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THE PAINTED CEILING OF THE NAVE OF THE CAPPELLA PALATINA IN PALERMO: AN ESSAY ON ITS GEOMETRIC AND CONSTRUCTIVE FEATURES

This inquiry investigates the geometrical and structural features of the wooden ceiling covering the nave of the Cappella Palatina in the Royal Palace (Palazzo Reale) of Palermo.[1] We do not offer here either an in-depth historical analysis or a detailed description of the rich and interesting paintings decorating the ceiling. Such issues have been widely investigated, mainly by art and architecture historians.[2] Rather, a brief discussion of the history of the Cappella is meant to draw attention to some of the previous studies on the cultural influences underlying the artistic and architectural features of this building in order to contextualize our findings on the geometric layout of the ceiling covering the nave.

Today, the ceiling on the nave of the Cappella Palatina appears to be the sole surviving example of this type of complex, painted wooden carpentry in Islamic culture. Given the absence of other similar examples, it could be argued that the ceiling is the peculiar product of multicultural Norman Sicily, and reflects the influence of its patron, Roger II (r. 1130–54). It is distinguished from other similar artifacts in Islamic art mainly by the material of which it is made and the technique used to construct it. Most *muqarnas* vaults are made of stone or stucco, with single elements that are carved or molded. In the ceiling of the Cappella Palatina, however, the spatial layout of the *muqarnas* is produced by a segmentation of the form: that is, it is divided into arch-shaped primary panels and into secondary hidden panels, which act as centerings for the placement of thin wooden elements that form the surface of the small vaults. No ceiling like that of the nave of the Cappella Palatina has survived in Sicily, but we will see that it must have served as the inspiration for the consoles of a later ceiling in Palermo.

This first study of the geometrical and constructive features of the ceiling is just one contribution to the research that has been conducted regarding the origin of the craftsmen and the cultural influences underlying the ceiling and its creation. The precise drawing of a reference grid, which will be described below, and the relations between that grid and the drawing of the shape of the vertical primary elements, referred to as "EL" panels in the following discussion, demonstrate that the ceiling was meant to be not a peripheral creation, but a unique and magnificent expression of Islamic culture. The Norman kingdom put an end to two centuries of Islamic domination in Sicily, even as it maintained relations with Islamic countries in North Africa and demonstrated an appreciation for Islamic art and architecture. The establishment of the Norman kingdom did not interrupt the influence of Islamic culture on art and architecture in Sicily. We see the remains of this impact in the ceiling of the Cappella Palatina, as well as in some palaces in Palermo that are still standing—the Zisa, Cuba, and Scibene—all of which were commissioned by Norman kings.

METHODOLOGY AND THESIS

Between 2005 and 2009, the Cappella Palatina underwent an accurate and comprehensive restoration, financed by a generous grant from Reinhold Wurth and directed by the Soprintendenza per i Beni Culturali of Palermo. The provisional structures used by the restorers allowed for new and closer views of the mosaics and other decorations, and gave researchers the chance to observe the ceiling from a privileged per-

spective.[3] Some of the best previous inquiries on the Cappella presumably also used provisional structures, either to get detailed photographs, such as, for instance, the ones published in Ugo Monneret de Villard's *Le pitture musulmane al soffitto della Cappella Palatina in Palermo*, or to survey the ceiling. The precise drawings done by Andrea Terzi in the late nineteenth century, which are discussed below, must have been based on measurements and observations attainable at that time only by actually touching the ceiling by hand.[4]

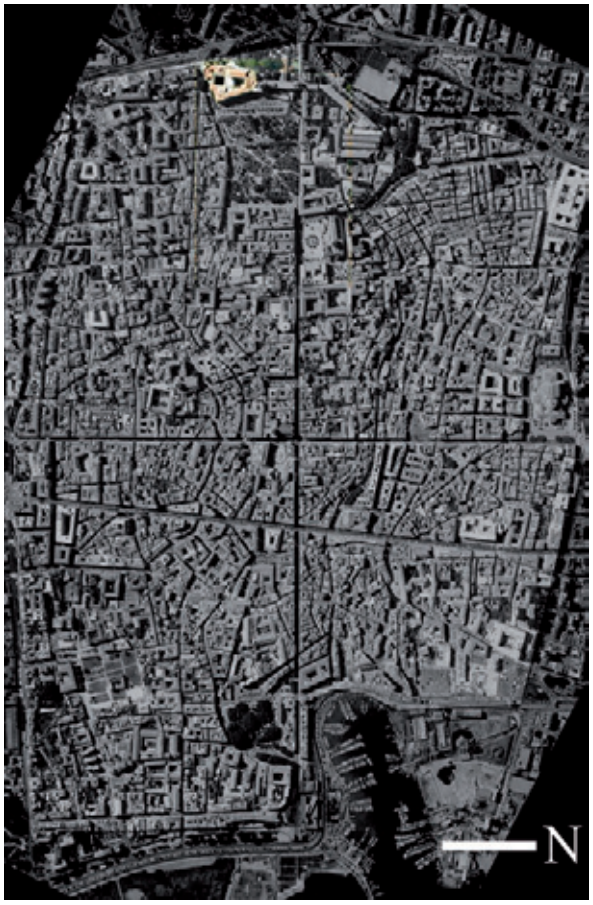
The results of the research here reported were based on 3D laser-scanning data of the eastern end of the wooden ceiling and on a survey of the dimensions of the entire nave. Indeed, 3D laser scanning has profoundly transformed the approach to cultural heritage analysis and documentation. Laser scanners quickly measure the 3D coordinates of a large number of points (usually referred to as a "point cloud") of the visible surfaces of an object; they also photograph the scanned area and link color values (RGB) to each surveyed point. With 3D laser scanning, scholars are able to examine an artifact in detail, allowing for both geometric analyses and the study of the quality and position of any colored feature. The 3D scanners are usually classified as long, medium, or close-range, depending on the distance allowable between the device and the object. The data measured in this inquiry were collected via a close-range optical triangulation laser scanner,[5] a highly accurate device that can detect distances of less than 1 millimeter; it is usually positioned at about 1.5 meters from the object and the scan is performed in a few seconds. Several scans of the area under examination were collected; they were registered to form one point cloud, which became the basis for the geometric analysis described in this paper.

There have been several studies devoted to the geometric analysis of the *muqarnas* vaults, mainly as a way to reconstruct the horizontal grid pattern of the vaults. The analysis of the elevation has often been regarded as a secondary matter, since it was assumed that the height of the tiers of the *muqarnas* was determined by the dimensions of the vaults and by the 1:2 ratio of the sides of the rectangle inscribing the basic element, in accordance with the description furnished by Al-Kashi in his treatise *Miftāh al-hisāb* (Key to Arithmetic). Laser scanning and 3D modeling software allow in-depth inspection of the three-dimensional features of the *muqarnas* vaults, offering the opportunity for new studies on the relations between the grid patterns and elevations.

As indicated above, laser scanners have generally been considered an effective technology for documenting of cultural heritage; they are particularly useful with respect to the issue of conservation. In this study we attempt to demonstrate that laser-scanning data can be employed to reconstruct the "reference drawing" of the ceiling of the Cappella Palatina and that relations between the reference grid and the elevation of the *muqarnas* vaults can be discerned by means of 3D metric data. We argue that this relation should not be regarded as a distinguishing feature of the ceiling of the Cappella Palatina, but rather as a common practice of craftsmen in Islamic and in premodern European art and architecture: "in the Topkapı and Tashkent scrolls abstract designs generated from modular geometric grids unencumbered by specific measurements were meant to be proportionally adapted to buildings and local materials at the construction time....Elevations were deduced by means of geometric procedures also common to Gothic building practice in which learning the method of projecting three-dimensional forms from two-dimensional templates played a central role."[6]

THE CAPPELLA PALATINA AND ITS CEILING

The Cappella Palatina is located in the Royal Palace of Palermo, at the western edge of the historical town (fig. 1). The history of the foundation and construction of the Royal Palace, though widely investigated, is still uncertain. What seems definite is that the site was selected as the residence of the Normans when Robert "il Guiscardo" (d. 1085) and his brother, Count Roger (d. 1101), conquered Palermo in 1072. They began building the palace on the ruins of a previously fortified site, as a counterpart to the fortified Muslim residence located by the sea at the eastern edge of the old town. Count Roger's son, Roger II, took advantage of the succession dispute that broke out following the death of Pope Honorius II, and was proclaimed king of Sicily by Anacletus II (d. 1138) in December 1130.[7] We know that Roger II was the patron of the Cappella Palatina (fig. 2).



Roger II was quite an interesting figure: named king by a Latin pope, he was known to wear Islamic clothing, thus embodying the multicultural climate of medieval Sicily, where Byzantine, Islamic, and Jewish cultures coexisted. His life is testimony to the effort and joys involved in synthesizing such different cultures and ways of life. The Cappella Palatina is a powerful visible expression of this cultural intent: its decorative program transforms a standard planimetric scheme in the assemblage of two distinct areas, a holy eastern space (the sanctuary, with transept, choir, and apses) and a secular space in the nave and aisles. Most historians agree on this assertion, pointing out that the nave was the king's area. It has also been argued that Roger II had a privileged place from which to listen to the liturgy, a balcony on the north wall of the northern transept arm, and that even the mosaics were oriented to the king's line of vision[8]

In 1132, the Cappella was granted the status of a parochial church and dedicated to Saint Peter the Apos-

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Fig. 1. Palermo, aerial image (taken in 2000) with Royal Palace highlighted. (Photo: courtesy of Centro Regionale per l'inventario, la catalogazione e la documentazione dei Beni Culturali ed Ambientali)

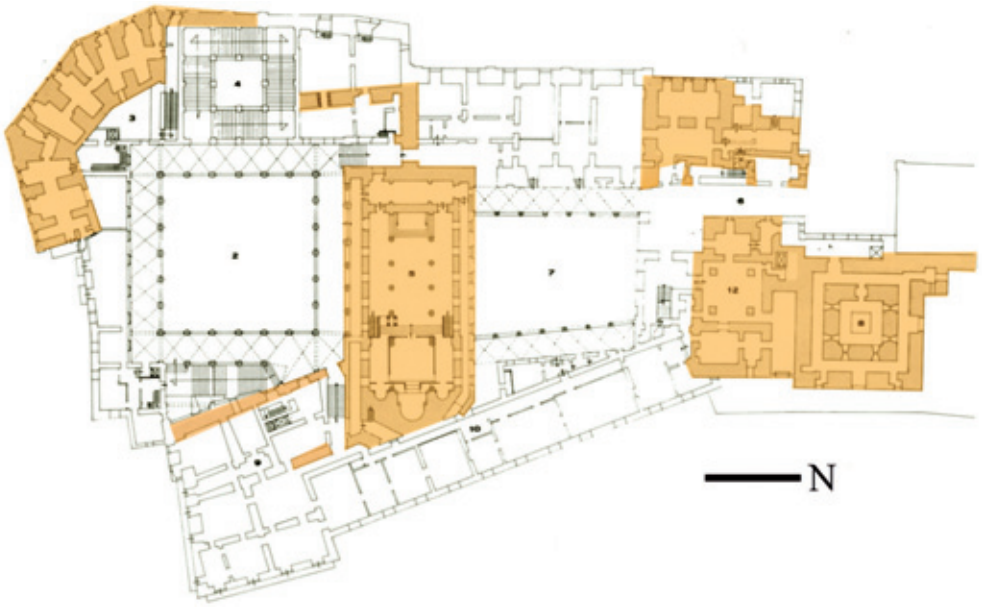

Fig. 2. Plan of the Royal Palace of Palermo. The medieval remains are highlighted. (After plan by Roberto Calandra and Dario Ciriminna in Roberto Calandra et al., *Palazzo dei Normanni* [Palermo, 1991], 54)

tle.[9] In a document signed by Roger II himself in 1140, he declared:

> And so, with the seven forms of the grace of the Savior stirring us, in honor of God, whose mercy makes us prosper, and of the Blessed Virgin Mary, and of all the Saints, with the highest devotion, we have built a church dedicated to Saint Peter, Prince of the Apostles, in our Royal Palace in Panormo.[10]

Another valuable testimony is the Greek inscription at the base of the dome covering the sanctuary:

> Other kings of old erected sanctuaries to other Saints; but I, Roger, mighty ruling king, [dedicate this church] to the foremost of the Lord's disciples, the leader and the archpriest Peter, to whom Christ entrusted His church, which He Himself had consecrated by the sacrifice of His blood...The third indiction...the fifty-first year in the correct measurement after 6000 and 600 years had elapsed in an ever moving cycle.[11]

This inscription provides evidence of the role played by Roger II in the construction and decoration of the Cappella. The inscription is written in the mosaics at the base of the tambour of the dome, which suggests that both the mosaics and the tambour were put in place at the same time.[12] The calculation of the year 6651 is also noteworthy: Luigi Boglino remarks that this was "the Greek way to compute the years," since in the Byzantine calendar the world was supposedly created in the year 5508 B.C.[13] The year of the inscription may therefore be determined by subtracting 5508 from 6651, that is 1143; most historians agree on this dating.[14]

We should note that in 1143 the Byzantine calendar was no longer used in western Europe. The date of the inscription, together with many other documents, thus reveals the strong presence of Byzantine culture in Sicily, as well as the weak influence of Latin culture.

Another valuable document is the sermon preached in the Cappella by Philagatos Kerameos in the presence of Roger II. Referring to the king, Philagatos notes that

> he has built [this church] as if a foundation and a protection for his palaces; large, most lovely, and distinguished by a fresh beauty; brilliant with lights, shining with gold, glittering with mosaics, and bright with paintings. He who has seen it many times, marvels when he sees it again, and is as astonished as if he were seeing it for the first time, his gaze wandering everywhere.

Fig. 3. The ceiling of the nave of the Cappella Palatina, Palermo: detail of the *muqarnas* frame. (Photo: Maria Antonietta Badalamenti and Domenico Carbone)

> As to the ceiling, one can never see enough of it; it is wonderful to look at and to hear about. It is decorated with delicate carvings, variously formed like little coffers; all flashing with gold, it imitates the heavens when, through the clear air, the host of stars shines everywhere.[15]

Though the sermon has not yet been dated, historians generally agree that Philigatos delivered it between the year 1140 and Roger II's death in 1154. The ceiling was therefore built under the supervision of Roger II.[16]

Philagatos states that the ceiling covering the nave was decorated with gold. The recent restoration has yielded evidence of some small, residual pieces of gold leaf on the ceiling, thus confirming that the ceiling must have had a golden sheen when it was first built. The gold leaf in the strips around the paintings, corresponding to the areas that today appear light yellow in color (fig. 3) has disappeared, and there is now much less light inside the chapel than there was during the time of Philagatos. Until the fifteenth century, the chapel was a freestanding structure visible from the town. Now it is surrounded by buildings on the northern side and by a loggia to the south. The interior of the Cappella is therefore scarcely illuminated, and it is hard for us to imagine what it must have looked like when mosaics on the walls and gold leaf on the wooden ceiling reflected the sunlight during the day and artificial lighting during nocturnal rituals.

Fig. 4. The ceiling of the nave of the Cappella Palatina, Palermo: laser-scanning survey of an element in the *muqarnas* frame depicting a man drinking. (3D laser scan: Fabrizio Agnello, Maria Antonietta Badalamenti, and Domenico Carbone)

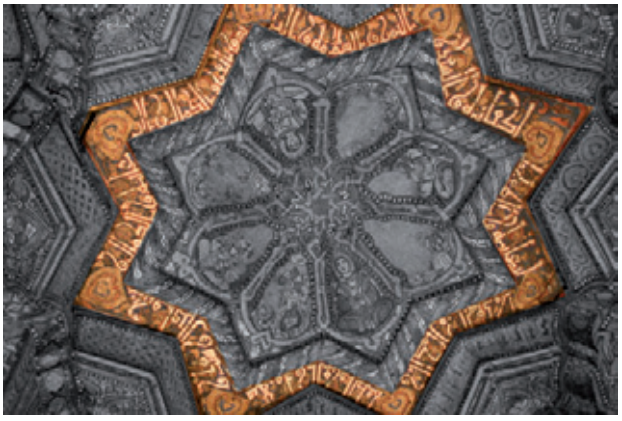

Fig. 5. The ceiling of the nave of the Cappella Palatina, Palermo: an eight-pointed star showing the Kufic inscription that frames it. (Photo: Maria Antonietta Badalamenti and Domenico Carbone)

The ceiling is richly decorated with paintings and kufic inscriptions. Previous studies on the paintings agree on the absence of a coherent iconographic project.[17] Monneret de Villard, the first to produce a comprehensive essay on the paintings, asserts that they refer to the pleasures and habits of life at the king's court; hunters, drinkers, dancers, and musicians thus complement Roger's majesty (fig. 4). The kufic inscriptions around the eight-pointed stars, translated by Michele Amari, celebrate the glory of the king and wish him health, wealth, and power (fig. 5).[18]

As has been previously pointed out, the arrangement of the nave itself must have been different during the time of Roger II. His successor, William I (r. 1154–66), is believed to have commissioned the mosaic decorations in the aisles and in the nave. Maria Andaloro refers to the third part of Philagatos's sermon[19] in support of her hypothesis that the walls were covered with richly decorated textiles during the time of Roger II.[20] It would seem, therefore, that William I's intention was to mitigate the strong Islamic character of the nave.

Most scholars are in agreement concerning both the influence of eastern Islamic culture on the paintings on the ceiling and the remarkable parallels between its geometric and spatial layout and North African *maghribi* architecture. Recently, further influences from western medieval culture have also been pointed out in order to support the hypothesis that the ceiling is to be regarded as a product of the cultural milieu of Norman Sicily.[21] An echo of the wooden *muqarnas* can be found two hundred and thirty years later (1377–80), in the flat ceiling covering the Sala Magna in the Steri of Palermo. The beams, decorated with painted, wooden panels, are supported by small, rough consoles driven into the walls and covered with a *muqarnas* wooden element, whose constructive technique seems to be a citation of the ceiling in the Cappella Palatina (fig. 6).

Fig. 6. The Palazzo Steri in Palermo: the ceiling of the Sala Magna and the wooden consoles. (Photos and 3D model: Fabrizio Agnello)

THREE STUDIES OF THE CEILING OF THE CAPPELLA PALATINA

The bibliography on the Cappella Palatina is particularly extensive. As noted above, most of these works are by art and architecture historians who have focused their attention mainly on mosaics, the dating of the Cappella and its decorations, and the origin of the craftsmen who built it. While most of the bibliography relevant to our analysis has already been cited,[22] we will here focus briefly on the studies conducted by Monneret de Villard; Amari, Cavallari, Boglino, and Carini; and, most recently, Grube and Johns.

Le pitture musulmane al soffitto della Cappella Palatina in Palermo, published in 1950 by Ugo Monneret de Villard, is a detailed analysis of both the history of the ceiling and the artistic and cultural influences that affected its design. Predicating his conclusions on a precise examination of the paintings themselves, as well as on his expansive knowledge of the Islamic world and its art, the author proposes some hypotheses on the origins of the craftsmen who built and painted the ceiling. Monneret de Villard's study is based on detailed photographic documentation that was financed by several universities and scientific organizations in the U.S.A. The photos themselves were taken by the Gabinetto Fotografico Nazionale della Direzione Generale delle Belle Arti.

The nineteenth-century work *La Cappella di San Pietro nella Reggia di Palermo* is divided into chapters written by Michele Amari (d. 1889), Luigi Boglino (d. 1917), Saverio Cavallari (d. 1896) and Isidoro Carini (d. 1895), the most prominent scholars of their time working on the humanistic and historic culture of Sicily. Michele Amari was a leading connoisseur of Islamic art and culture whose books are to this day a reference for those who study Islamic culture in Sicily. In this work, he proposes an interpretation of the inscriptions around the eight-pointed stars in the central longitudinal area of the ceiling. In the foreword, the priest and librarian Luigi Boglino lists priests and other renowned men who had a role in the running of the Cappella. Saverio Cavallari, the author of surveys and drawings published in books on Sicilian archaeology and medieval architecture by the Duke of Serradifalco, examined Byzantine, Islamic, and Norman influences on the architecture of the Cappella. Isidoro Carini, a historian and archivist, compiled a bibliography on the Cappella and outlined the history of the Royal Palace. The book is enriched by the valuable and detailed drawings made by Andrea Terzi (fig. 7). The colored drawings depict details from the ceiling covering the nave, the sloping ceilings on the aisles, and the mosaics and marble decorations. Terzi's black and white drawings of the plan and of the vertical sections of the Cappella are highly accurate and clearly the result of a good survey. They have been corroborated by metric data collected by means of modern technology. Obviously, these drawings do not take account of deformations that have occurred over the centuries (caused, for example, by construction materials that have fallen on the extrados of the ceiling), but the elements are correctly sized and proportioned.

The recent work by Ernst Grube and Jeremy Johns, *The Painted Ceiling in the Cappella Palatina of Palermo*, published in 2005, is an important contribution to the study of the historical and artistic features of the ceiling. The book opens with an essay by Johns on the date of the ceiling. This is followed by the first complete translation of the ekphrasis by Philagatos Kerameos and then Grube's analysis of the paintings.

Johns makes some interesting observations on the respective dating of the mosaics and the ceiling, predicated mainly on a new interpretation of the ekphrasis of Philagatos Kerameos and on the contributions of several scholars—Ernst Kitzinger, Vladimir Zori©c, Otto Demus, Bruno Lavagnini, et al. Particularly interesting is the analysis of the relation between the ceiling and the mosaics below it, based on a close observation of the molding placed between them. The essay by Grube aims to "impose some order on the considerable literature on the history, and the art and culture, of 12th-century Norman Sicily, and its relation to the eastern and western Muslim traditions to which it is so intensely linked."[23] The author praises "the indefatigable enterprise of Monneret de Villard,"[24] but regrets the absence of a "full description" of the paintings. Grube then asserts that "any serious study of it [the ceiling] must begin with a simple description of what is actually there." [25] He then describes the ceiling, focussing on some "forms" that act as a reference for the layout of an alphanumeric code linked to a schematic plan and to four vertical views of the *muqarnas* frame. [26] Having set

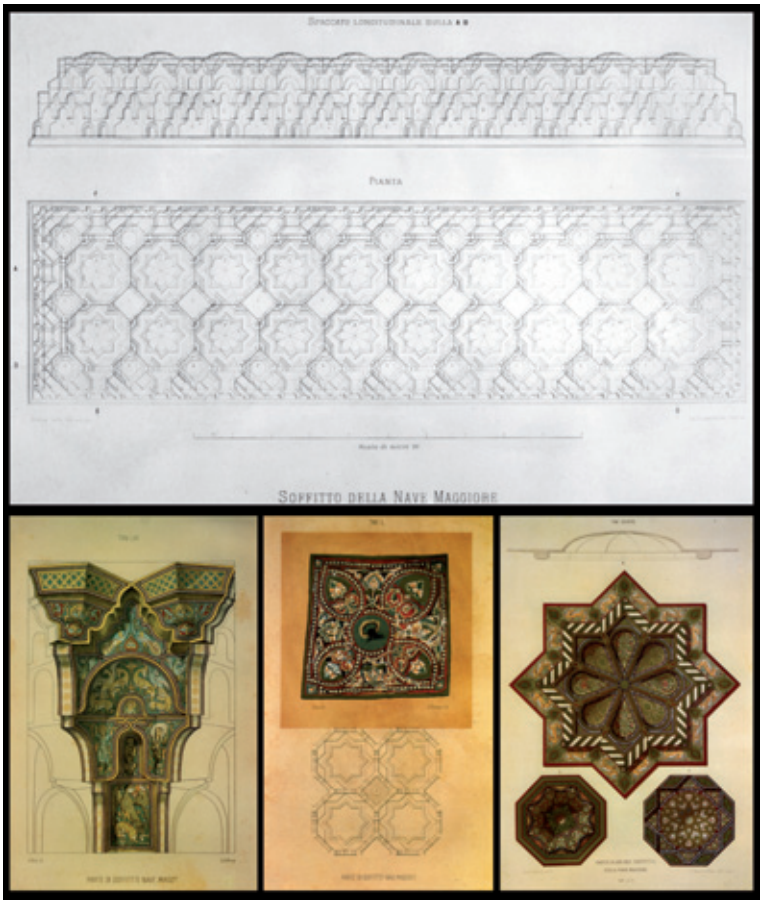

Fig. 7. Cappella Palatina in Palermo: drawings of the ceiling by Andrea Terzi. (After Michele Amari et al., *La Cappella di San Pietro nella Reggia di Palermo, dipinta e cromo litografata da Andrea Terzi* [Palermo, 1882: repr. Palermo, 1987], pl. XXXVI)

up an adequate reference system, Grube offers a comprehensive description of the subjects of the paintings, concluding with some interesting stylistic remarks on them, strongly supported by a comparison with coeval minor arts (ivories, pottery, woodworks, etc.) in medieval Sicily.

The essays are followed by a rich collection of images: detailed photos of the ceiling, historic pictures of the Cappella, and an accurate "assembly of iconographical parallels to the Cappella Palatina paintings."[27] The Grube and Johns's book closes with a comprehensive bibliography of more than two hundred pages.

(Figures 8-61 are grouped together at the end of the article.)

GEOMETRIC ANALYSIS

The present analysis, based on data gathered by 3D laser-scanning and restricted to the eastern area of the ceiling, investigates the geometry of the orthogonal projection of the ceiling, as well as, through hypothesis, the geometric relationships between the horizontal projection and the spatial arrangement of the *muqarnas* frame.[28]

The ceiling is set upon a horizontal wooden cavetto molding whose lower end crosses the upper part of the windows that allow light into the nave (fig. 8). Upon first inspection of the entire ceiling, we detect a longitudinal and transverse symmetry; an axis of symmetry oriented at a 45° angle, which is repeated in each of the corners, appears as well. The ceiling is composed of a central hor-

izontal field with a star-and-crosses pattern and hanging bosses; a *muqarnas* frame made of small, vaulted niches arranged in five horizontal tiers makes the transition between the central field and the walls of the nave (figs. 9–11). Our geometric analysis is supported by a study of the extrados of the ceiling, which reveals, at least for the higher tiers of the *muqarnas* frame (i.e., the third, fourth, and fifth tiers), the position and form of the wooden elements of which the ceiling is made.

The main features of the field of the ceiling are twenty eight-pointed stars, here named "St," arranged in two longitudinal lines (fig. 12). These stars are the result of overlaying two squares rotated at 45° angles to each other, a familiar scheme in Islamic art and architecture. Eight-pointed stars are inscribed in octagons and rhomboidal bosses allow for the transition between them. Smaller, octagonal eight-pointed stars, here named "Oc," are placed between the stars and the *muqarnas* frame; the longitudinal strip between the "St" stars is covered by squares here referred to as "Sq" (fig. 13).

The geometrical analysis was conducted with reference to a regular rectangle, here called the "reference rectangle," corresponding to the horizontal section of the ceiling just above the cavetto molding. We are well aware that the horizontal section of the ceiling is not a regular rectangle, but we assume all elements considered in the geometrical analysis to be pure forms, thus ignoring the imperfections caused by the deformations that the structure has suffered in the last nine hundred years. The same method of simplification has been adopted in the analysis of the basic elements of the ceiling, almost all of which are deformed or have slightly shifted from their original position. The reference rectangle was divided in two by a longitudinal medial axis and the central points of "St," referred to as C-1, were thus detected. Through points C-1 transverse and longitudinal straight lines were drawn. The distance between the longitudinal axis and the longitudinal lines through C-1 is named *d*; *d*+*d* is the side of a square centered on C-1. The distance between the square and the sides of the reference rectangle is *d*; that is to say, the transverse width of the ceiling is divided into six *d*-length units (fig. 14).

Assuming *d* is the basic module of the grid and considering the ceiling as a whole, we discern a central grid and an external frame; the central field consists of 10 pairs of *d*+*d* squares, (with a 1:5 ratio); since each *d*+*d* square is made of four *d*-length squares, the central grid can also be regarded as if consisting of 4 per 20 *d*-length squares (ratio 1:5); the external frame is *d* wide (fig. 15). The orthogonal projection of the 3D-surveyed data leads us to assume that the vertices of the *d*+*d* squares are the center points of both the twenty four "Oc" small octagons bordering the central field and the nine "Sq" squares along the longitudinal axis of the ceiling. The center points of the "Oc"s are named C-2 and those of the "Sq"s are named C-3 (fig. 16).

Dividing each segment *d* into three parts, a secondary grid, made up of 36 cells per *d*+*d* square, is set up. We now draw circles circumscribing "St" and "Oc" (or "Sq"). These circles, respectively centered on C-1 and C-2 (or C-3), are tangent to each other. The tangency points are vertices of the secondary grid. The radius of the circle centered on C-2 is equal to the diagonal of the square unit in the secondary grid, while the radius of the circle centered on C-1 is equal to the length of the diagonals of two squares in the secondary grid (fig. 17).

Drawing two identical squares circumscribing the circle centered on C-2, rotated at 45° to each other, we direct our attention to the small right-angled isosceles triangles[29] that result when we subtract the square whose sides are parallel to the reference rectangle from the one that is oriented at 45°. Each triangle and its symmetrical counterpart play an important role in the following steps of our analysis. We next draw longitudinal and transverse straight lines connecting the hypotenuses of the symmetrical triangles. The area between such lines and the external edge of the reference rectangle is equal in length to the thickness of the panels in the first register (fig. 18).

The end points of the hypotenuses of the green triangles are the center points of concentric circles. The radius of the blue circle is half the length of the hypotenuse and the radius of the red circle is equal in length to the side of the triangle. The segment that is the difference between the radius of the red circle and that of the blue circle is named *m* (fig. 19).

The blue and red circles underlie the shape and size of a wooden vertical panel, here named EL-1. If we name the radius of the blue circle *r*, the width of the panel is

r+*m* and the height is *r*+*r*+*m*. We may also say that the height of the EL-1 panel is equal to the diameter of the blue circle plus the segment *m* (fig. 20). The EL-1 panel is the basic element in the first, second, and third tiers: its width is kept unchanged, while its height is slightly resized (fig. 21).

A strict relation between the grid and the height of the *muqarnas* frame is thus supposed. This relation is probably due to a common feature of premodern architecture, namely, craftsmen's use of the horizontal grid to draw the constructive vertical elements of the *muqarnas* frame. Other relations between elements of the tiers and the grid will be discussed below.

We will now point out the features of each tier in the *muqarnas* frame, including the geometry of the basic constructive elements and their relationship to the grid. The modular arrangement of the entire ceiling allows us to restrict analysis to a limited area. We will thus refer to the northeastern corner in the images that follow. The area under examination will be enlarged when describing the higher tiers (i.e., the fourth and fifth ones), in order to allow all the elements to be fully visible. Except for those related to the first tier, the images that follow show two tiers at a time, namely, the one under examination and the one below it. In each image, the grid is placed on a horizontal plan positioned at the baseline of the lower of the two tiers featured.

The first tier

EL-1 vertical panels are parallel to the lines of the grid or oriented at 45° angles, sharing a common vertical edge placed on the point where the red circles intersect with the green longitudinal and transverse lines connecting the hypotenuses of the green triangles (fig. 22).

The secondary structural element in the first tier, here named EL-2, is drawn by simply rescaling the shape of EL-1; the width and length of the EL-2 panel are equal to the width and length of EL-1 minus *m* (fig. 23). The EL-2 panel is also the basic element in the fourth tier.

The EL-2 vertical panels in the first tier are oriented at 45° angles and arranged in right-angled pairs; their distance from the 45°-oriented EL-1 panels is equal to *m* (fig. 24). The EL-2 pairs are the sides of a right-angled isosceles triangle. On the hypotenuse of the triangle is set a panel pierced by an arch, whose radius still appears on the grid. We notice that a wider concentric circle defines the intersection line of the small vaults placed between that panel and the EL-2 panel. Concentric arches are quite common in the ceiling, probably as a result of the technique used to build it. Craftsmen would likely overlay two panels, respectively pierced with concentric curves, in order to have a support for the thin wooden elements that cover the empty spaces. The niche ends with a barrel vault that follows the profile of the smaller arch until it intersects with the vertical panels bordering the *muqarnas* frame (fig. 25).

At the corners of the ceiling, the axial symmetry is set upon the bisector of the right angle: the EL-1 and EL-2 panels are simply matched, thus forming two semicircular arches; the niches are placed in their usual positions (fig. 26).

We conclude our analysis of the first tier with a description of an element filling the empty, right-angled corners between the EL-1 panels; it appears to be a simple barrel vault. The intersection between the vault and the 45°-oriented EL-1 panels should be an ellipse, but craftsmen were probably not concerned about that and simply attached to EL-1 panels further elements that were shaped with circular concentric arches and used as centerings to hold in place the thin, linear wooden elements that form the surface of the vault (figs. 27 and 28).

The second tier

The main constructive elements in the second tier are nothing but vertical EL-1 panels oriented according to the lines of the grid or rotated 45°; they are placed upon the upper corners of the EL-1 panels in the first tier. The orthogonal projection on the grid shows that the EL-1 panels are arranged to form, in combination with the vertical extension of some of the EL-1 panels in the first tier, right-angled isosceles triangles and rhombs (fig. 29). Pairs of EL-1 panels, rotated on the hypotenuse of the right-angled isosceles triangles, intersect each other to form pointed arches (fig. 30).

Triangular areas are covered by vaults that can be regarded as the quarter part of a cross vault whose ribs are circular; the arches of the vault are the result of the rotation of ribs around a vertical axis. Stone cross vaults built in Sicily and Spain up to the sixteenth century are

based on the same geometrical layout. An arch in the back panel of the cross vault opens to a pointed niche covered by a barrel vault; the spatial sequence closely resembles the double niches in the first register (see fig. 22).

Rhombs are assumed to be the union of two isosceles triangles. The angle opposite the base of each of these triangles is 45°. The equal angles are therefore 67.5°; they are covered by two barrel vaults whose generative line is parallel to the base of the isosceles triangles. An element in the second tier has not yet been described—a pendentive placed at the right-angled corner and made up of EL-1 panels parallel to the lines of the grid, whose form can be assumed to be a part of a cross vault (fig. 31). The sequence of rhombs and right-angled isosceles triangles is interrupted by a flat, rectangular panel placed above the pendentive in the first register (fig. 32).

The third tier

In the third tier, the EL-1 panels of the second register are vertically extended to create rectangular filled areas. Only the rectangles upon the 45°-oriented EL-1 panels, arranged in right-angled couples, are visible from the intrados; the others are hidden by vaults (fig. 33).

In the orthogonal projection, visible rectangular panels form the equal sides of an isosceles "right-angled" triangle, on the hypotenuse base side of which we find the projection of a vertical panel pierced by a circular arch. The radius of the arch is drawn on the horizontal grid.

The triangular area is covered by half of a cross vault (fig. 34). We could also describe this triangle as the union of two right-angled triangles, each filled with a vault orthogonal to the hypotenuse (fig. 35). From a constructive point of view, this is the correct way, since in the extrados we can observe a panel dividing the big right-angled triangle in two halves.

In the orthogonal projection, the big right-angled triangle is mirrored on the hypotenuse. The sides of the new triangle are once again EL-1 panels oriented at 45°. The triangle is covered by the quarter part of a cross vault, similar to the one described when discussing the second tier (figs. 36 and 37). These mirrored right-angled isosceles triangles are arranged in pairs to form a square.

The rectangular area sharing one side with the square is filled with barrel vaults placed above the pendentives in the second tier; the directrix lines of such surfaces are simply an offset of the shape of the EL-1 panels that enclose the vault (fig. 38). The photo of the extrados well shows that the EL-1 panels are doubled by adding further panels, which act as centerings for the placement of the small wooden elements that make up the surface.

Other EL-1 panels are oriented 45° and arranged in pairs, with one of the panels framing the barrel vault mentioned just above. The last element to be described in the third tier is a barrel vault having a directrix line made of arcs of circles tangent to each other, and generatrices that are straight lines orthogonal to the plane of the directrix. The back of the barrel vault is the vertical extension of the flat filled panel in the second tier; it is shaped to form the centering of the vault, a polygonal base line whose shape resembles a bonnet (figs. 39 and 40). The distance between the panels that frame the vault is fixed on the horizontal grid. Another craftsmen's trick underlies this element: the element cut from the front panel matches exactly the shape of the back panel. We see this hypothesis illustrated in figure 33, where the figure is drawn on only one panel, which is cut along the line. The back and front panels of the vault are therefore pieces of the same wooden board (fig. 41).

The fourth tier

Two attached rectangular panels are placed above the barrel vaults in the third register; the front panel is pierced by an arch whose circle is drawn on the grid, while the back panel is solid. The flat arches are connected to each other by additional vertical panels that are parallel to the side of the reference rectangle and pierced by an identical arch. These panels are intersected along the vertical axis of symmetry by other hidden panels, whose shape is half the arch. A niche is generated connecting the straight edges of the three panels with a cylindrical surface, and the circular edges with a quarter of a sphere. It is to be noted that half-panels, covered by the surface of the niche, clearly appear in the extrados.

Panels with flat arches share a vertical edge with a pair of EL-1 panels oriented orthogonally to the sides of the reference rectangle (fig. 42). The pairs of EL-1 elements frame a conical vault whose directrix, made of

arcs of circles tangent to each other, is similar to the one in the "bonnet" arch mentioned above (fig. 43).

We should note that the shape of this polycentric arch recalls a particular geometric figure known in mathematics as "Archimedes's saltcellar." The area of this shape equals the area of the circle whose diameter is the axis of symmetry of the saltcellar (figs. 44–47).

The fifth tier

The panels with flat arches in the fourth tier are vertically extended to form the back panel of a conical vault identical in shape to the one mentioned above (fig. 48).

The conical vaults of the fifth tier form in orthogonal projection two sides of a square (three at the corners of the ceiling). At the corners of the square, small pendentives are inserted to make the transition to the octagon named "Oc" (figs. 49 and 50).

The front panels of the conical vaults in the fourth tier are vertically extended to the fifth; parallel panels are placed in the front and pierced with a polygonal arch.[30] We refer to the shape of this arch in order to demonstrate once again that craftsmen did draw all types of shapes on the horizontal grid. The geometrical analysis of this arch reveals that its shape is based on the main leitmotif of the horizontal grid, that is, a pair of squares rotated 45° to one another (fig. 51). Observing the extrados of the ceiling, we see that the front and back faces of the arch are parts of the same panel cut along the polygonal line, just as was seen in the surface of figure 33 (fig 52).

The gap between the front and back panels of the polygonal arch is covered by a surface made of thin wooden elements (fig. 53). Other, similar panels are arranged in pairs and oriented at 45° angles.

All the polygonal arches are joined to form an octagonal area covered by the eight-pointed stars referred to as "St" at the beginning of our analysis. The transition from the regular octagon to the star-shaped figure occurs through the big pendentives clearly visible from the nave (see fig. 47). The shape of the pendentives is simply a copy of the polygonal arch mentioned above. The surface is made of planar triangular elements set at 45° angles with respect to the panels bordering the octagon and intersecting each other on the diagonals of the octagon (fig. 54). The octagon is then covered by the eight-pointed star. The octagons and eight-pointed stars are, in the constructive point of view, autonomous elements acting just like caps (fig. 55).

In the orthogonal projection, the pairs of panels oriented at 45° play different roles, depending on their position inside the ceiling. The ones placed at the edge of the *muqarnas* frame border the square covered by the octagons referred to as "Oc." Those placed in the inner area form all the sides of the squares referred to as "Sq," which are aligned along the longitudinal axis of the ceiling (figs. 56 and 57).

CLOSING REMARKS

This study of the ceiling covering the nave in the Cappella Palatina of Palermo (fig. 58) was based on an analysis of geometrical forms in three dimensions utilizing 3D laser-scanning data and on our observations of the constructive elements of the extrados (fig. 59). Our intention was to prove that a horizontal geometric grid not only served to regulate the proportion and extension of the elements but also acted as a guide for their size and spatial layout in three dimensions. The geometric analysis revealed that the profile of the vertical elements was drawn on the grid and that the drawing was executed in the areas of the grid corresponding to the orthogonal projection of the elements (fig. 60). Some elements are repeated, keeping their form with variable size, e.g., the conical vaults in the fourth and fifth tiers. Other elements are the result of different ways of covering the same figures, e.g., the mirrored triangles in the third level. The main geometric technique seems to have involved matching triangular forms in a variety of ways: squares are divided into two right-angled isosceles triangles, which are themselves divided in two further right-angled isosceles triangles; rhombs are created from the union of two non-right-angled isosceles triangles; and so on.

The main constructive elements seem to be two arch-shaped panels, El-1 appearing in the first, second, and third tiers and El-2 appearing in the first and fourth tiers. The shapes of the panels are intimately connected to one another (see fig. 20).

We have taken the method of construction into account only in particular areas, in order to specify the

link between geometry and the constructive process. The bibliography provided in note 2 includes more detailed analyses, which point out the techniques used to connect wooden elements and the relation between the ceiling and the upper, covering structures.

This analysis of the ceiling in the Cappella Palatina was based only on the geometric relations between the grid and the elevation. At the end of the analysis, the horizontal projection of the drawing of the ceiling was scaled with reference to the similar projection attained through 3D laser-scanning data (fig. 61). The strict correspondence between these two horizontal projections corroborates our hypothesis regarding the layout of the grid and demonstrates that the construction of the nave of the Cappella Palatina was closely connected with the construction of the ceiling. Roger II may be regarded as not only the commissioner but also the director of this enterprise, in which architecture and art are intimately connected. We do not know much about the craftsmen involved in this endeavor but we assume that they had to have been familiar with the Islamic method of building *muqarnas* vaults.

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[Geometric analysis: figures 8–21]

Fig. 8. The molding (in color) at the base of the ceiling. Over the molding is the first tier of the *muqarnas* frame. The lower edge of the molding fixes the higher end of the mosaic decorations on the walls of the nave; the windows that let light into the nave intersect with the molding. (Photo: Maria Antonietta Badalamenti and Domenico Carbone)

Fig. 9. The ceiling of the nave of the Cappella Palatina, Palermo. (Photo: Fabrizio Agnello)

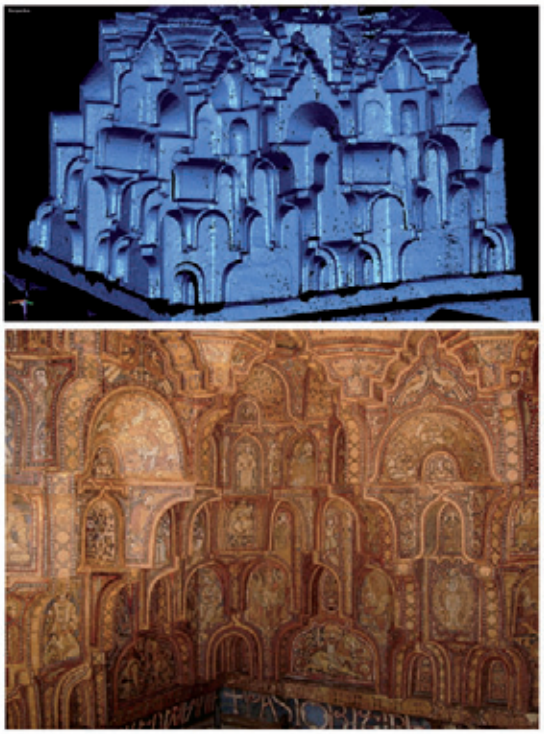


Fig. 10. The ceiling of the nave of the Cappella Palatina, Palermo: northeastern end, detail of 3D laser-scanning data (above) and photo of the *muqarnas* frame (below). (Photo and 3D laser scan: Fabrizio Agnello, Maria Antonietta Badalamenti, and Domenico Carbone)

[Geometric analysis: figures 8–21]

Fig. 11. The ceiling of the nave of the Cappella Palatina, Palermo: the *muqarnas* frame arranged in five horizontal tiers. (Photo: Maria Antonietta Badalamenti and Domenico Carbone)

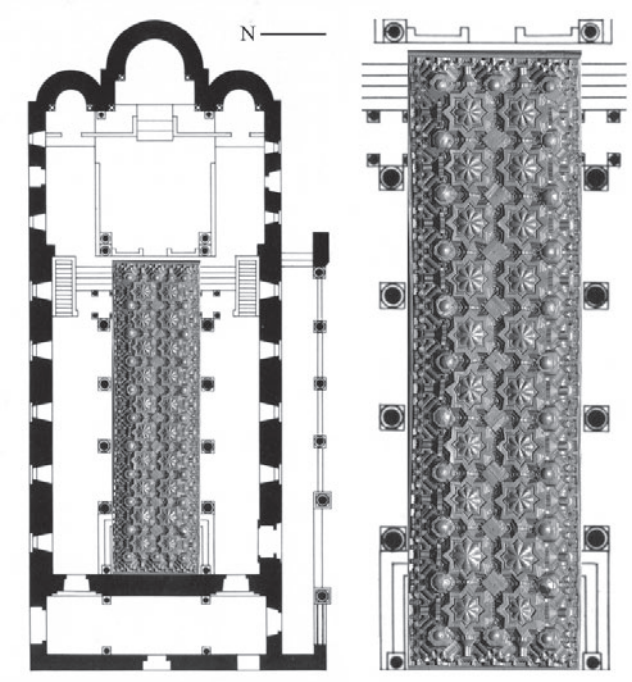


Fig. 12. The ceiling of the nave of the Cappella Palatina, Palermo. Left) An image of the ceiling attained through laser-scanning data superimposed on the plan of the Cappella Palatina by Andrea Terzi. (After Amari et al., *La Cappella di San Pietro nella Reggia di Palermo*, pl. II.) Right) Magnification of the image of the ceiling.

[Geometric analysis: figures 8–21]

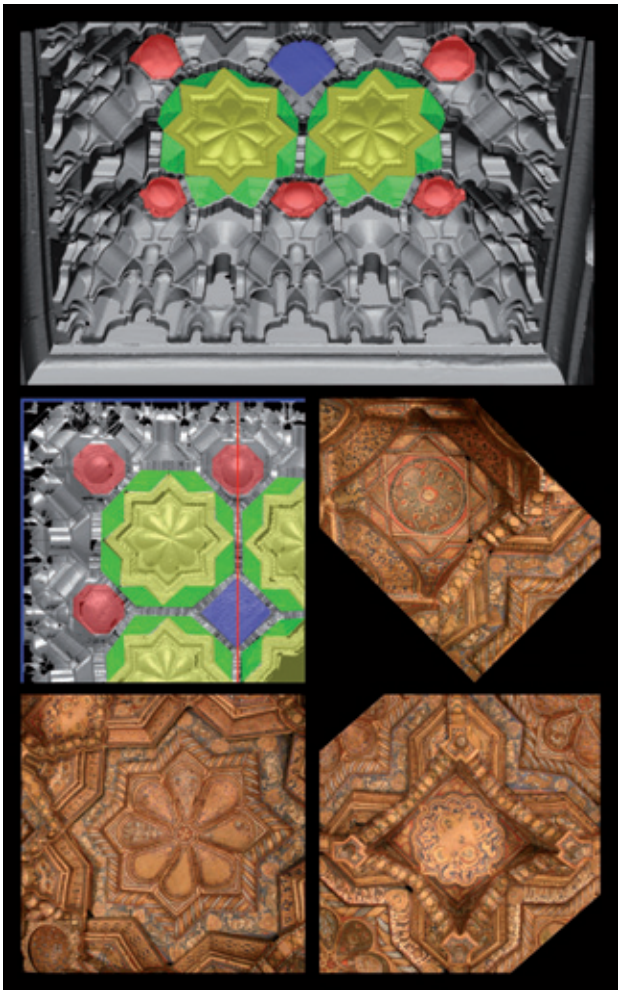


Fig. 13. The ceiling of the nave of the Cappella Palatina, Palermo. Above) Perspectival view of laser-scanning data with the elements of the central field highlighted: eight-pointed stars ("St") (yellow): octagons ("Oc") (red): bosses (green): square ("Sq") (blue). Below) Clockwise sequence: planimetric view of laser-scanning data, with elements highlighted and the red line marking the longitudinal axis of symmetry; an octagon; a square forming a cross with the bosses that surround it; and an eight-pointed star framed by bosses. (3D laser scans: Fabrizio Agnello, Photos: Maria Antonietta Badalamenti and Domenico Carbone)

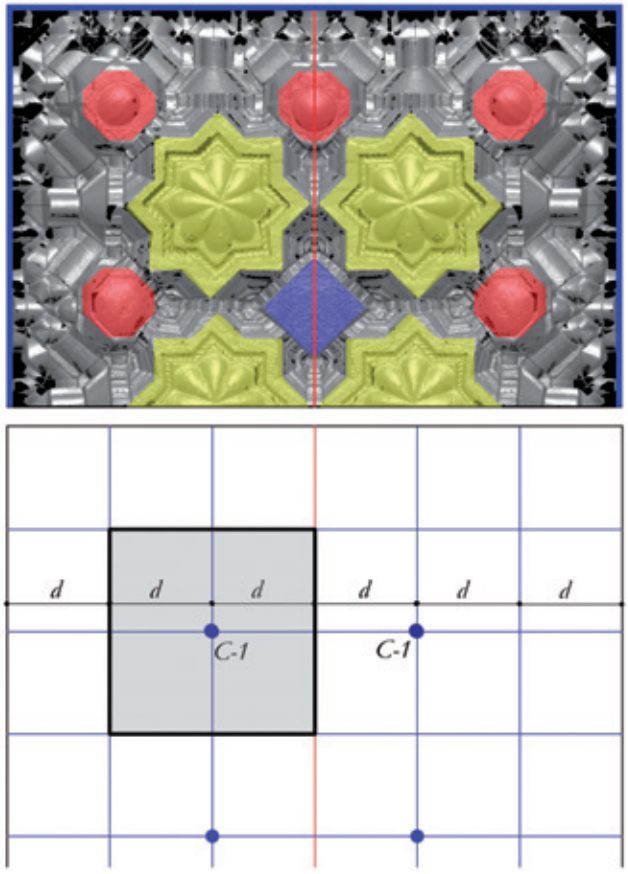


Fig. 14. The eastern end of the ceiling of the nave of the Cappella Palatina, Palermo. Above) Planimetric view of laser-scanning data with elements highlighted. Below) Geometrical scheme. Red line: longitudinal axis of symmetry; blue dots: centers of eight-pointed stars (C-1); blue lines: transverse and longitudinal straight lines through points C-1; black line: *d*+*d* square centered on C-1. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

[Geometric analysis: figures 8–21]

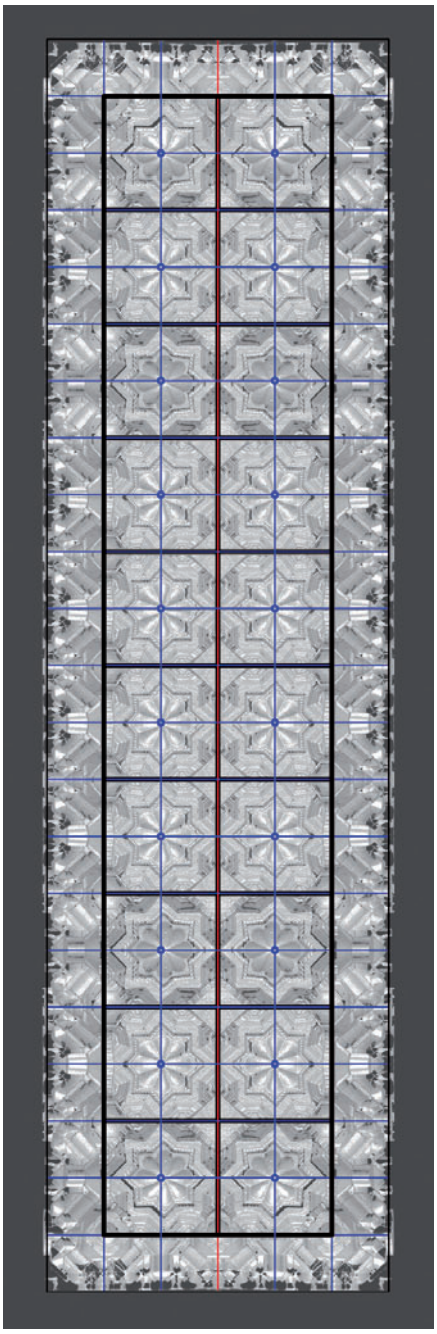


Fig 15. Planimetric view of the entire ceiling as derived from laser-scanning data, with geometric grid superimposed. Black lines: *d*+*d* squares centered on C-1 points (blue dots); blue lines: grid divided into *d*-length squares. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

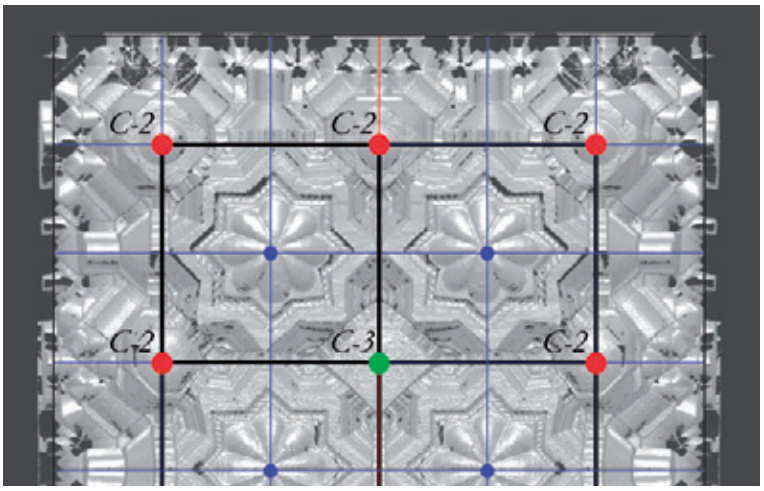


Fig. 16. The eastern end of the ceiling: planimetric view derived from laser-scanning data and geometric scheme. Blue dots: C-1 points (not identified); red dots (C-2): center points of octagons; green dot (C-3): center point of squares ("Sq"). (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

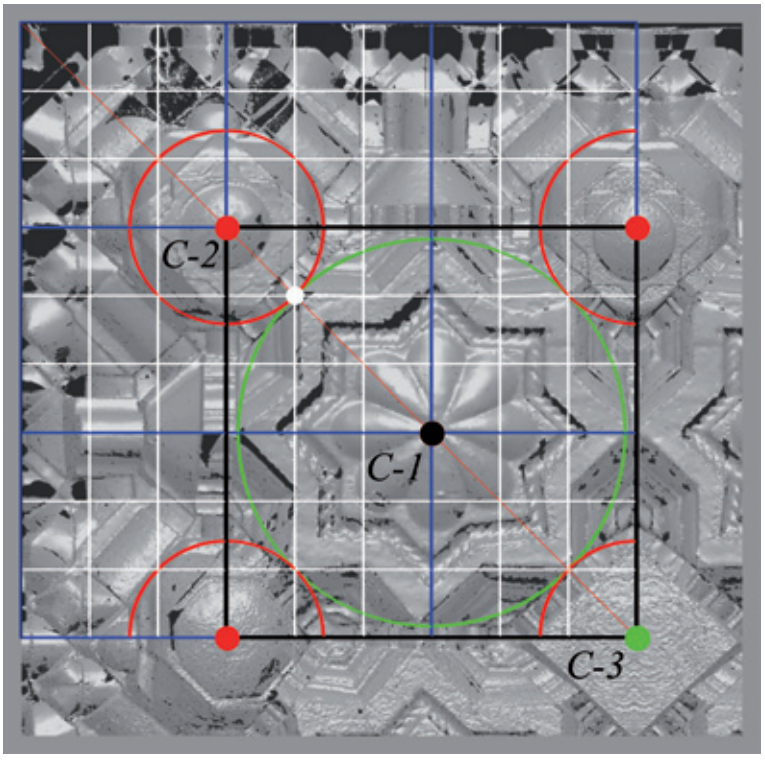


Fig. 17. Detail of the northeastern corner of the ceiling: planimetric view derived from laser-scanning data and geometric scheme. Blue lines: *d*-spaced grid; white lines: secondary grid; black lines: *d*+*d* square; the red circle is centered on C-2 and the green circle is centered on C-1. The tangency point is the vertex of a square unit in the secondary grid. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

[Geometric analysis: figures 8–21]

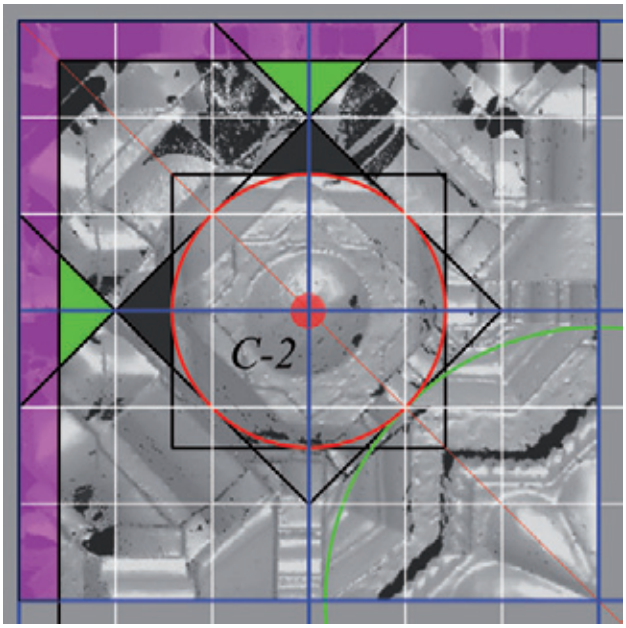


Fig. 18. Detail of the northeastern corner of the ceiling: squares rotated at 45° circumscribing the red circle centered on C-2; gray areas: right-angled isosceles triangles between squares; green areas: specular copy of gray triangles; purple area: frame between the hypotenuse of the green triangles and the external edge of the grid. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

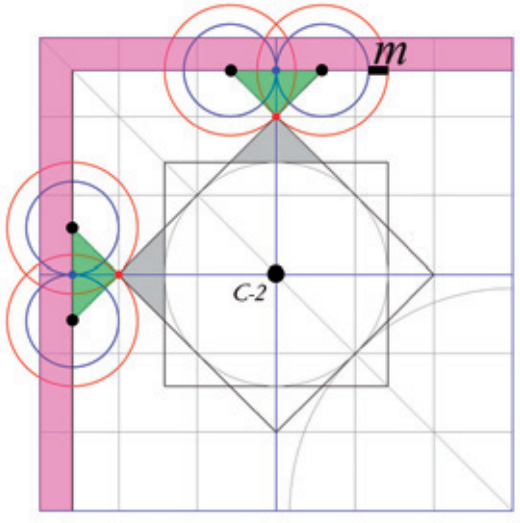


Fig. 19. The northeastern corner of the ceiling: drawing of circles centered on the end points of the hypotenuses of the green triangles. Segment *m* is the difference between the radius of the blue circle (equal in length to half the hypotenuse) and the radius of the red circle (equal in length to the two equal sides of the green triangle). (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

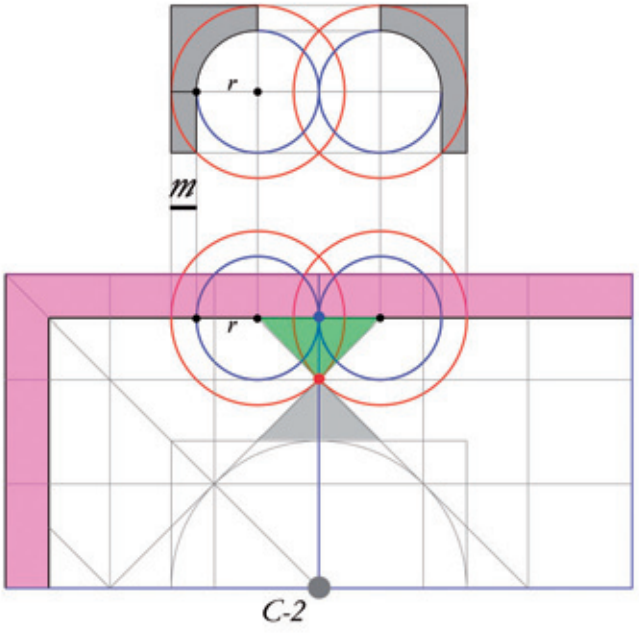


Fig. 20. Geometric drawing of an EL-1 panel, based on blue and red circles drawn on the grid. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

[Geometric analysis: figures 8–21]

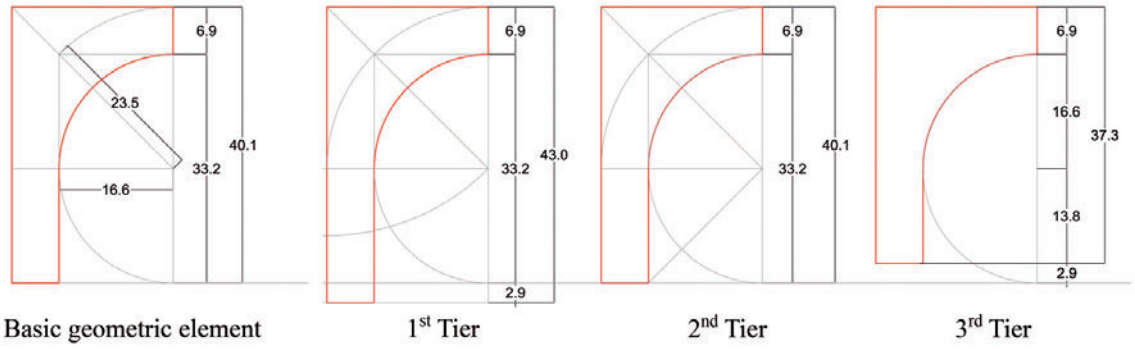


Fig. 21. Profile of the EL-1 panel and variations in the first, second, and third tiers (dimensions are measured in centimeters). (Image: Fabrizio Agnello)

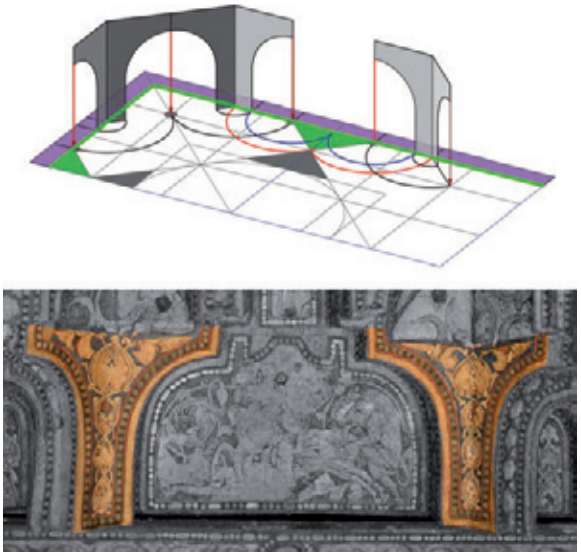


Fig. 22. First tier: arrangement of the EL-1 panels (above) with photo (below). The grid is drawn on the horizontal plan below the first tier, whose elevation is approximately 11 meters above the floor of the nave. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti; photo: Maria Antonietta Badalamenti and Domenico Carbone)

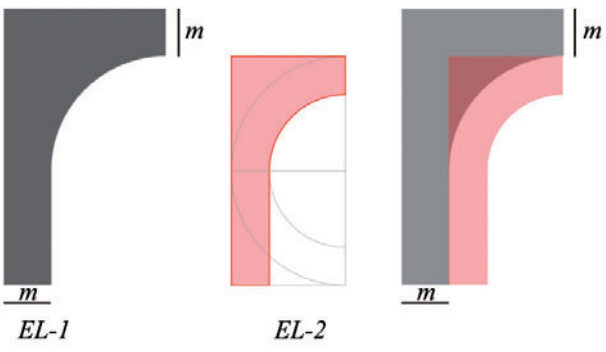


Fig. 23. First tier: geometric scheme of the EL-2 panel (light red), which is drawn by rescaling the EL-1 panel (gray) so that the height and width are equal to EL-1 minus *m*. In the image on the right, EL-2 is superimposed on EL-1. (Images: Fabrizio Agnello and Maria Antonietta Badalamenti).

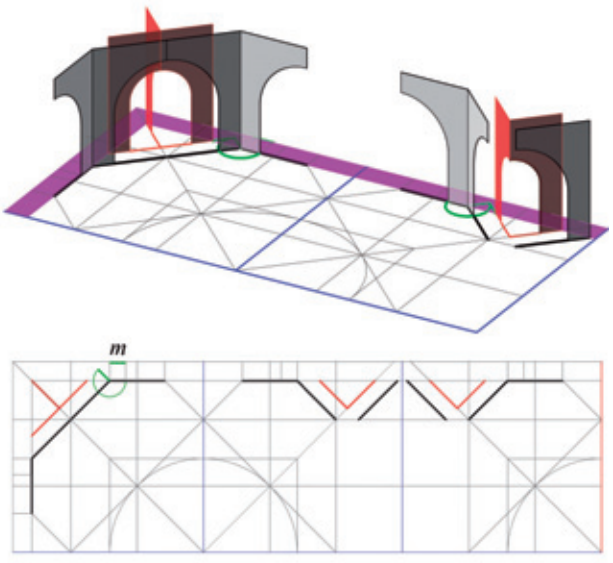


Fig. 24. First tier: the placement of the EL-2 panels. The radius of the green circles is equal to *m*. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

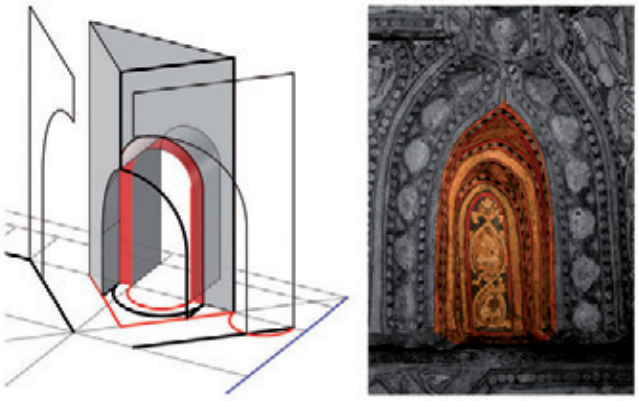


Fig. 25. First tier: niche. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti; photo: Maria Antonietta Badalamenti and Domenico Carbone)

[First tier: figures 22–28]

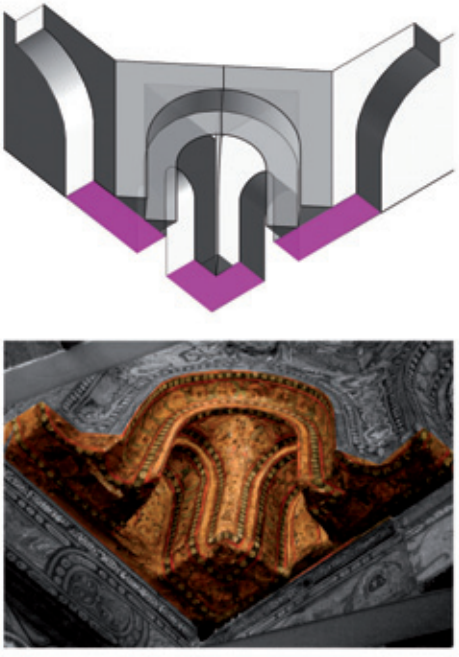


Fig. 26. First tier: corner niche. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti; photo: Maria Antonietta Badalamenti and Domenico Carbone)

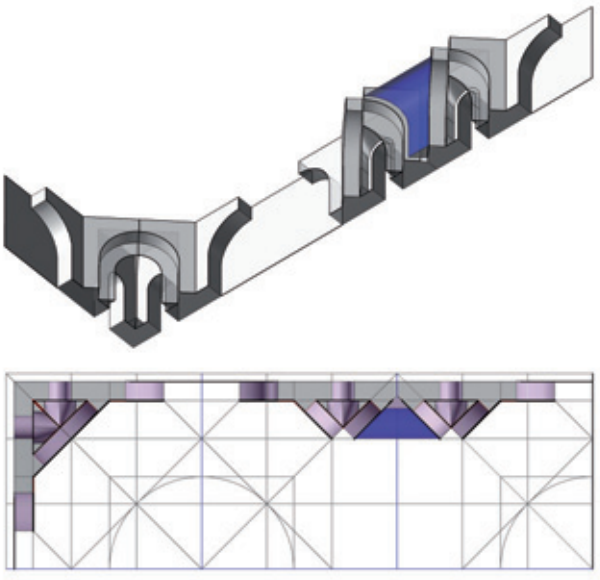


Fig. 28. First tier: axonometric and planimetric view of the 3D model. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

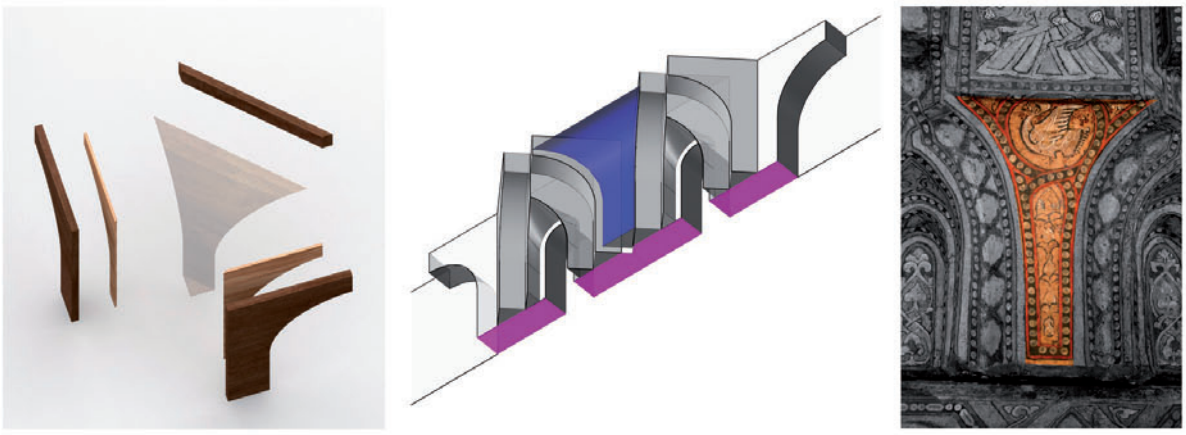


Fig. 27. First tier: the pendentive. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti; photo: Maria Antonietta Badalamenti and Domenico Carbone)

[Second tier: figures 29–32]

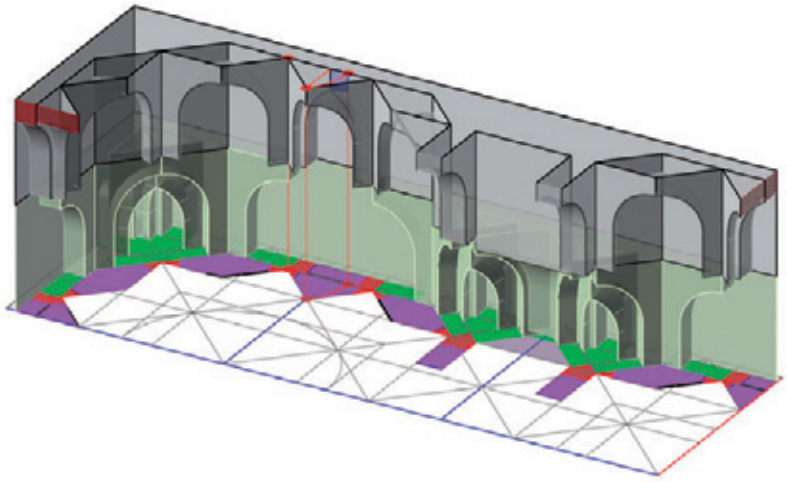


Fig. 29. Second tier: EL-1 panels. The orthogonal projection of the second tier on the grid is highlighted in purple. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

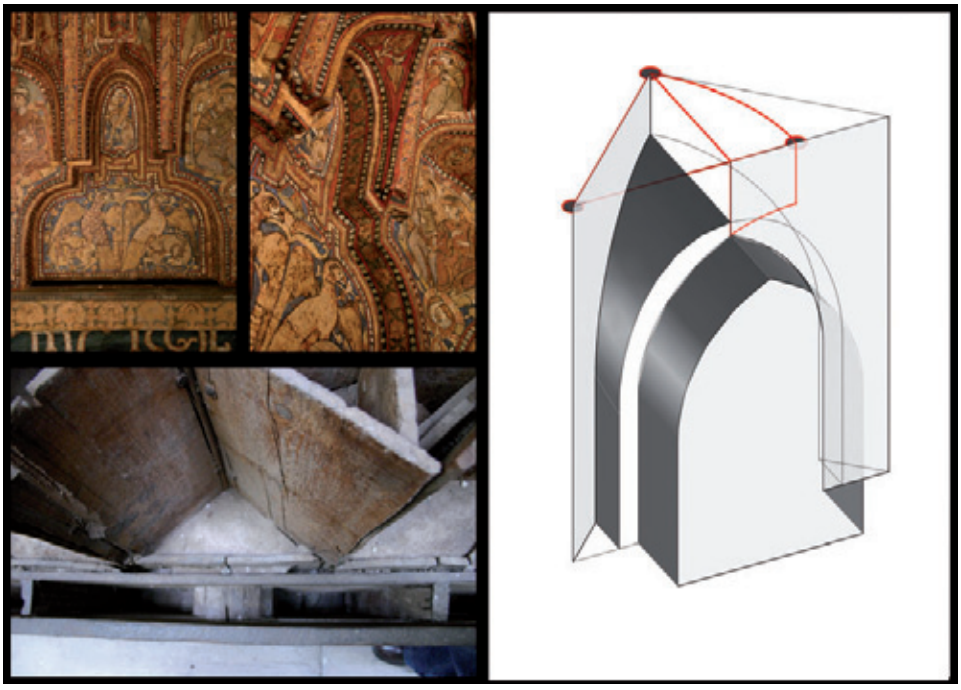


Fig. 30. Second tier: cross vault and niche. Left, above) The intrados. Left, below) The extrados. Right) 3D model with lines showing that the pointed arch is built using the same arch shapes oriented at 45°. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti; photos of the intrados: Maria Antonietta Badalamenti and Domenico Carbone; photo of the extrados: courtesy of Arch. Mario Li Castri)

[Second tier: figures 29–32]

Fig. 31. Second tier. Left) Barrel vaults on rhombs. Middle) Pendentive. Right) Photo with these elements highlighted. (Images: Fabrizio Agnello and Maria Antonietta Badalamenti; photo: Maria Antonietta Badalamenti and Domenico Carbone)

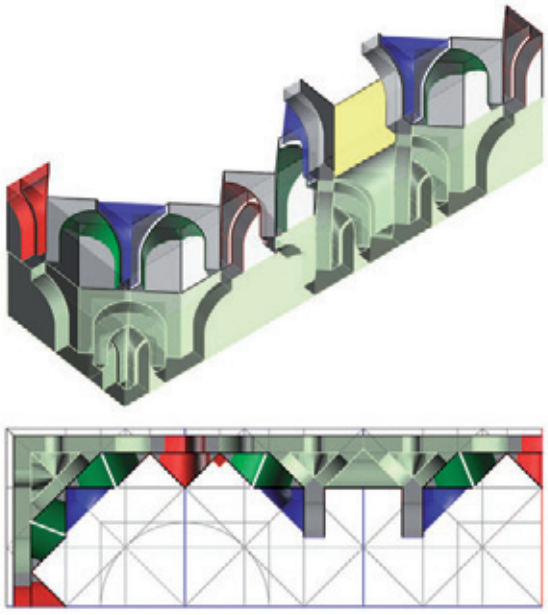


Fig. 32. Second tier: axonometric view. Cross vaults and niches (red); barrel vaults on rhombs (green); pendentives (blue); flat panel (yellow). The first tier is light green. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

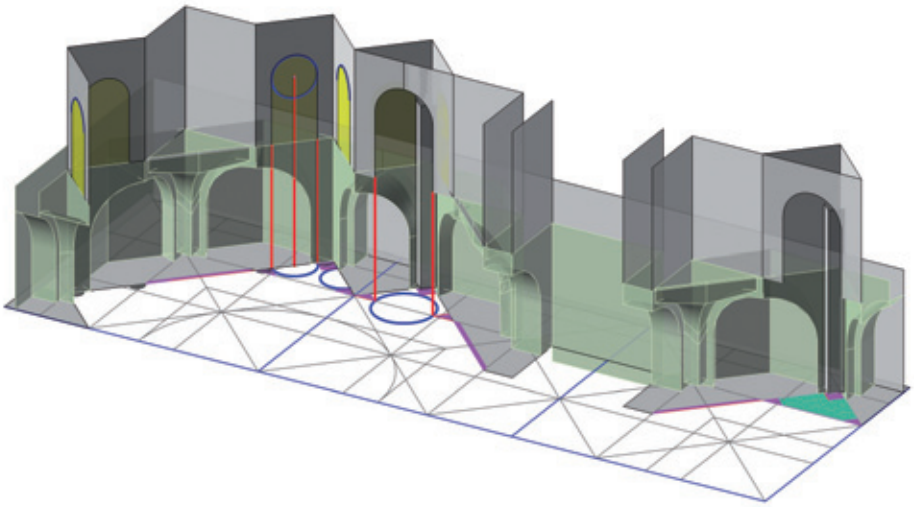


Fig. 33. Third tier: triangle-based niche. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

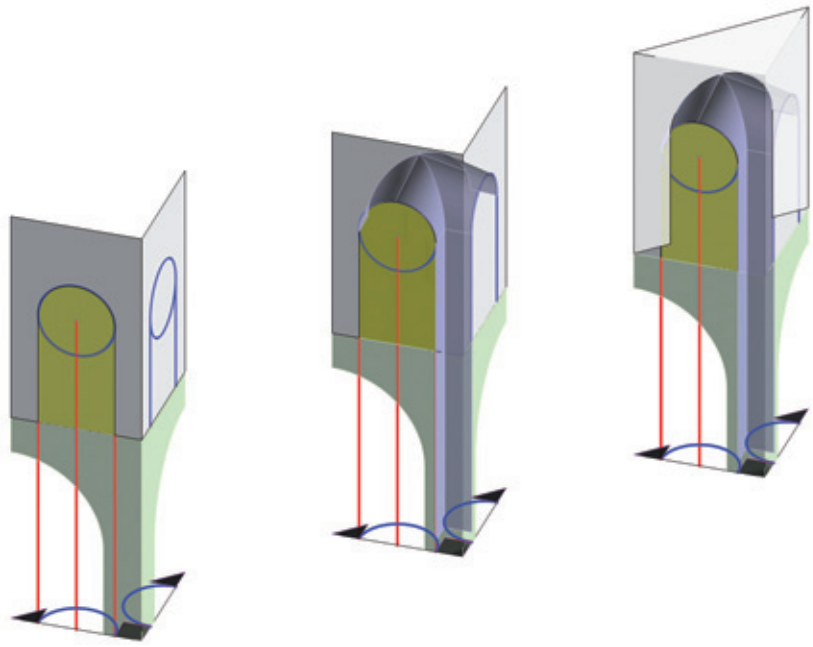


Fig. 34. Third tier: geometrical layout of the niche on a right-isosceles triangle covered by half of a cross vault. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

[Third tier: figures 33–41]

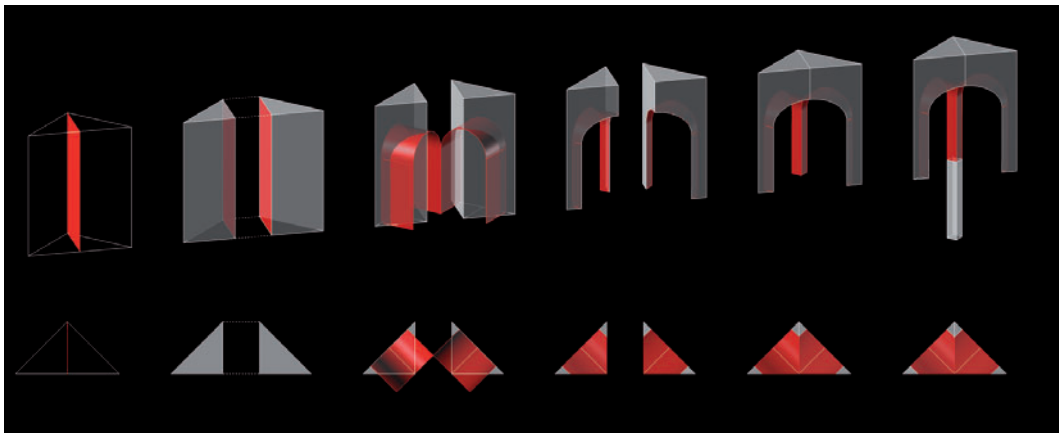


Fig. 35. Third tier: geometrical interpretation of the niche as the combination of two triangular niches sharing one side. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

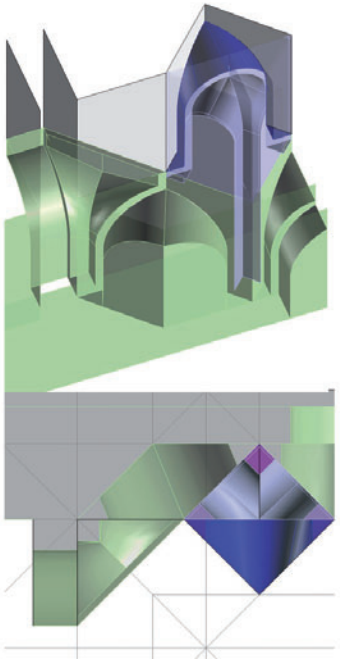


Fig. 36. Third tier: axonometric and planimetric view of the 3D model, vaults on right-angled isosceles triangles. In the orthogonal projection, triangles are joined along the hypotenuse, thus forming a square. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

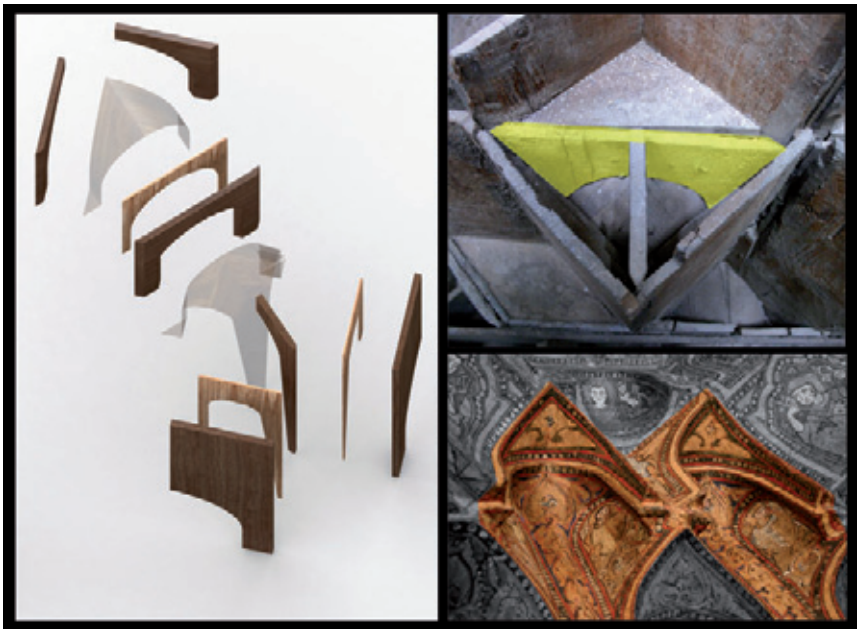


Fig. 37. Third tier: constructive elements of the vaults covering the two right-angled isosceles triangles. The shared hypotenuse is highlighted in yellow. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti; photos of the intrados: Maria Antonietta Badalamenti and Domenico Carbone; photo of the extrados: courtesy of Arch. Mario Li Castri)

Fig. 38. Third tier: barrel vault. Above, left) Layout of the constructive elements. Above, right) The intrados. Below) The extrados. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti; photos of the intrados: Maria Antonietta Badalamenti and Domenico Carbone; photo of the extrados: courtesy of Arch. Mario Li Castri)

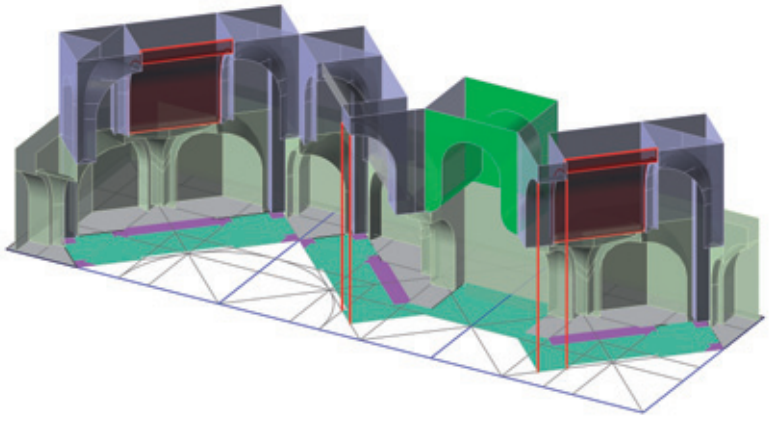


Fig. 39. Third tier: axonometric view, with barrel vaults on rectangular areas highlighted in red and "bonnet" vaults highlighted in green. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

[Third tier: figures 33–41]

Fig. 40. Third tier: demonstration of hypothesis concerning the construction of the back and front panels in the "bonnet" niche. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti; photos of the intrados: Maria Antonietta Badalamenti and Domenico Carbone; photo of the extrados: courtesy of Arch. Mario Li Castri)

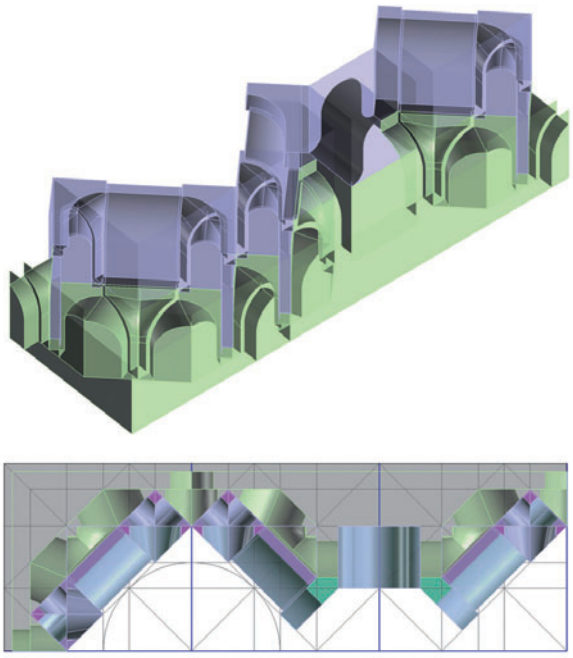


Fig. 41. Third tier: axonometric and planimetric view of the 3D model. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

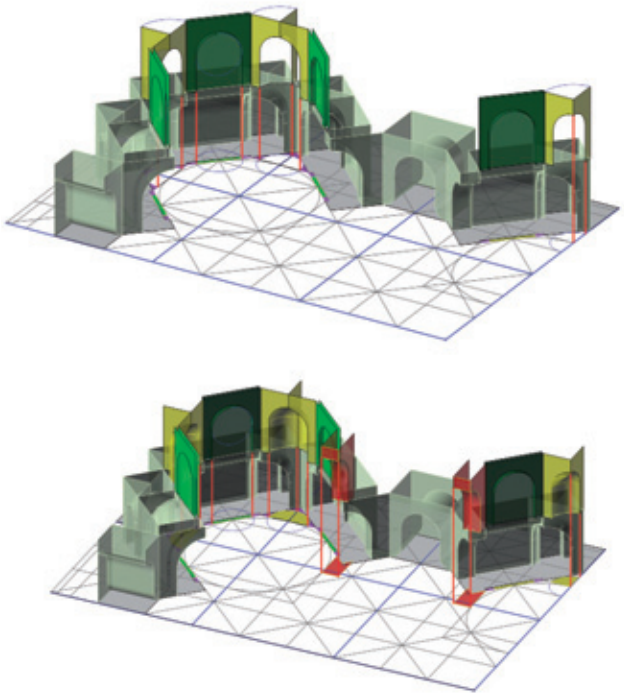


Fig. 42. Fourth tier. Above) Flat arches (highlighted in green) and panels acting as centerings for the niches (highlighted in yellow). Below) Niches (highlighted in yellow) and pairs of EL-1 panels (highlighted in red). (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

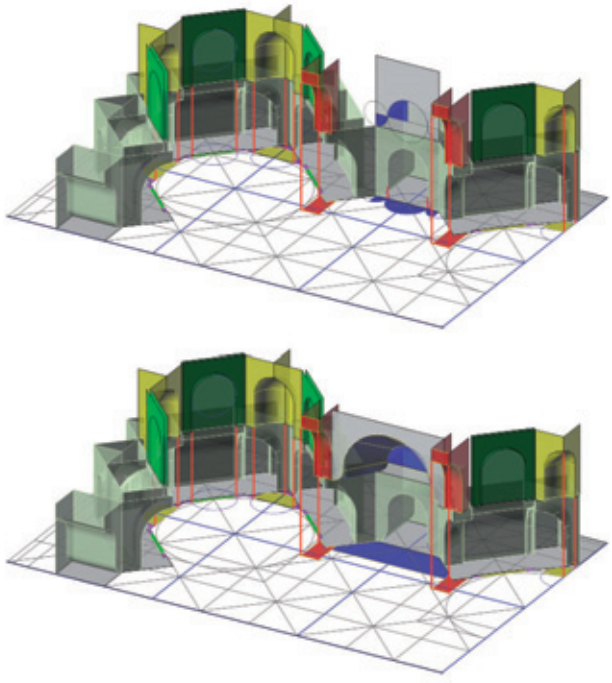


Fig. 43. Fourth tier. Above) Drawing of the directrix on the back panel of the conical vault (between the two pairs of EL-2 panels highlighted in red). Below) The conical vault. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

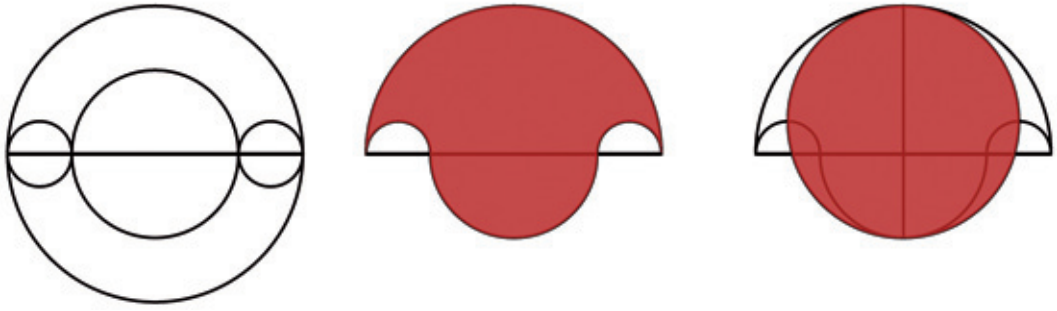


Fig. 44. Fourth tier: geometric properties of Archimedes's saltcellar. Left) Two concentric circles and two smaller circles tangent to both of them. Middle) Area delimited by halves of the circles. Right) Area of the circle whose diameter is equal to the sum of the radii of the concentric circles. The areas highlighted in dark red are equal.

[Fourth tier: figures 42–47]

Fig. 45. Fourth tier: constructive elements of the conical vault. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti; photo of the intrados: Maria Antonietta Badalamenti and Domenico Carbone; photo of the extrados: courtesy of Arch. Mario Li Castri)

Fig. 46. Fourth tier. Above, left) Flat and cylindrical niches. Below, left) The extrados of the cylindrical niche is highlighted in yellow. Right) Constructive layout of the cylindrical niche. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti; photo of the intrados: Maria Antonietta Badalamenti and Domenico Carbone; photo of the extrados: courtesy of Arch. Mario Li Castri)

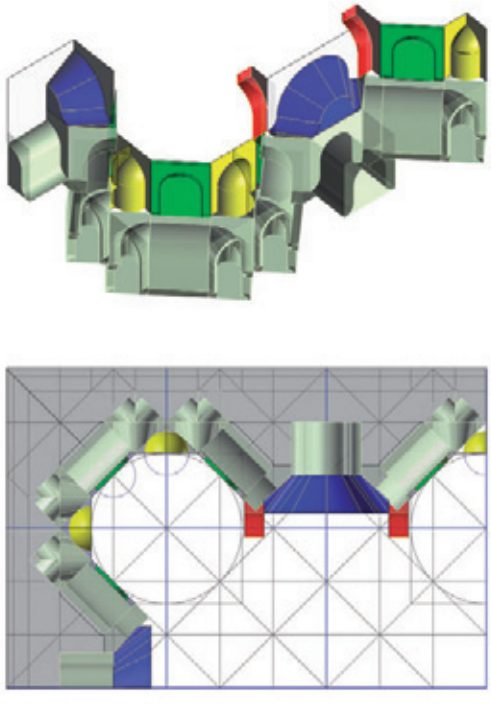


Fig. 47. Fourth tier: axonometric and planimetric view of the 3D model. Conical vaults (highlighted in blue); cylindrical niches (highlighted in yellow); flat niches (highlighted in green); pairs of El-1 panels (highlighted in red). (Images: Fabrizio Agnello and Maria Antonietta Badalamenti)

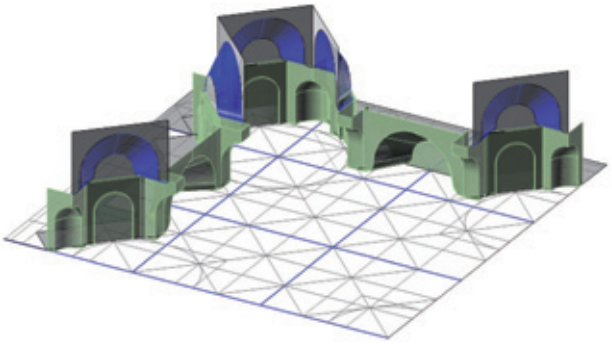
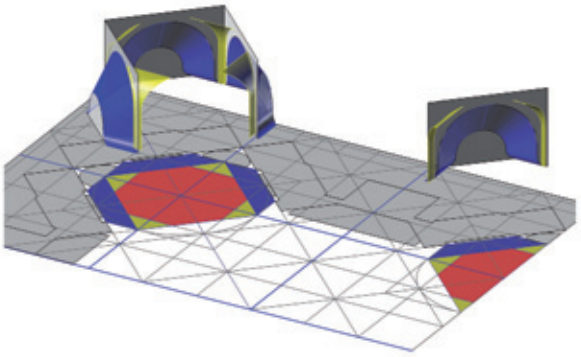


Fig. 48. Fifth tier: conical vaults. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)



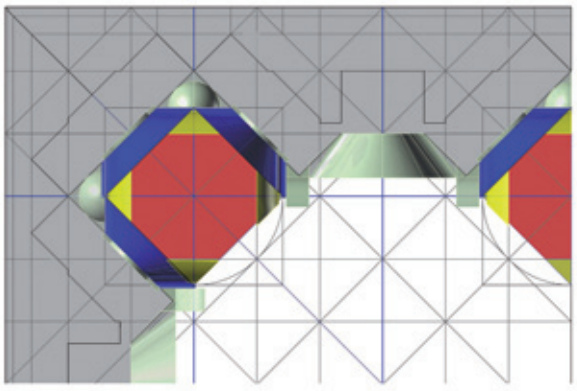
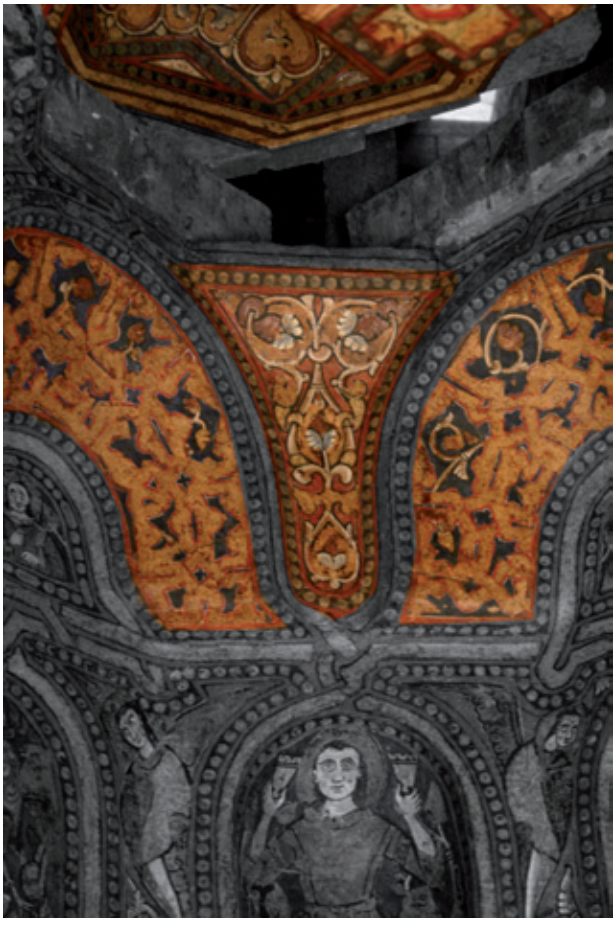


Fig. 49. Fifth tier: the pendentives (highlighted in yellow) that make the transition between the squares and the octagons ("Oc") (highlighted in dark red). (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)



←
Fig. 50. Fifth tier: the conical vaults, pendentives, and covering of the octagon ("Oc") are highlighted. (Photo: Maria Antonietta Badalamenti and Domenico Carbone)

[Fifth tier: figures 48–57]

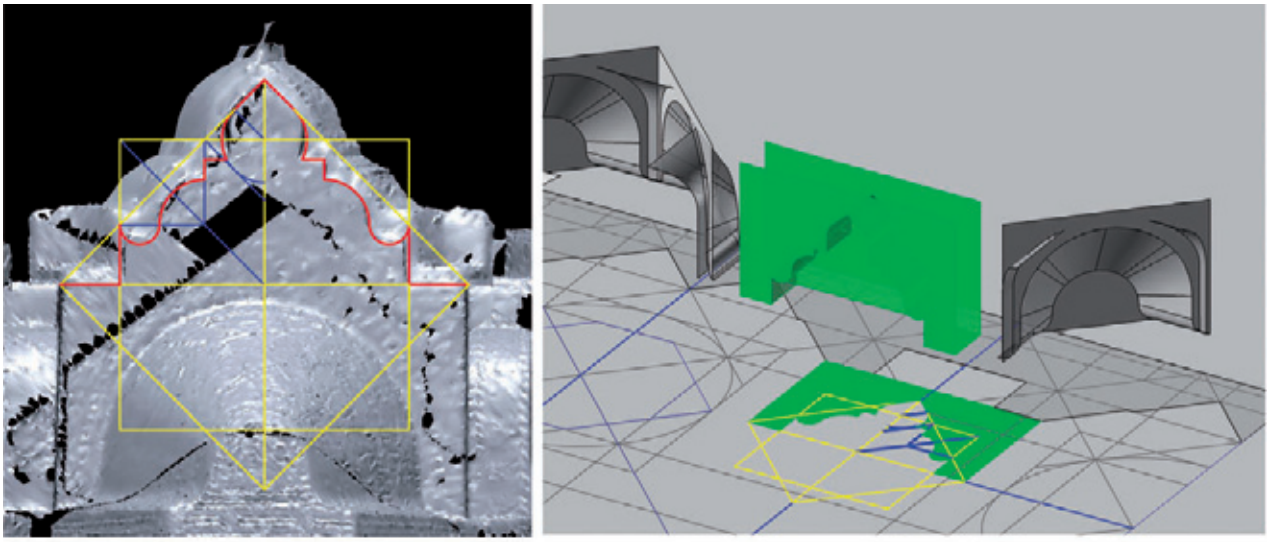


Fig. 51. Fifth tier. Left) Geometric drawing of polygonal arches superimposed on laser-scanning data. Right) The arch is highlighted in green in the axonometric view of the 3D model. (Images: Fabrizio Agnello and Maria Antonietta Badalamenti)

Fig. 52. Fifth tier: constructive layout of polygonal arches (left) and "bonnet" vaults (right). (Images: Fabrizio Agnello and Maria Antonietta Badalamenti)

[Fifth tier: figures 48–57]

Fig. 53. Fifth tier: the intrados (above) and extrados (below) of the polygonal arch. In the image of the intrados, the big pendentives are clearly visible. (Photo of the intrados: Maria Antonietta Badalamenti and Domenico Carbone; photo of the extrados: courtesy of Arch. Mario Li Castri)

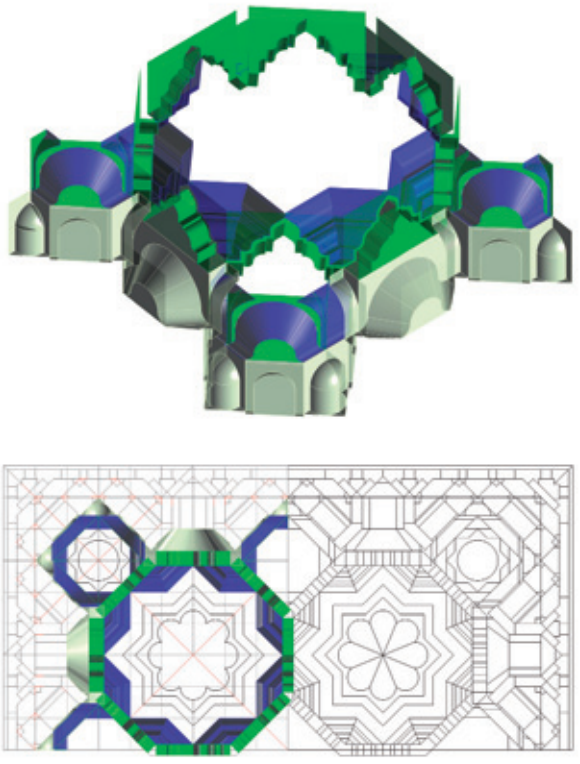


Fig. 54. Fifth tier: placement of the polygonal arches (highlighted in green) and big pendentives (highlighted in blue). (Images: Fabrizio Agnello and Maria Antonietta Badalamenti)

Fig. 55. Fifth tier: extrados of the caps of the eight-pointed stars (left) and of the octagons (right). (Photo: courtesy of Arch. Mario Li Castri)

[Fifth tier: figures 48–57]

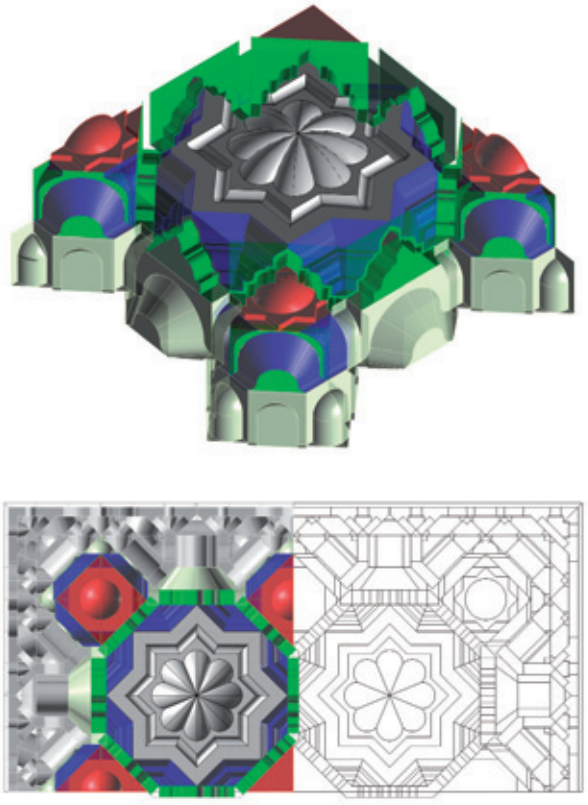


Fig. 56. Fifth tier: axonometric and planimetric view of the 3D model. The octagons ("Oc") and a quarter of a square ("Sq") are highlighted in red. (Images: Fabrizio Agnello and Maria Antonietta Badalamenti)

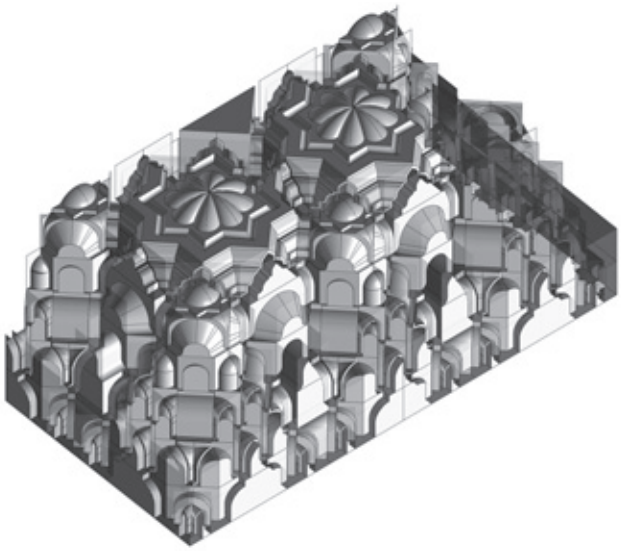


Fig. 57. Axonometric view of the 3D model of the eastern end of the ceiling. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

[Closing remarks: figures 58–61]

Fig. 58. The northeastern corner of the ceiling. (Photo: Maria Antonietta Badalamenti and Domenico Carbone)

Fig. 59. The extrados of the ceiling. (Photo: courtesy of Arch. Mario Li Castri)

[Closing remarks: figures 58–61]

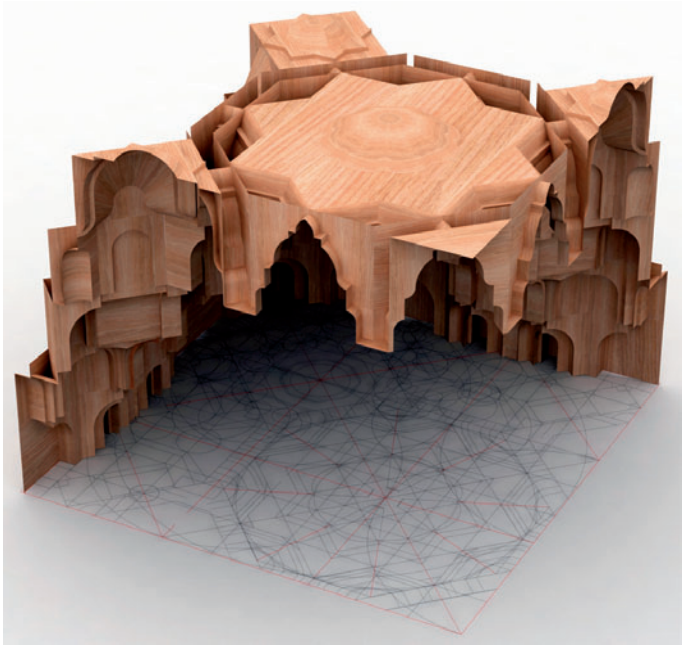


Fig. 60. Axonometric view of the 3D model and the grid. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

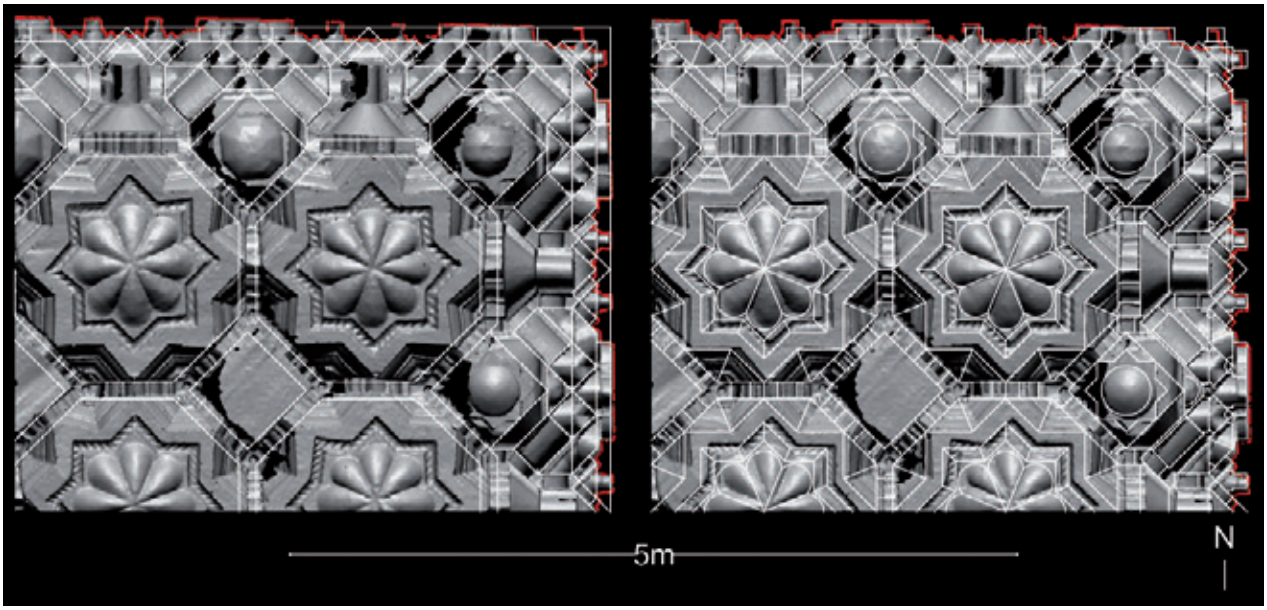


Fig. 61. Planimetric view of the northeastern corner of the ceiling: comparison of drawing and laser-scanning data. (Image: Fabrizio Agnello and Maria Antonietta Badalamenti)

NOTES

1. This study of the ceiling of the Cappella Palatina started as a thesis project titled "Laser Scanning Survey in Cultural Heritage Documentation," defended by the author at the Faculty of Architecture in the University of Palermo in March 2008. I would also like to thank two of my students, Domenico Carbone and Maria Antonietta Badalamenti, for their assistance.
2. Much work has been done on the Cappella Palatina and a complete and detailed bibliography can be found in Ernst Grube and Jeremy Johns, *The Painted Ceilings of the Cappella Palatina* (London, 2005), an up-to-date study on historical and artistic issues concerning the Cappella Palatina and the paintings of the ceiling. We will here mention only those works most relevant to our analysis. *La Cappella di San Pietro nella Reggia di Palermo, dipinta e cromo litografata da Andrea Terzi* (Palermo, 1889: repr. Palermo, 1987) consists of essays by Michele Amari, Saverio Cavallari, Luigi Boglino, and Isidoro Carini, the most prominent scholars of their time of the humanistic and historic culture of Sicily; Andrea Terzi surveyed the Cappella and drew the plates that illustrate the book. A more recent work is William Tronzo, *The Cultures of His Kingdom: Roger II and the Cappella Palatina in Palermo* (Princeton, N.J., 1997).

   The first essay dedicated to the paintings of the ceiling was Alexis Pavlovskij, "Decoration des plafonds de la Chapelle Palatine," *Byzantinische Zeitschrift* 2, 3 (Munich, 1893): 361–412. Ugo Monneret de Villard, *Le pitture musulmane al soffitto della Cappella Palatina in Palermo* (Rome, 1950), is the first comprehensive investigation of the paintings of the wooden ceilings covering the nave and the aisles. His work was continued by Ernst Grube, whose detailed analysis of the paintings was initially published in Ernst J. Grube, "La pittura islamica nella Sicilia normanna del XII secolo," in *La pittura in Italia: L'altomedioevo*, ed. Xavier Barral i Altet and Carlo Bertelli (Milan, 1994), 416–31.

   For an accurate analysis of the constructive features of the ceiling, see Vladimir Zori©c, "Sulle tecniche costruttive islamiche in Sicilia: Il soffitto della Cappella Palatina di Palermo," in *Scritti in onore di Giovanni M. D'Erme*, ed. Michele Bernardini and Natalia L. Tornesello, 2 vols. (Naples, 2005),2: 1281–1349.

   On the mosaics and other artistic features of the Cappella, see Otto Demus, *The Mosaics of Norman Sicily* (London, 1949); Ernst Kitzinger, *I mosaici del periodo normanno in Sicilia* (Palermo, 1992); Beat Brenk, "La parete occidentale della Cappella Palatina a Palermo," *Arte Medievale*, 2nd ser., 4, 2 (1990); and Maria Andaloro, "La cappella Palatina di Palermo e l'orizzonte mediterraneo," in *Il Mediterraneo e l'arte nel Medioevo*, ed. Roberto Cassanelli and Maria Andaloro (Milan, 2000), 237–55.
3. The author wishes to thank all the individuals and institutions that have contributed to this work: architect Mario Li Castri, for having encouraged and supported this inquiry; the restoration company Martino Solito Restauratore and the Soprintendenza ai BB.CC.AA. of Palermo, for granting us access to the provisional structures of the restoration yard; the Department of Rappresentazione of the University of Palermo; and architect Paolo Mori and engineer Gianni Giordano, for their kind and patient support of the surveying operations.
4. Monneret de Villard, *Le Pitture musulmane al soffitto della Cappella Palatina in Palermo*; Amari, Cavallari, Boglino, and Carini, *La Cappella di San Pietro nella Reggia di Palermo*. See n. 2 above.
5. The laser scanner, a Minolta Vivid 9i, was kindly supplied by the laboratory Conoscenza, gestione e fruizione di Beni Culturali con tecnologie informatiche avanzate of the University of Palermo. The laboratory is under the direction of Prof. Benedetto Villa.
6. Gülru Necipoğlu, "Geometric Design in Timurid/Turkmen Architectural Practice: Thoughts on a Recently Discovered Scroll and Its Late Gothic Parallels, in *Timurid Art and Culture: Iran and Central Asia in the Fifteenth Century*, ed. Lisa Golombek and Maria Subtelny (Leiden 1992), 62.
7. Robert il Guiscardo and his brother, Count Roger, came to Italy in 1047. They fought against the Byzantines in southern Italy and the Muslims in Sicily. By 1072, they had conquered only Palermo and a few other towns. That same year Robert left Sicily, keeping for himself the town of Palermo and leaving his brother the task of completing the conquest of Sicily. In 1085, Robert il Guiscardo died in Cefalonia and Roger helped his nephew, Ruggero Borsa, to keep Puglia under his control; as a reward, Ruggero Borsa granted Roger half of the town of Palermo. By 1091, Roger had full control of Sicily: he conquered Siracusa and, after supporting Ruggero Borsa in his quest to reconquer the town of Cosenza (Calabria), was awarded the other half of the town Palermo. When Roger died in Calabria in 1101, his son, Roger II (d. 1154), was six years old. Roger II's mother ruled as regent until he came of age in 1112. Upon the death of Pope Honorius II in 1130, a dispute broke out when Anacletus II (d. 1138) contested the election of Innocent II. Roger II sided with Anacletus II, who crowned him king of Sicily in December 1130. He had to fight for many years against the supporters of Innocent II, who became pope in 1138, though the latter ultimately named him "king of Sicily, Puglia and Capua" on July 22, 1139. Roger II was the first Norman king who lived in Sicily; he took a serious interest in the government of the island.
8. Tronzo, *Cultures of His Kingdom*, 54–56, cites the investigations of Kitzinger, *I mosaici del periodo normanno in Sicilia*, according to which the standard layout of the Byzantine mosaics was altered to offer the king a view of those he liked most.
9. Vladimir Zori©c has argued that in 1132 the parochial status was granted to an earlier chapel located in the present crypt under the Cappella Palatina. See Vladimir Zori©c, "Arx praeclara quam Palatium Regale appellant: Le sue origini e la prima Cappella della corte normanna," in *La città di Palermo nel Medioevo*, ed. Franco D'Angelo and Vladimir Zori©c (Palermo, 2002).

10. "Aspirante itaque nobis septiformi Salvatoris gratia, ad onorem Dei, cujus misericordia nostra prosperantur in melius, et Beatae Virginis Mariae, omniumque Sanctorum, titulo S. Petri Apostolorum principis intra nostrum regale palatium, quod est in urbe Panormi, ecclesiam, summa cum devotione, fabricari fecimus." The Latin text is provided in Luigi Boglino, "Dello edificio della Real Cappella," in Amari, Cavallari, Boglino and Carini, *La Cappella di San Pietro nella Reggia di Palermo*, pt. I, chap. III, p. 17. Panormo is the medieval name for Palermo; it means "all harbor" in Greek.
11. Jeremy Johns, "The Date of the Ceiling of the Cappella Palatina in Palermo," in Grube and Johns, *Painted Ceilings of the Cappella Palatina*, 2.
12. Ernst Kitzinger, *I mosaici del periodo normanno in Sicilia: Fasc. I. La cappella Palatina di Palermo, I mosaici del Presbiterio*, vol. 1 (Palermo 1992), 12–14. Jeremy Johns, "Date of the ceiling," 5.
13. Boglino, "Dello edificio della Real Cappella," 20.
14. On the dating of the Cappella, the mosaics, and the ceiling, see Johns, "Date of the Ceiling," 1–7.
15. What follows is the full description of the Cappella Palatina by Philagatos Kerameos, as cited in Grube and Johns, *Painted Ceilings of the Cappella Palatina*, 13:

    "1. O city, I rejoice with you, and with you, sacred Church of the palaces, that all ages have flocked to you today; that all who are respected for their rank, and so many priests, have honored this festival with their presence. The first cause of all these events is God, from whom arise and originate all the blessings of mankind, but the second is a pious ruler; a benevolent guardian when he regards his subjects, who reserves his anger for his enemies. Now, he, having provided us with many, great benefits, and having surpassed all his contemporaries and predecessors in piety and magnanimity, just as the blazing sun outshines the splendor of the stars, has given another proof of that truly great and kingly spirit, in this delightful church of the Apostles, which he has built as if a foundation and a protection for his palaces; large, most lovely, and distinguished by a fresh beauty; brilliant with lights, shining with gold, glittering with mosaics, and bright with paintings. He who has seen it many times, marvels when he sees it again, and is as astonished as if he were seeing it for the first time, his gaze wandering everywhere.

    2. As to the ceiling, one can never see enough of it; it is wonderful to look at and to hear about. It is decorated with delicate carvings, variously formed like little coffers; all flashing with gold, it imitates the heavens when, through the clear air, the host of stars shines everywhere. Most beautiful columns support the arches, raising the ceiling to an extraordinary height. The most holy floor of the church actually resembles a spring meadow because of the many-coloured marbles of mosaics, as if it were adorned with flowers; except that flowers wither and change, while this meadow is never-fading and ever-lasting, and within itself maintains eternal spring. Every wall is entirely covered with many-coloured marbles; the upper parts are occupied with gold mosaics, wherever they are not crowded with the host of holy images. As to the place of the inexpressible holy mysteries, a screen of marbles surrounds the presbytery on all sides. Within this, one can linger and stay with safety, gladdening the eye with the spectacle. This is also a barrier, lest anyone rash and unconsecrated should attempt to cross into the innermost sanctuaries.

    3. The sacred altar, which flashes with the sparkling of silver and gold, amazes the beholder; but whatever else is there shall be honoured by our silence. The whole church, just like a cave, softly joins in the singing of the sacred hymns with its own voice, because the echo causes the sound to return upon itself. A great many curtains are hung, the fabric of which is threads of silk, woven with gold and various dyes, that the Phoenicians have embroidered with wonderful skill and elaborate artistry. A mass of lamps vie with each other, so to speak, to illuminate the church with their never-sleeping flames, making the night as bright as the day. Who has words for the number and the beauty of the gold and silver vessels destined for the holy rite? But time presses me to direct my discourse to the explanation of the Divine Gospels. Since we have dealt with the particulars on the encenia, let us listen to the holy sayings."
16. For some insightful observations on the date of the sermon by Philagatos Kerameos, see Johns "Date of the Ceiling," 1–9, and Andaloro, "La Cappella Palatina di Palermo e l'orizzonte mediterraneo," 244.
17. The matter of the absence of a coherent iconographical project was first proposed by Monneret de Villard, *Le pitture musulmane al soffitto della Cappella Palatina in Palermo*, 40: "Paintings in the (ceiling of the) Cappella Palatina show no organic iconographic project." Grube, after describing the subjects of the paintings, asserts that: "while this particular way of looking at the Cappella Palatina paintings does not seem to yield the impression of a systematic sequence, or a 'program', there are, of course, other ways to look at these images, namely, as individual units or groups of units." He then reports an assertion made by Umberto Scerrato that "according to the anti-naturalistic Muslim trend the cycle of paintings is not structured by a narrative program, but is divided and disconnected in many single figures related only by an abstract symbolic reference." Grube, "The Painted Ceilings of the Cappella Palatina in Palermo and Their Relation to the Artistic Traditions of the Muslim World and the Middle Ages," in Grube and Johns, *Painted Ceilings of the Cappella Palatina*, 22–23.
18. Michele Amari, "Epigrafi arabiche della Real Cappella: Soffitto della Navata maggiore," in Amari, Cavallari, Boglino, and Carini, *La Cappella di San Pietro nella Reggia di Palermo*, pt. IV, chap. II.
19. See n. 15 above.
20. See Andaloro, "La cappella Palatina di Palermo e l'orizzonte mediterraneo," 255. Johns does not agree with this hypothesis and argues that silken curtains would simply be, just like lamps and vessels, a part of the furnishing of the whole church. Johns, "Date of the Ceiling," 6.
21. "Must the ceiling necessarily be seen as an 'import' from Fātimid Egypt? Or might there not be indications that other,

perhaps indigenous, traditions provided both inspiration and artists who could have created it? And lastly, are the paintings arranged in a manner that would indicate a 'program'? And can such a program be understood only in terms of 'Islamic' art, or did the general medieval, Romanesque tradition of the contemporary West have an equal part in its creation?" Grube, "The Painted Ceilings of the Cappella Palatina in Palermo and Their Relation to the Artistic Traditions of the Muslim World and the Middle Ages," 16.

22. See n. 2 above.
23. Grube, "The Painted Ceilings of the Cappella Palatina in Palermo and Their Relation to the Artistic Traditions of the Muslim World and the Middle Ages," 17.
24. Ibid.
25. Ibid., 20.
26. The alphanumeric code and the schematic drawings of the ceiling first appeared in Grube, "La pittura islamica nella Sicilia normanna del XII secolo."
27. Grube, "The Painted Ceilings of the Cappella Palatina in Palermo and Their Relation to the Artistic Traditions of the Muslim World and the Middle Ages," 17.
28. The literature on the geometric analysis of Islamic art and architecture is too vast even to outline here. The studies mentioned below use an approach to geometric analysis that has strict connections with this essay: Armen Ghazarian and Robert Osterhout, "A Muqarnas Drawing from Thirteenth-Century Armenia and the Use of Architectural Drawings during the Middle Ages," *Muqarnas* 18 (2001): 141–154; Yvonne Dold-Samplonius and Silvia L. Harmsen, "The Muqarnas Plate Found at Takht-i Sulayman: A New Interpretation," *Muqarnas* 22 (2005): 85–94; Gülru Necipoğlu, *The Topkapı Scroll: Geometry and Ornament in Islamic Architecture, Topkapı Palace Museum Library MS. H 1956* (Santa Monica, Calif., 1995).
29. The term "right-angled isosceles triangle" indicates right-angled triangles whose sides have the same length.
30. The term "polygonal" is used here to indicate a line made of arcs of circle and segments of straight lines.