift from the Danish King Svend Grathe to the Nordic Archdiocese of Lund:

The Archdiocese of Lund was Danish, established in 1104, and the gift was a conciliation particularly selected to please Archbishop Eskil.

Eskil had in 1137 succeeded his uncle, Asser, the first Archbishop of Lund. When the Danish King Erik Lam left the throne I 1146, Denmark got divided between three kings, who fought each other, and Eskil took part against Svend Grathe, but despite this, Svend managed to take over the province of Skåne – the Archdiocese's province.

Svend then imprisoned Eskil, but fearing the Pope's intervention, the king regretted his enmity towards Eskil and wanted to reconcile with him. In 1149, Svend gave ¾ of Bornholm to the Archdiocese of Lund as conciliation. (Suhm, 1793, vol. 6, p. 40)

The question is whether it was the king who reckoned that this gift could appease Eskil - or whether it was Eskil who had expressed what could appease him. Based on Eskil's remarkably close contact with Burgundy and his friendship with Bernhard of Clairvaux - and a possible interest in Bornholm among the Burgundian aristocracy - this gift could be exactly what Eskil had wanted.

Eskil had five years earlier, in 1144, invited Cistercians from Bernhard's monastery to establish the first Danish Cistercian monastery Herrevad in Skåne. The previous year, 1143, he had assisted the Swedish King Swerker with a contact to Clairvaux, resulting in the establishment of two Cistercian monasteries, Nydala and Alvastra in Sweden. (Benninghoven 1956, p. 15,16.)

Eskil continued his contact with the Cistercian Order by further establishing the Danish Cistercian monasteries Esrum in 1154, Vitskøl 1158 and Sorø in 1161, (Benninghoven 1956) all in all four Cistercian monasteries, which, when compared to the number of inhabitants in Denmark, brings Denmark on top of a list of Cistercian interest during Medieval times.

Due to the close ties between the Knights Templar and the Cistercians, it is striking that the Cistercians are so strongly represented, without there having apparently been Knights Templar in Denmark.

The Danish Cistercian monasteries established subsidiaries on the southern shores of Balticum: Dargun 1172, Kolbatz 1173, Olivia 1186 and Eldena 1188. (Benninghoven 1956)

This is symptomatic of the growing Danish interest in extending the kingdom towards east - and further a symptom of the coinciding interest between the Church and the State. This mutual interest is a weight-carrying element in Denmark's involvement in Baltic crusades, to which we shall return. In this regard one should again bear in mind the close connection between the Order of the Cistercians and the Order of the Knights Templar, and we shall soon see how the Templar's influence was established in the Baltic region.

Two years after Eskil got the supremacy over the majority of Bornholm, he went to Clairvaux to meet with Bernhard. He wanted to become a monk in Bernhard's monastery, but Bernhard persuaded him to continue as Archbishop, because this "would be more beneficial to the Church at large". (Kettenburg 1909).

What they talked about is not available, and how Eskil as Archbishop in Lund specifically could be more beneficial "to the Church" is not described. But when examined in relation to what we now know about Bornholm, it is tempting to jump to the interpretation, that this might have something to do with certain interest "from the Church" relating to the island of Bornholm.

Eskil goes back to Lund, but shortly after his return, he gets information about Bernhard's death (1153). He then immediately returns to Clairvaux "to pray at his grave". It is not difficult to think of a more pragmatic motif. If he indeed had promised something to Bernhard concerning Bornholm and knew about a plan for the laborious and painstaking work, we now know must be behind the island's geometry, he simply had to return to talk to Bernhard's successor. The man to talk to would in this case probably have been Bernhard's uncle, André de Montbard, Grand Master of the Knights Templar from 1103 to 1156.

Eskil did not get back to Lund until five years later and then only for a short period. A conflict between the Pope, Alexander III, and the German Emperor Frederick I, also known as Barbarossa, had resulted (1159) in the emperor's appointment of an antipope. In Denmark, the conflict between the three kings was solved – only one, Valdemar I, survived the conflict. But Valdemar's way to power had made him a vassal of Barbarossa, and as such he had to approve of the emperor's antipope. Eskil could not live with this and went in exile (1161) for the following 7 years. When he returned in 1168, the legitimate pope, Alexander III, had been reinstated.

Interestingly, when leaving Denmark, Eskil's first act was to travel to Jerusalem. As mentioned above, it is likely the Templar Grand Master, being Bernhard's uncle, would have been in Clairvaux for some time following Bernhard's death, but the head quarter for the Order's Grand Master was at the time in Jerusalem.

The Order got a new Grand Master in 1156, Bertrand de Blanchefort. Among Eskil's reasons to travel to Jerusalem could therefore also have been a wish to discuss important issues like Bornholm with Montbard's successor. Eskil travelled from Jerusalem directly to Bernhard's monastery in Burgundy and spent the following years, until 1168, in Clairvaux "in close proximity to, the now de-throned, Pope Alexander III". (Kettenburg 1909).

Eskil's years in Clairvaux and the subsequent influence of the Order of Cistercians seem to have been vastly important for Denmark as a crusading nation over the years to come.

A few details about the Cistercians:

In 1164, and with the pope's (Alexander III) permission, Eskil appoints a Swedish Archbishop and he chooses a Cistercian monk, Stephan, from the Cistercian monastery Alvastrad for the powerful position Archbishop of Uppsala. (Benninghoven 1956, 16)

Also in 1164, in Clairvaux, Pope Alexander III appoints the Cistercian monk Fulco from the monastery La Celle as first bishop of Estonia. (Benninghoven 1956).

Fulco is assigned to Eskil, which means the number of bishops in Denmark increases from eight to nine.

To have a bishop over Estonia is remarkable, because, at that time, there was not a single Christian church in Estonia. The German historian Friederich Benninghoven has this conclusion: An extensive military operation against the pagan Wends was scheduled. (Benninghoven 1956, 16)

It is also noteworthy, that when Eskil returns to Denmark in 1168, he has changed remarkably. Previous he was strongly against several attempts from King Valdemar I to canonize his father, Canute Lavard, who was brutally murdered only days before the birth of Valdemar. But suddenly, after his return from Clairvaux, he sanctions King Valdemar's new application to Pope Alexander III to have Canute Lavard beatified.

This happens during a spectacular celebration in 1170, where also Valdemar's son, later Canute VI, was crowned by Eskil.

Did Eskil's years in Clairvaux teach him something about the Cistercian organization of chivalric orders like the Templars?

He must have learned that in the years following his first visit to Clairvaux, several chivalric crusader orders, which also followed the Cistercian rules, emerged. Among them the Spanish Order of Calatrava, founded in 1157 and approved by Alexander III in 1164, thus during Alexander III and Eskil's stay in Clairvaux. The Order of Calatrava was only the second military order to receive papal approval. The Order of Alcántara in the Kingdom of León and the Order of Avis in Portugal began under Calatrava's protection and during the visit of its grand master. The order Fratres Militie Christie de Livoni, which was established in Riga in 1202, closely following the rules of the Templars. (Benninghoven 1956, 39). Furthermore, the two Portuguese Orders, the Order of Évora and later the Order of Christ, were established in the early 14th century as a direct continuation of the now abolished and banned Templar order. All these military orders sprang from an ideology and a mode of organization that was fundamentally Cistercian and they were tools to be used in the crusades. (Jensen 2017) Importantly, it seems such chivalric crusading Orders in the slipstream of the Templars, were often local, needing a local Patron Saint of their own.

Canute Lavard became such a saint for the Danish Confraternity of Canute. The Confraternity was militarized, had the king as a brother and was widespread throughout the Baltic region at the same time as the Danish crusades in the Balticum.

Historians do not have sources enough to finally prove that this Confraternity is a Danish equivalent to chivalric crusading Orders like the Templars, but the Danish historian, Professor Kurt Villads Jensen, has pointed out a possible link between this fraternity and the so-called List of Brethren. (Jensen 2017, see also Jensen 2002).

The List of Brethren is found in a document called the Danish Census Book or the Danish Book of Land Taxation (Latin: Liber Census Daniæ). Most of its text is from c. 1230, but the List of Brethren is believed to have been written around 1180 - 1200. (Lind e al 2006, 133.) It is a long list of about 215 names, put together in groups of mostly three persons, geographically spread over all the western part of Danmark: Jutland, Funen and Zealand. Opposite each group is written: fratres, i.e. brothers. King Canute VI, son of Valdemar, is on the list, and so are the Danish bishops, but not necessarily mentioned in their own diocese.

The list is still at the center of an ongoing debated mystery.

Kurt Villads Jensen points to the possibility that it is a list of "brothers" within a Danish chivalric crusading Order connected to Saint Canute (Lavard) and he notes: "If it is the names of the members of this military order that are preserved in the so-called List of Brethren, the membership included, as one would expect, the Hvide family on Zealand around the Cistercian monastery in Sorø. Perhaps this chapter of the order met in the copy of the Holy Sepulchre, which Ebbe Sunesen had erected shortly before 1170, in nearby Bjernede". (Jensen 2017).

This "copy of the Holy Sepulchre" is the round church of Bjernede. The church has – like the other two preserved round churches in western Denmark and all four round churches on Bornholm – a second floor, which is completely separated from the church on the ground floor.

It is this second floor Jensen suggests was the meeting place for the members of the chapter. (Jensen 2002, 81)

This is interesting because it provides a reason for floor number two - in fact, as Jensen seems to suggest, the second floor is another church that might be reserved for the consecrated members of the fraternity to hold mass for their saint and pray for their deceased members

But not necessarily alone for that use.

In Clement V's bull "Vox in Excelso" (1312) he mentions "the secret and clandestine reception of the brother of this Order". What really happened during these initiation ceremonies has remained a secret. The confessions made by members of the order during torture were never the members' own answer to a question about what went on during the ceremonies.

The prosecutor asked them to confirm that during the initiation ceremonies they were spitting on the cross, denying Christ, worshipping a head, and performing obscene kisses to encouraging to homosexuality. None of the members of the order felt compelled to speak of their own free will with details of what was really going on. [19]

Today's orders, which claim to be associated with the Knights Templar, such as the Freemasons, have degrees to which the brothers are gradually promoted. Each new promotion takes place during the performance of secret rituals. It takes place in a room decorated with movable furniture, which among other things consists of an altar as in a church. The fact that the furniture is movable means that the room can be decorated in accordance with the degree of initiation in question, and it also means that the room itself does not later leave traces of the secret initiations.

The Danish "Order of the Brotherhood" may have had ordination ceremonies and promotion ceremonies held in a room decorated with an altar as in a church - and with equipment that could vary depending on what ritual and what degree was to be initiated in, which means that the chamber built for these ceremonies would basically be empty of decorations.

It may well be in this light that one should see the purpose of a church room number two, and then not only in Bjernede round church, but, in all the round churches with two floors that were built in Denmark in this period.

We should have the same explanation for the second floor in all four round churches on Bornholm. This means we must explain why there was a need on Bornholm for such a vast number of churches reserved for fraternity members - when compared to the relatively small number of inhabitants on Bornholm.

There is a degree of probability that the orders of our day, such as the Freemasons, and the medieval Knights Templar, all draw on the same ancient mystery cult traditions and rituals.

Thus, there is no reason why the general scenario for the initiation rites - including progress for brothers to slowly advance in "degrees" through new initiations - would be quite different from the corresponding scenarios in the Order of the Knights Templar or in any of the other mentioned orders that was created in the gliding current of the Knights Templar.

If Jensen is right, the four round churches on Bornholm with its four floors for initiation must have been specifically designed for an exceptionally large number of both new and advancing members of such an Order. Thus, they cannot have been built for servicing the population on Bornholm alone.

A remarkable architectural design of the room on the 2nd floor of Østerlars can even give us an idea of a ceremonial detail that may have been an important part of the secret inauguration rituals:

As can be seen from a survey from 1878 (Holm 1878), there is a light passage on the second floor of Østerlars church, which goes through the thick outer wall, further through an opening in the hollow center pillar and continues through an opening on the opposite side of the hollow center pillar, so that a light beam from a certain direction will penetrate across the whole room, see Figure 49.

From in situ observations on the day of the sunrise at winter solstice, it appears that the aperture precisely captures the first light from the sunrise on this very date, see figure 48.

The sunrise on this date has always had a special ritual significance - it marks, so to speak, the rebirth of the sun.

The architectural design of the four round churches has strong similarities with a specific Templar architecture, which was first revealed by art historian Mette Wivel.

She emphasizes that the four Bornholm round churches are built with a vaulted ceiling, supported only by a single central pillar, an architecture that is not found in any other Danish round churches, but which she points out is found in a devotional chapel in the most famous of the Knights Templar castles, Château Pélerin in Athlit, Palestine, and in several of the Knights Templar churches in Europe.

As an example, she highlights the Knights Templar church, Convento de Christo, in Tomar, Portugal:

"There is a resemblance in the inner structure, which is created by the pillars and the arches, so that a smaller separate space arises in the center. This is the case with the (Knights Templar's) temples or churches of Paris, London, Northampton, Cambridge, Dover, Segovia, Tomar and Østerlars". (Wivel 1989. 62). See figure 49. No other round churches in Scandinavia has this design.

The hollow central pillar in Østerlars continues up through the next two floors. The hollow pillar in the Knights Templar's church in Segovia in Castile similarly continues up through the floor above and forms a chapel in which a fragment of the True Cross was kept. (Barber 1994. 195).

Also, the fortress Hammershus, the largest medieval castle in northern Europe, bears a great resemblance to the castle of the Knights Templar in Tomar, Portugal (see Figure 52), where you also find the round church of Convento de Christo.

As mentioned in the introduction, there are no sources as to when and by whom Hammershus and the medieval churches on Bornholm were built. And there are no records that any members of the Order of the Templars were ever present on Bornholm - not even records of any templar activity in all of Denmark.

This is strange for the following reason:

Denmark was an outstanding crusading nation in the Baltic from the late 12th century to the beginning of the 13th century, not least due to a close cooperation with the Order of Cistercians, result of Eskil's preparatory work.

King Valdemar II, son of Valdemar I, continued his father's and later his brother's (Canute VI) crusades and, in 1219, he finally conquered Estonia during an exhaustive Danish crusade.

This happened with substantial help from Fratres Militie Christie de Livonia in Riga, also known as the

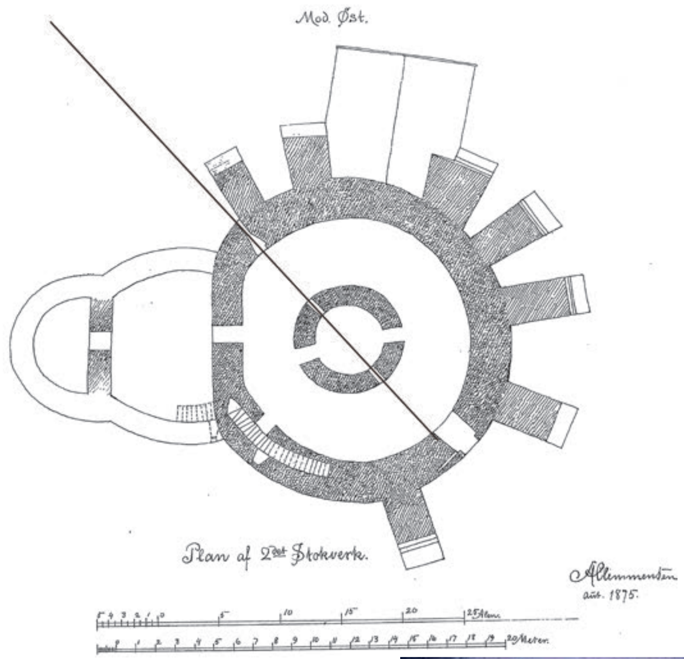


Figure 49: The sketch shows how a ray of light with a certain direction from the outside can penetrate through the outer wall and further through two openings in the hollow middle column and thus penetrate diagonally through the entire space on Østerlar's second floor.

Figure 50: This photo was taken at sunrise on the morning at the winter solstices. It is a fascinating experience to stand in the totally black church room before dawn and witness a ray of light that, like a laser beam or a flame sword, suddenly penetrates and illuminates the entire space.

Figure 51: Østerlars (left), the templar church Convento de Christo in Tomar (right).

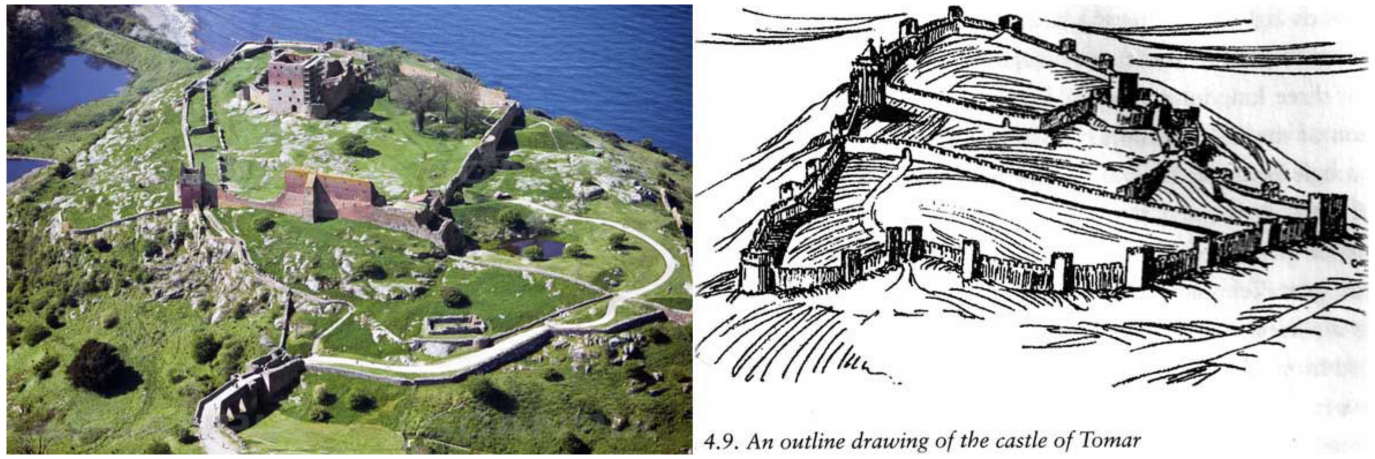


Figure 52: Hammershus (left), Castle of Tomar (right). Hammershus is not only the largest castle in Northern Europe - but there are no other Danish castles with this extensive division of the fortification walls into three rings within each other. The entire design of Hammershus, on the other hand, has a striking resemblance to the Knights Templar's castle complex in Tomar - just as Østerlar's church has a striking resemblance to the Knights Templar's church, Convento de Christo, found in the same castle.

Brothers of the Sword. (Benninghoven 1956. 152 ff)

The Brothers of the Sword was founded upon the rules of the Templars.

At the time "Bornholm is Denmark's most visited "port" and a safe anchorage for ships that usually depart to the pagan and to Greece".[20] Bornholm is conveniently located directly on the navigation route for Valdemar's crusading fleet.

King Valdemar II was married to the Portuguese Princess Berengaria, daughter of King Sancho I of Portugal. Sancho's father, Alfonso I, was the first king of Portugal, son of Duke Henry of Burgundy and a prominent member of the Knights Templar - Bernhard of Clairvaux was his uncle, and he established the Kingdom of Portugal in 1139 in close cooperation with the Knights Templar.

Thus, Valdemar II's marriage to Berengaria brought him in close family ties with the core of the Burgundian families, who founded the Templars. Berengaria was the mother of Danish kings Eric IV, Abel and Christopher I, and the Burgundian blood continued in the royal Danish family up to and including the present monarch Margrethe II and her descendants.

It seems strange that no documentation of Templar activity relating either to Bornholm or to Denmark in general can be found.

Could documents deliberately have been removed or kept secret?

If the Bornholm experiment not only were meant to determine the shape and size of the Earth but also was connected to superior knowledge about accurate map making, an interest in keeping the whole project secret could seem to be obvious for those, who put so much time and effort into achieving such financially important scientific knowledge. If the organization behind the Bornholm project was the Templars, they would have had a clear interest in keeping it secret.

In addition, if the Knights Templar were behind the churches and Hammershus, it would explain where the money for the buildings came from - something that is just as mysterious as the buildings themselves.

In the early 1190s, the Knights Templar bought the island of Cyprus from the English King Richard for the sum of 100,000 Saracen besants, of which the Order initially paid 40,000, a sum which shows the depth of the Templars' financial resources. (Barber 2019. 119).

If Archbishop Eskil - or his successor - has negotiated with the Knights Templar about Bornholm, it is not inconceivable that the Knights Templar have paid the archbishopric in a similar way. When Clement V dissolved the Knights Templar Order, he simultaneously issued the bull Ad Providam, in which he orders that all the Knights Templar's properties should pass to the Order of Knights of the Hospital of Saint John of Jerusalem, commonly known as Knights Hospitaller or the Order of Saint John. (Papal bull Ad Providam, May 2nd, 1312). The Pope made sure that this command also was specified in three letters specifically addressed to 1: the Danish king, 2: the Archbishops (!) and bishops I Denmark, and 3: to dukes, margraves, counts and barons in the Kingdom of Denmark. (1312. 16. Mai. Livron-sur-Drôme. Diplomatarium Danicum nr. 13120516001). The Pope must obviously have erroneously assumed that there could be Knights Templar's properties in Denmark, since he has made these three efforts to ensure that his decision was complied with also in Denmark.

It is not hard to imagine that if the Archbishop of Lund was the only one who knew of an agreement with the Knights Templar about Bornholm, then he would do much to keep this agreement a secret - as the churches and the Hammershus would otherwise pass to the Order of Saint John.

In addition, an intense study of the remarkable light openings in the church of Østerlars could have brought forward new knowledge. Like the accuracy of the geometry, there might be new evidence connected to a study of the movement of the Sun, which can be conducted from these light openings. Something might have appeared which could contradict the church's dogma and thus also motivate the church to destroy any evidence of this experiment, just as we have seen the church's later response to the work of Copernicus and Galileo Galilei.

It could therefore be a win-win situation for both the Archbishop of Lund and the Pope to hide any trace of Knights Templar activities on Bornholm

Finally, it is important to point out that there are obvious but unexplored opportunities to find archaeological traces that might help to shed light on the many questions raised in this study.

In Østerlars, the existence of a room, located under the church choir, has been documented. Two studies, one with geo-radar and one with gravimeter measurements, have concordantly documented an empty space under the floor measuring 63 cubic meters. (Haagensen 2003. 121-125).

In Olsker, a seemingly pointless niche under the stairs up to the first floor has been interpreted as a possible covered descent to a basement (Haagensen

Figure 53: There is a peculiar hollowing out of the masonry under the stairs leading up to the upper floors of Olsker. The hollow includes both the masonry in the outer wall and the masonry in the triumphal arch, so that a cave is formed deep into the triumphal arch. It has been suggested that this could be related to an initial descent to a basement, which in this way could be hidden from view. (Haagensen & Lincoln 2000, 138)

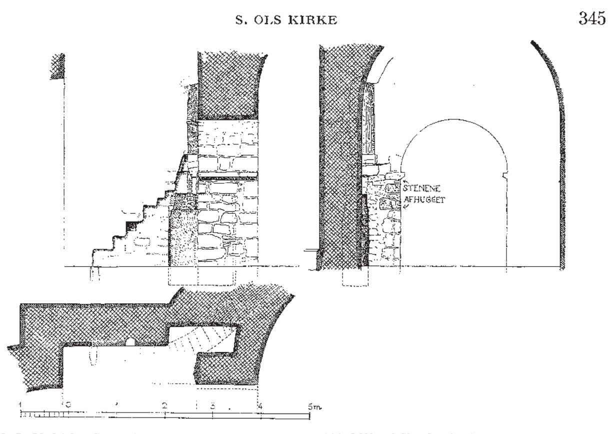


Figure 54: Drawing of the peculiar hollowing out of the wall and triumphal arch (Norn et al. 1954, 345)

In 2016 the international engineering company Ramboll – on behalf of the danish national tv, DR2 - made a geo-radar investigation of the ground beneath the floor in Olsker church. The result is that in all probability there is a total second floor beneath the ground floor.

Senior geo-physicist Jørgen Ringgaard confirm in the program, that from the niche beneath the staircase to the upper floors there is a surface going down, which could very well be a staircase continuing down to a cellar.

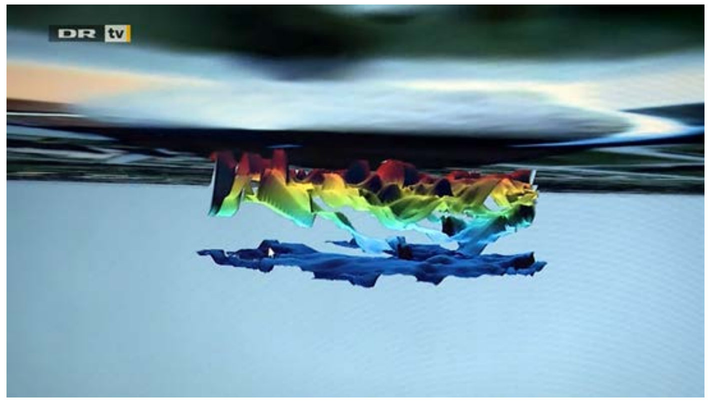


Figure 55: Ramboll's computer image of the result of their radar survey in 2016 of the ground below the ground floor of Olsker Church. The blue surface is what Ramboll suspects is a basement floor. The upper surface, which looks very bulging, has been interpreted by Ramboll to resemble vaults - an arch-like ceiling.

He says to DR2: "Our conclusion must be that there is something, which looks like a floor that is a straightened surface – I cannot say whether it is stamped or paved but it looks like a floor some two and a half, three meters under the existing ground floor – thus it seems there has been – or is – a room down there."

Since neither Østerlars nor Olsker have any written sources mentioning a basement or a room under the floor, these rooms must have been covered and sealed early in the history of the churches. It gives hope that these spaces can store archaeological evidence that can help clarify the history of the churches.

This case study research is primarily presented as a foundation for further research.

Notes:

"Hammershus is a rather big castle. The fortified area with the moats is about 15 hectares. The outer wall is about 900 metres long. This layout seems to be too big even for the archbishop both in building expense and in size. He would have needed a whole army to defend it…" "It is now quite certain that the castle was constructed as one grand design during a relatively short time." (Vesth 2015).

2 The calculations of sunrise at solstices are based on the latitude of Østerlars, the height above sea level and an ecliptic slope 23.54° in the year 1200, calculated for the author of former amanuensis at the Technical University of Denmark, Associate Professor Hanne Dalgas Christiansen.

3 Haagensen, 2014, page 164 – 165.

4 A manuscript from 1299 describes the use of an instrument called sphaera horarum noctis or astrolabium nocturnum, with which it is possible at night to calculate time from the position of certain stars. (Lull 1299)

5 Al-Biruni introduced techniques to measure the earth and distances on it using triangulation. He found the radius of the earth to be 6339.6 km, a value not obtained in the West until the 16th century*:* Norhudzaev, K: al-Biruni and the science of geodesy (Uzbek), in Collection dedicated to the 1000th anniversary of the birth of al-Biruni (Tashkent, 1973), 145-158. From: MacTutor History of Mathematics Archive: https://mathshistory.st-andrews.ac.uk/Biographies/Al-Biruni/.

6 Note that the coordinates of Østerlars and Nylars both are to the tip of the conical roof, that is, to the center of the church rotunda, and that the coordinates of Rutsker are to a lightning conductor sitting on the church tower.

7 Professor emeritus at Waterloo University, Niels Lind, has rejected Wienberg's postulate that geometry may have arisen by chance. Niels Lind has analyzed Haagensen's presented data in two articles. In the first, from 2002, he says in his introduction:

This paper aims to show how probability indeed can be put to work to assess the book by Haagensen. Linds conclusion is:

The postulate that four of the churches were deliberately aligned two and two with Christiansø is overwhelmingly favored by high odds over the alternative that any such alignment is accidental. (Lind 2002)

In his second article, he says in his introduction:

Four of the 15 medieval churches on Bornholm island align two and two with a point on the islet of Christiansø. Also, 12 of the 105 distances between these churches have remarkably simple ratios, conforming to a common module. Couldn't all these coincidences be due to chance? You cannot talk about the probability of what has already happened, but you can study the probability of hypotheses about past events by Bayesian analysis.

The hypothesis that the coincidences reflect deliberate design is favored by the evidence.

His conclusion:

It is concluded that Haagensen's hypothesis can be seriously (quantitatively) examined and cannot simply be dismissed outright. Bayesian analysis supports the geometrical claims made by Haagensen (1993) that four of the churches are aligned pairwise with Christiansø, and that many distances between the churches are simple multiples of a common module. The idea that these features are deliberate rather than accidental is supported by quite high odds. (Lind 2005)

8 Nylars-Vestermarie = (14335.505 * ¼) m = 3583.876 m. Angle N-Nylars-Vestermarie = (N-Nylars-C = 40.711930 dg, – 30 dg = 10.711930 dg.

KmsTrans koordinates to Vp: 55.105612424 N; 14.8253811818 E; Vestermarie to Vp: 35.74 m in direction az 102.51 dg

9 Church Protocol signed Sodemann, April 30. 1890

10 [The geographical coordinates can be calculated as follows (angles are calculated from table 2):

Angle Knudsker-Rutsker-Kp = angle Knudsker-Rutsker-P1 = 36.293384 dg

Angle Rutsker-Knudsker-Ibsker: (360 – 359.41527 = 0.58473) 0.58473 + 86.98751 = 87.57224 dg

Knudsker – Rutsker: 12 050.05 m

Thus triangel Rutsker-Knudsker-P1:

Rutsker-P1: 14 499.04 m; Rutsker-P1-Knudsker: 56.13438 dg;

Rutsker-Knudsker-P1: 87.57224 dg: Knudsker-Rutsker-P1: 36.293384;

P1-Knudsker: 8589.9858 m

(Rutsker-Knudsker) – 36.293384 dg = (179.41369 – 36.293384) dg = 143.120306 dg]

11 Control KMSTrans: P1-Rutsker: 14499.040 m and angle N-P1-Rutsker: 33.232218 dg
P1-Kp: 8898.936 m and angle N-P1-Kp: 33.232218 dg – ergo P1 is on the extension of the line Rutsker-Kp.
Control KMSTrans: P1-Knudsker: 8589.978 m and angle N-P1-Knudsker 267.09778 dg;
P1-Ibsker: 13947.852 m and angle N-P1-Ibsker: 87.097762 dg; 180 + 87.097762 = 267.097762 dg ergo control OK.

12 Calculation with KMSTrans: C to P1: 30148.021 m; FA: 219.565396 dg BA: 39.318259 dg;

13 1: The geometry makes it possible to calculate the distance Rutsker-D (Figure 40), which is a cord to the parallel through Rutsker. We can calculate the isosceles triangle Rutsker-N-D and find: Rutsker-D = 27831.875 m.

If the earth is a prefect spere, the meridian convergence (v) divided by sinus of the latitude (u) gives the corresponding longitude degree. Thus 0.35935 dg represent (0.35935/sin 55.215238) dg = 0.437537536 dg longitude. Let O be the center of the parallel through Rutsker. Then we have the isosceles triangle Rutsker-D-O, which give Rutsker-O = r = 3644608.10 m. (2.946 meter longer than calculated above).

The circumference of the parallel is thus 22899748.06 m. This also correspond to a perfect sphere with the circumference 40,140 km.

2 : it is also possible to calculate the distance Rutsker-D from the triangle Rutsker-C-D, because from the meridian convergence we can calculate the angles Rutsker-D-C (90 – (0.35935/2) dg = 89.820325 dg and D-Rutsker-C [(90 – (0.35935/2) - 67,03404) dg = 22.786285 dg, together with Rutsker C = 30147.99 m it also give us Rutsker-D = 27832 m.

3: Finally, it is possible to calculate the size of the earth from Rutsker-D being 27832 m and representing 0.437537536 dg longitude = [0.437537536 * cos (55.215238)] dg latitude = 0.249613047 dg latitude. 1 dg latitude = (27832 / 0.249613047) m = 111500.5819 m. 360 dg = 40,140,209.5 m, also 40,140 km.
dg

14 Ø1 is not identical to Østerlars, but measurements from Ø1 form the conditions used to determine Østerlars› location in relation to Rutsker and C.

15 "The north portal is also round-arched, but its style is young-Gothic" (Norn et al. 1954, p. 539), and "The very distinct late character of the church building does not invite the north portal to be considered an addition" (Ibid , p. 540).

16 A map projection is usually a projection of the spherical landscape onto a flat surface. Here it looks like one have gone the opposite way on Bornholm and projected the flat map onto the landscape - after which it was possible to measure *in vivo* the distortions that result from the projection. It is noteworthy that - unlike all other distances not on the Nylars-Østerlars-C line - the distance between Olsker and Nylars is hardly affected at all by the projection. Nyker was never completed and must therefore be the last of the four observatories built. There might be a further sophisticated purpose in selecting this projection method - but it has not been detected in this study.

17 Adam of Bremen: Gesta Hammaburgensis ecclesiae pontificum, 1073-1076 AD. In his description of Scandinavia the author include the island Holmus (Bornholm) as being part of Denmark. He also claims the inhabitants were baptized by the Danish bishop Egino around 1060, but archeological finds prove that the inhabitants were Christian centuries earlier.

18 Wulfstan of Hedeby (Latin Haithabu) was a late ninth century traveler and trader. His travel accounts, as well as those of another trader, Ohthere of Hålogaland, were included in Alfred the Great's Old English translation of Orosius: "Histopria adversus paganos". In this Wulfstan writes from a travel 880 AD: "And thonne Burgendaland wæs uns on bæcbord, and tha habbad him sylf cyning" (and Burgendaland (Bornholm) was on our portside and they have their own king).

19 Malcolm Barber has detailed - based on source material - what the "brothers" confessed during the trial of The Knight Templars. The papers suggest that the confessions of "spitting on the cross," "denying Christ," obscene kisses and calls for homosexuality" were charges invented by those responsible for the interrogations - and therefore, under torture, the brothers agree that this took place during their "secret" initiation and inclusion. (Barber 2012). What is interesting, however, is that there is not a single confession that describes how the initiations took place - and what, in addition to these "confessions," took place by secret rituals. In other words, during these interrogations, the brothers kept their oaths of silence and confessed only what they were required to confess.

20 Adam of Bremen: Gesta Hammaburgensis ecclesiae pontificum, 1073-1076 AD

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Table 1

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TABEL 1: Transforming of coordinates from ***KMS system 1945 Bornholm*** to geographical coordinates in **European Terrestrial Reference System 1989 (calculation: KmsTrans)**

Number refers to fix points listed by Danish Geodata Agency (GST)		**GST coordinates system 1945 Bornholm**		**Geo euref89**		**Measure point**
Original church *(new church)*	**Fix point number**	**Y**	**X**	**La N**	**Lo E**	**Description**
C **Big Tower**		73 241.26 73 299.55	31 083.43 31 102.51	**55 19 12.42955 55.320119 dg 55 19 14.31592 55.320643 dg**	**15 11 14.00005 15.187222 dg** 15 **11 12.93092 15.186925 dg**	**Calculated according to figure 1 and based on the locations of Østerlars and Nylars Tower built in 1884**
G				**55 12 31.22602 55.208673499 dg**	**14 57 42.06695 14.961685 dg**	**Calculated according to figure 1 and based on the meridian through Østerlars.**
Rutsker	140-04-827	61 535.30	58 866.14	**55 12 54.85755 55.215238 dg**	**14 44 59.87987 14.749967 dg**	**Church tower, foot of northern wing pole**
Østerlars	139-03-002	*56 658.79*	*45 385.33*	***55 10 17.40502 55.171501 dg***	***14 57 42.06695 14.961685 dg***	**Spire on conical roof**
Ø*				***55 13 12.69774 55.2201938 dg***	***15 02 07.17040 15.0353251 dg***	**Calculated according to figure 1 and based on the locations of Østerlars and Nylars**
Ø**				**55.122761071**	**14.888222599**	
Nylars	137-03-001	45 803.09	54 748.17	**55 04 26.33266 55.073981 dg**	**14 48 53.80081 14.814945 dg**	**Spire on conical roof**
Nl2				***55 16 07.83154*** *55.268842 dg*	**15 06 32.91593** 15.109143 dg	**Calculated according to figure 1 and based on the locations of Østerlars and Nylars**
(Klemensker) Kp theoretically	140-02-002	57 063.72	55 525.51	***55 10 30.44248 55.175123 dg 55.174989238***	**14 48 09.15296 14.802542 dg 14.802714570**	***(Church tower, spire)***
(Rø) Rp theoretically	140-05-819	61 011.26	49 564.33	**55 12 38.21803 55.210616 dg 55.210592941**	**14 53 45.97540 14.896104 dg 14.896487542**	***(Church tower, northern gable wing pole)***
Olsker	140-03-001	63 844.61	55 653.27	**55 14 09.71087 55.236031 dg**	**14 48 01.41872 14.800394 dg**	**Spire on conical roof**
Nyker	137-02-003	53 086.37	57 665.44	**55 08 21.71748 55.139366 dg**	**14 46 08.64830 14.769069 dg**	**Spire on conical roof**
(Vestermarie) ***Vp theoretically***	137-04-007	49 331.53	54 112.87	55 06 20.45612 **55.105682 dg 55.105612424**	14 49 29.40612 **14.824835 14.825381814**	***(Church tower, spire)***
Knudsker	137-01-002	49 484.62	58 767.81	**55 06 25.20955 55.107003 dg**	**14 45 06.83536 14.751899 dg**	**Church tower, northern gable**
Bodilsker	138-02-001	44 474.00	38 287.27	**55 03 42.97998 55.061939 dg**	**15 04 21.32146 15.072589 dg**	**Church tower, northern gable**
Ibsker	139-02-001	50 624.19	36 258.57	**55 07 01.67653 55.117132 dg**	**15 06 16.65912 15.104628 dg**	**Church tower, northern gable**
Povlsker	138-04-007	40 109.48	40 349.97	**55 01 21.99864 55.022777399 dg**	**15 02 24.59527 15.040165354 dg**	**Top of western gable**
Povlsker Entrance tower	138-04-006	40 110.82	40 300.32	**55.022788504 dg**	**15.040941682 dg**	**Top of northern gable**
(Østermarie)	139-04-008	52 968.16	41 924.38	**55 08 17.90912 55.138308 dg**	**15 00 57.23218 15.015898 dg**	***(Church tower, northern gable wing pole)***
P				**55.1109839288**	**14.886315585 dg**	Calculated intersection (Rutsker-Klemensker extension)/(Knudsker-Ibsker)
Aakirke	138-01-007	45 442.21	48 089.75	**55.070763597**	**14.919181664**	***Tower nv gable***

Table 2

TABEL 2 angles (degree) and distances (meter) calculated with program KMStrans, Geo euref89 with input from table 1
Includes 14 of the islands 15 medieval churches and point C on Christiansø.
With this table it is possible to calculate the real angle and the meridian convergence between sightlines to the listed locations.

From	to Østerlars	to Nylars	to C	to G	to Olsker	to Nyker	to Klemensker	to Rø	to Rutsker	to Knudsker	to P	to Bodilsker	to Ibsker	to Povlsker	to Østermarie	to Åkirke	to Vmarie
Østerlars Angle to N		14 335.51 220.83219	21 897.88 40.83219	4138.36 0	12 532.66 305.04114	12 789.14 253.83512	10 148.28 272.34247	6 033.91 316.22032	14 335.69 289.94242	15183.61 241.86348	8 275.80 215.5270	14101.29 149.83272	10941.29 123.52796	17311.33 162.97311	5 059.49 136.89449	11537.82 193.61087	11 395.53 230.03988
Nylars Angle to N	14 335,51 40.71181		36 233.39 40.71193	17675.05 31.90584	18 064.27 357.06258	7 845.84 338.10625	11 287.48 355.98533	16 067.35 18.75671	16 262.26 345.26631	5 451.50 312.42899	6 142.754 47.856992	16 514.32 94.55057	19 107.62 75.32045	15 528.60 111.43775	14 689.63 60.74106	6 668.17 93.03598	3 585.17 10.14087
C Angle to N	21 897.88 221.01769	36 233.39 221.01761		18960.76 229.22231	26 305.29 249.31199	33 358.85 233.07092	29 310.77 236.74157	22 161.04 236.74583	30 147.99 247.39339	36 479.31 229.60830	3 0148.02 219.5654	29 655.18 194.29951	23 201.40 193.12917	34 388.11 195.78716	22 989.48 208.37631	32 588.04 211.69732	33 196.68 224.16638
G Angle to N	4138.36 180	17675.05 212.02625	18 960.80 49.036834		10 706.82 286.59240	14 496.81 237.92195	10 801.88 249.83560	4 180.48 272.99136	13 496.99 273.19056	17 519.44 229.84070	11 889.22 203.8634	17 801.05 156.54169	13 669.56 138.14582	21 302.79 166.23410	8 561.42 156.18208	15 590.41 190.02952	14 406.92 217.32069
Olsker Angle to N	12 532.66 124.90869	18 064,27 177.05064	26 305.29 68.99404	10 706.82 106.45992		10 944.83 190.51665	6 782.10 178.84372	6 715.91 114.87718	3 956.70 234.21476	14 692.89 192.16075	14 958.91 158.4966	26 015.24 138.04613	23 471.92 124.20339	28 266.51 147.02442	17 515.12 128.31032	19 896.06 157.57957	14 594.66 173.86415
Nyker Angle to N	12 789.14 73.67704	7 845,84 158.06862	33 358.85 52.72743	14 496.81 57.76383	10 944.83 10.49093		4 516.48 28.17797	11 332.74 45.52719	8 533.81 351.80885	3 765.68 196.91847	8 119,70 112.8526	21 205.68 113.85908	21 547.87 96.45849	21 677.30 126.66440	15 741.45 90.32744	12 252.59 128.49658	5 169.12 136.48280
Klemensker Angle to N	10 148.28 92.21183	11 287.48 175.97515	29 310.77 56.42551	10 801.88 69.70493	6 782.10 358.84548	4 516.48 208.20544		7 149.73 56.41229	5 581.59 323.16216	8 242.54 203.08768	8.898.94 143.163617	21 346.06 126.06647	20 314.53 108.40581	22 785.98 137.99748	14 204.38 106.68277	13 796.71 147.31187	7 860.23 169.57074
Rø Angle to N	6 033.91 136.16647	16 067.35 198.82331	22 161.04 56.50659	4 180.48 92.93750	6 715.91 294.95579	11 332.74 225.63147	7 149.73 236.48911		9 316.54 273.22608	14 749.30 218.60948	11 108.06 183.350238	20 016.15 145.71047	16 879.90 127.97876	22 861.28 156.09594	11 093.21 136.47395	15 638.58 174.59066	12 534.15 201.27920
Rutsker Angle to N	14 335.69 109.76858	16 262.26 165.21299	30 147.99 67,03404*	13 496.99 93.01668	3 956.70 54.17334	8 533.81 171.79317	5 581.59 143.11899	9 316.53 93.10606		12 050.05 179.41369	14 499.04 143.120306	26 731.43 129.54239	25 102.76 115.64496	28 349.36 138.96984	18 984.66 116.70638	19 367.88 146.07377	13 096.79 158.60095
Knudsker Angle to N	15 183.61 61.69134107.62	5 451.50 132.37728	36 479.31 49.25077	17 519.44 49.66853	14 692.89 12.12095	3 765.68 16.90438	8 242.54 23.04612	14 749.30 38.49113	12 050.05 359.41527		8 589.98 86.987525	21 084.64 103.63311	22 537.83 86.98751	20 710.59 116.79667	17 199.58 78.20127	11 417.93 110.62261	4 657.45 91.77953
P Angle to N	8 275.801 35.472990	6 142.754 227.915521	30148.021 39.318259	11 889.22 23.801574	14 958.91 338.5671	8 119.70 292.9488	8 898.94 323.232218	11 108.06 3.341899	14 499.04 323.232218	8 589.978 267.09778		13 088.01 114.579679	13 947.85 87.097762	13 893.72 134.90933	8 808.67 69.745087	4 944.891 154.87552	3 934.60 261.28323
Bodilsker Angle to N	14 101.29 329.92369	16 514.32 274.76179	29 655.18 14.20539	17 801.05 336.63269	26 015.23 318.26950	21 205.68 294.10801	21 346.06 306.28800	20 016.15 325.85528	26 731.43 309.80711	21 084.64 283.89607	13 088.01 294.732426		6 475.98 18.40180	4 805.01 204.91308	9 239.96 336.96589	9 850.06 275.78706	16 554.18 287.20913
Ibsker Angle to N	10 941.29 303.64526	19 107.62 255.55802	23 201.40 13.06133	13 669.57 318.26314	23 471.92 304.45314	21 547.87 276.73380	20 314.53 288.65371	16 879.90 308.14992	25 102.76 295.93607	22 537.83 267.27685	13 947.852 267.276842	6 475.98 198.42808		11 263.18 201.20098	6 131.46 292.64799	12 916.04 246.51961	17 900.89 266.03142
Povlsker Angle to N	17 311.33 343.03811	15 528.60 291.62299	34 388.11 15.66709	21 302.79 346.29912	28 266.51 327.22178	21 677.30 306.88733	22 785.98 318.19300	22 861.28 336.21475	28 349.36 319.20854	20 710.59 297.03363	13 893.72 315.035457	4 805.01 24.88715	11 263.18 21.14876		12 959.24 352.92062	9 439.11 304.50876	16 607.31 303.84480
Østermarie Angle to N	5 059.49 316.93899	14 689.63 240.90588	22 989.48 28.23558	8 561.42 336.22659	17 515.12 308.48726	15 741.45 270.52998	14 204.38 286.85788	11 093.21 316.57229	18 984.65 296.92469	17 199.58 258.41785	8 808.67 249.851396	9 239.96 156.91939	6 131.46 112.57520	12 959.24 172.90009		9 728.76 219.42455	12 719.39 253.48623
Åkirke Angle to N	11 537.82 13.57600	6 668.17 273.12144	32 588.04 31.47723	15 590.41 9.99464	19 896.06 337.67705	12 252.59 308.61971	13 796.71 327.40756	15 638.58 354.60960	19 367.88 326.21262	11 417.92 290.75979	4 944.89 334.902473	9 850.06 95.66129	12 916.04 66.36752	9 439.11 124.40896	9 728.76 39.34522		7 169.67 302.87086
Vmarie Angle to N	11 395.53 49.92759	3 585.17 190.14898	33 196.68 43.86876	14 406.92 37.20837	14 594.66 353.88421	5 169.12 316.52855	7 860.23 349.58903	12 534.15 21.22071	13 096.79 338.66239	4 657.45 271.83935	3 934.60 81.233249	16 554.18 107.00598	17 900.89 85.80191	16 607.31 123.66763	12 719.39 73.32949	7 169.67 122.79349	

Table A

A	B	C	D	E	F	G	H	I
0: N-Øl-C	40,89339465	40,83219	Kolonne1	40,832192	0,0612046	0,06	40,83339465	0,00120465
1: Ol-Øl-C	95,7894853	305,04114	40,83219	95,79105	0,0015647	0	95,7894853	-0,0015647
2: C-Ol-Øl	56,039231	124,90869	68,99404	55,91465	-0,124581	-0,12	55,919231	0,004581
3: Ol-C-Øl	28,1712837	249,31199	221,01769	28,2943	0,1230163	0,12	28,2912837	-0,0030163
4: Ny-Øl-Ol	51,3907567	305,04114	253,83512	51,20602	-0,1847367	-0,18	51,2107567	0,0047367
5: Ny-Ol-Øl	65,7894853	190,51665	124,90869	65,60796	-0,1815253	-0,18	65,6094853	0,0015253
6: Øl-Ny-Ol	62,819758	73,67704	10,49093	63,18611	0,366352	0,36	63,179758	-0,006352
7: Ny-Øl-Nl	32,819758	253,83512	220,83219	33,00293	0,183172	180 - (1)-(4)	32,999758	-0,003172
8: Øl-Ny-Nl	84,618611	158,06862	73,67704	84,39158	-0,227031	calculated	84,394457	0,002877
9: Ny-Nl-Øl	62,561631	338,10625	40,71181	62,60556	0,043929	calculated	62,603685	-0,001875
10: Nl-Øl-Ol	84,2105147	305,04114	220,83219	84,20895	-0,0015647	180 - (1) = (4)+(7)	84,2105147	0,0015647
11: Nl-Ol-Øl	52,3124897	177,05064	124,90869	52,14195	-0,1705397	calculated	52,142604	0,000654
12: Ol-Nl-Øl	43,4769956	357,06258	40,71181	43,64923	0,1722344	180-(10)-(11)	43,6468813	-0,0023487
13: Nl-Ol-Ny	13,478598	190,51665	177,05064	13,46601	-0,012588	(5)-(11)	13,4668813	0,0008713
14: Nl-Ny-Ol	147,4341	10,49093	158,06862	147,57769	0,14359	(6)+(8)	147,574215	-0,003475
15: Ny-Nl-Ol	19,087303	357,06258	338,10625	18,95633	-0,130973	(9)-(12)	18,9568037	0,0004737
16: Ny-Ol-C	121,8287163	190,51665	68,99404	121,52261	-0,3061063	(13)+(11)+(2)	121,5287163	0,0061063
17: C-Ny-Ol	41,981589	10,49093	52,72743	42,2365	0,254911	calculated	42,2306803	-0,0058197
18: Ol-C-Ny	16,18969	249,31199	233,07092	16,24107	0,05138	180 - (16) - (17)	16,2406034	-0,0004666
19: Ny-Øl-C	147,180242	253,83512	40,83219	146,99707	-0,183172	(1)+(4)	147,000242	0,003172
20: C-Ny-Øl	20,838169	73,67704	52,72743	20,94961	0,111441	(6)-(17)	20,9490777	-0,0005323
21: Øl-C-Ny	11,981589	233,07092	221,01769	12,05323	0,071641	(3)-(18)	12,0506803	-0,0025497
22: Nl-Ol-C	108,3517207	177,05064	68,99404	108,0566	-0,2951207	(2)+(11)	108,061835	0,005235
23: Nl-Ny-C	105,45678	158,06862	52,72743	105,34119	-0,11559	(8)+(20)	105,3435347	0,0023447

Column A indicates an angle; column B is the magnitude of the theoretical plane geometric angle in column A; columns C and D are the actual azimuths of this angle on the right and left legs of the angle, respectively, taken from Table 2; Column E is the actual size of the angle, calculated from C and D; column F is the deviation between the theoretical angle in column A and the actual angle in column E. In column G, the deviation in column F is rounded to a product of 0.06 degrees. In column H, the angle is adjusted with the deviation in column G. Column I shows the deviation between the adjusted angle in column H and the actual angle in column B. As can be seen, the respective adjustment of the angles with a product of 0.06 degrees means a theoretical accuracy of between 0.002 .. and 0.006 .. degrees.

Appendix A:

calculation of all angles between C and four round churches.

A hexagonal landscape geometry connects the four round churches with a point on the small island of Christiansø, as shown in Figure 24.

Because “triangle” Nl-Øl-C is a straight line, these 5 points generate 9 triangles with 22 different angles plus orientation towards North. This is depicted in Figure 2A.

To calculate how accurately the geometry in Figure 24 is constructed in the landscape, we can compare the actual angles and distances in the landscape with the corresponding plane geometric theoretical angles and distances in Figure 2A.

There are many ways of making such a comparison, for instance by translating, scaling, and orienting the quadrilateral of the churches. The conventional approach is to minimize the errors in the four distances (the least-squares method) between actual and theoretical locations as a function of the displacement, scale, and orientation parameters.

But this approach would disguise a surprisingly remarkable systematic in the angle inaccuracies, which has become observable through the method of analysis described below:

The basis for the calculations is the set of coordinates to the centers of the rotundas of the round churches. These coordinates have been measured and published by *The Danish Geodata Agency* (GST) and are found in *Table 1*.

With these coordinates it is possible to calculate any distance between the churches and the bearing of the lines connecting the churches. These calculations are found in *Table 2*. Lines between locations in the landscape in this study will always be a segment of a geodesic between the locations, which is practically the same as a sightline, the shortest distance between two points in the landscape. This case study thus corresponds to in situ observations in cases where there is a direct view between the sites in question.

The geometry in Figure 24 is transformed to plane geometry in figure 2A with angles numbered from 0 to 23.

Analysis method

All the relative distances in the plane geometry in Figure 2A can be determined by the Pythagorean theorem.

After fixing Øl at the location of Østerlars and Nl at the location of Nylars, this study simply compares a calculation of each of the 23 real angles in the landscape geometry in Figure 24, presented in Table A, column E, with a calculation of its corresponding theoretical angle in Figure 2A, presented in Table A, column B.

Thus:

If:

the geometry in figure 3 is considered a plane geometry and defined from the position of Nylars and Østerlars and the direction towards north in Østerlars.

Then:

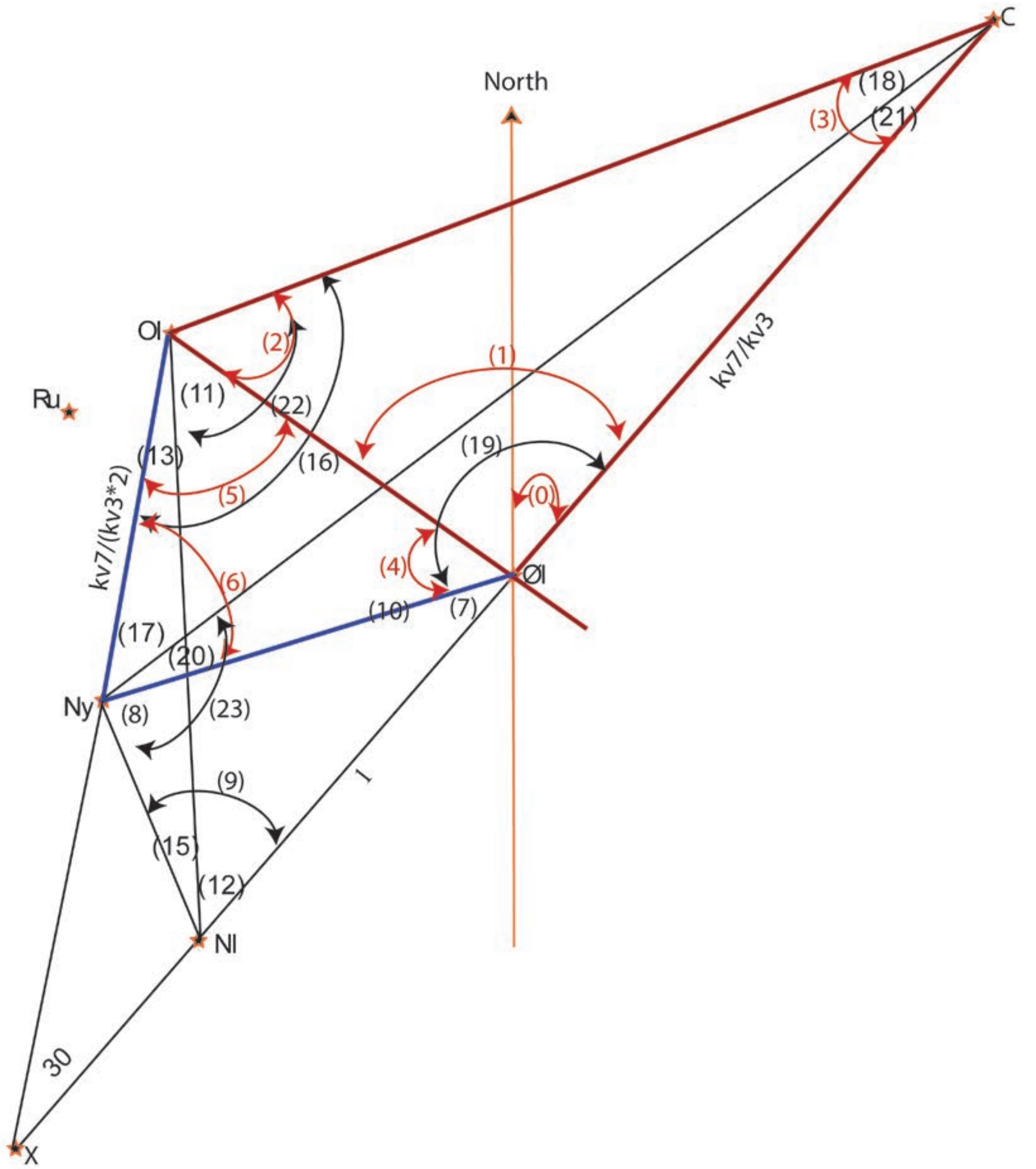
all angles in the so defined theoretical geometry can be calculated as presented in Table A, column B.

The 5 points: Østerlars, Nylars, Olsker, Nyker and C, would statistically form [5*(5-1)/ 2] lines = 10 lines, and these lines can be composed to [(5*4* 3) / (3*2*1)] = 10 triangles. But because “triangle” Nl-Øl-C is a straight line, and because 8 angles in pairs are equal, the 5 points: Østerlars, Nylars, Olsker, Nyker and C, generate *10 lines* and *9 triangles* with *23 different angles*, see Figure 4.

Lines: 1: Øl-C, 2: Øl-Nl, 3: Øl-Ny, 4: Øl-Ol, 5: Ol-C, 6: Ol-Nl, 7: Ol-Ny, 8: Nl-C, 9: Nl-Ny, 10: Ny-C.

Triangles:

A: Ol-Øl-C - angles 1,2 and 3



Calculations of the size of the angles can be read in Table A.

B: Ny-Øl-Ol - angles 4,5 and 6

C: Ny-Øl-Nl - angles 7,8 and 9

D: Nl-Øl-Ol - angles 10,11 and 12

E: Nl-Ol-Ny - angles 13,14 and 15

F: Ny-Ol-C - angles 16,17 and 18

G: Ny-Øl-C - angles 19, 20 and 21

H: Nl-Ol-C - angles 12, 3 and 22

I: Nl-Ny-C - angles 9, 21 and 23

Because of the geometric relations, described in Figure 24, lines and angles of the triangles C,D,E,F,G,H,I are all determined from lines and angles, that make up the first two triangles A and B (5 lines and angles 1,2,3 4,5,6) in Figure 2A.

Real angles in the geometry in Figure 24 are calculated from Table 2. The angles are thus calculated from a segment of a geodesic between the locations, forming spherical triangles. But due to the size of the triangles compared to the size of the Earth, the corresponding angles in a plane geometry appear to be equal to the spherical angles within at least the first three decimal places. Thus, all the calculated angles in Table A, column E represent measured angles between sightlines in the landscape, and their size can be compared to their theoretical equivalent in column B.

The real angles diversion from their corresponding plane geometrical theoretical angles are shown in table A, column F.

Appendix B

Proposed basic calculation to determine the key locations in the geometry in figure 24.

Since angle Nord-Ø* should be $\tan^{-1}(\frac{\sqrt{3}}{2})$, angle North-C-Østerlars must be 180 dg + [$\tan^{-1}(\frac{\sqrt{3}}{2})$ + (0.18333 – 0.06)] dg = 221.0167246 dg. [real: 221.01769 (table 2), deviation 0.001 dg]
Angle Østerlars-C-Rutsker is then angle (North-C-Østerlars) ÷ angle (North-C-Rutsker) = (247.39339 ÷ 221.0167246) dg = 26.3766653 dg [from Table 2 the real angle is 26.3757 dg, deviation 0.001 dg].
By extending the line C-Østerlars across Bornholm, and - based on established measuring stations - triangulating 1 unit along this line to find the location of Nylars, then:
1: Ø* becomes the center of a line which is three units long, therefore the increased meridian convergence at the north end of the line will be approximately balanced by the decreased meridian convergence at the south end of the line.
2: With observatories in Østerlars and Nylars and the possibility of making observations in C on Christiansø, three observation posts are achieved on the line.
3: Having determined 0.5 units between Østerlars and Ø* which corresponds to a meridian convergence of 0.06 dg, the line's total meridian convergence is average 6 * 0.06 dg = the desired 0.36 dg.
Calculations (see figure 41):
In triangle Østerlars-C-Rutsker we know angle (Rutsker-C-Østerlars) and the side Østerlars-Rutsker = 1, and Østerlars-C = $\frac{\sqrt{7}}{\sqrt{3}}$. From this it is possible to calculate the other angles and calculate the side Rutsker-C = 2.10302511, which is equal to the calculated distance Rutsker-C = 30147.99 meter. Thus, the geometrical unit 1 will be
(30147.99/2.1030251114) m = 14,335.53 meter (from table 2). (The real distance Østerlars-Rutsker is 14,335.69 meter and Østerlars-Nylars is 14,335.505 meter).

With the above calculations and by use of triangulation from natural points in the landscape on the line P1-Rutsker, plus further calculations and use of established trigonometric measure stations in form of other church towers, placed in pre-calculated support points, it will be possible to create the landscape geometry illustrated in Figure 24.

It means:
The distance from Nylars to X2 = 3 * (Østerlars-Nylars) = 43006.515 m. (See figure 43).

(KMSTrans): Coordinates to X2:
55.366002472 dg N; 15.257322192dg E;

Because Ø* is the point on the line Nylars-C where the line has the theoretically accurate angle [$\tan^{-1}(\frac{\sqrt{3}}{2})$] to true north, its vertical angle Nylars-Ø*-Ø*n also becomes the theoretically accurate (see Figure 43). This means that the side opposite this angle in triangle Nylars-Ø*-Ø*n in Figure 43, (Nylars-Ø*n) with great approximation will obtain its plane-geometric length of $\frac{3}{2} * \frac{\sqrt{3}}{\sqrt{7}} = \frac{3\sqrt{21}}{14}$.
($\frac{3\sqrt{21}}{14}$ * 14335.505) m = 14007.19 m. KmsTrans: distance Nylars-Ø*n = 14077.07 m, difference 12 cm)

Nylars-Nø is a chord to the parallel through Nylars. Therefore, it will be natural to let the points Nylars, Ø * and Nø form the basis for a calculation using the Bornholm method and thus be satisfied with using half of the line Nylars-X1.
Consequently, in the parallelogram in Figure 26, we will substitute A with Nylars, B with Nø*, C with Ø* and D with Øn, see Figure 42 and 43.

Calculations:
Nylars latitude: 55.073981 dg
Angle N-Nylars-Ø* = 40.71181 dg
Nylars-Ø* = (14335.505 * 1.5) m = 21503.2575 m
Meridian convergence Nylars – Ø*:
(table 2) = 0.180849 dg, accordingly:
Nylars-N = 4459810 m
r = 3656560 m,
Parallel circumference: 22974844.07 m
Earth size (perfect sphere): 40129 km

Or:

Angle N-Nylars-Ø* = 40.71181 dg
Meridian convergence Nylars – Ø*:
(table 2) = 0.180849 dg
Angle Nylars-O-Øn = 0.180849/sin 55.073981 = 0.220576621 dg
Nylars-Øn = (14335.505*$\frac{3\sqrt{21}}{14}$) m = 14077.18645 m
(Nylars-Øn real: 14077.07 m)
Accordingly:
R = 3656615.40
Parallel circumference:
2297512.16 m;
Earth size (perfect spehere): 40130 km

Or:
Angle Nylars-Ø*-Øn = $\tan^{-1}(\frac{\sqrt{3}}{2})$ = 40.89339465 dg
Angle Ø*-Øn-Nylars = 90 - 0.180849/2 = 89.9095755 dg
Nylars-Ø* = (14335.505 * 1.5) m = 21503.2575 m

Accordingly:
Nylars-Øn = 14077.2040 m
r = 3656622.18 m
Parallel circumference:
22975234.76 m;
<u>Earth size (perfect sphere): 40130 km</u>

Discussion:
Since the purpose is to determine the circumference of a parallel, and because the distance Nylars-Nø can be calculated with sufficient accuracy based on plane geometry and the determined plane geometric unit, it makes sense to prioritize the above calculation.
With observatories in Østerlars and Nylars and good observation possibilities in point C on Christiansø, it is possible to check and improve the accuracy. ”*Repeated measurement from any pair of fixed observatories (eg, Nylars and Østerlars) and averaging improves the accuracy.*” (Haagensen & Lind 2015)

Beside the plane-geometrical accurate angle N-Ø*-C, the geo-geometry in figure 43 contains further two remarkable conditions in relation to plane-geometry:
1: Since the angle Nylars-Ø * - Øn very accurately is $\tan^{-1}(\frac{\sqrt{3}}{2})$, this means that the distance Nylars-Øn on the parallel through Nylars very accurately correspond to the plan geometrical theoretical $\frac{3\sqrt{21}}{14}$.
($\frac{3\sqrt{21}}{14}$ * 14335.505) m = 14077.19 m: KmsTrans Nylars-Øn = 14077.07 m).

2: The latitude difference between Nylars (one end of the line) and X2 (the other end of the line) correspond very accurately to plane geometrical $\frac{6}{\sqrt{7}}$ * the unit of the geometry (see below and figure 43).
The reason for this is, that: On the line Nylars-X2, Nylars is in the same distance from the map north meridian through Ø* as is the distance Ø* to X2 on the other side of the meridian. Due to the meridian convergence the angle N-Nylars-Nx will be diminished with the same degrees as the angle N-Nylars-X2 is diminished. Thus, in triangle Nylars-X2-Nx, the angle X2-Nylars-Nx will preserve its plane geometrical size $\tan^{-1}(\frac{2}{\sqrt{3}})$.
If we accept half the meridian convergence to be 0.18 dg and the distance Nylars-X2 = 3, the side X2-Nx will be 2.2677980, which differs from $\frac{6}{\sqrt{7}}$ with only 0.000011162.
($\frac{6}{\sqrt{7}}$ * 14335.505) m = 32509.87 m. KmsTrans: X2-Nx = 32510.04 m. Difference 0.17 m).

Inauguration Cross of the Knights Templar Church Convento de Christo in Tomar, Portugal

Cross over the entrance portal to the Knights Templar castle in Tomar, Portugal

Inauguration cross in Nyker round church on Bornholm.