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Planar vaults in the Monastery of El Escorial

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Those involved in the construction of the monastery of San Lorenzo in El Escorial faced the challenge of building Renaissance shaped ashlars vaults. In accordance with this intention they abandoned the rib and panel Gothic vaulting, making in any case non-structural ribs as in the church dome and intrados of the towers. They got to build in the Prince's Pantheon some vaults with an external Gothic appearance, which does not actually consist of a self-resistant framework of ribs supporting light panels.

The study of the monastery basement is especially interesting: there are splendid and *strong* vaults that solve the covering of these rooms with a considerable span and low height structure. Because of the height limit, a wide repertoire of basket arches was tried and a search on low profile vaults was began. On the other hand, the sail vault type was profusely employed developing amazing solutions for quartering, in spite of its location in service rooms.

A good example of this design and construction effort can be found in the planar vault made by Juan Bautista de Toledo in the basement, under the initial king's room, in the middle of the southern façade, in the place of the discarded Noon Tower. It is an almost square plan room with a central column supporting four arches. A planar ashlars vault with rounded quartering rests on the arches and four smooth pendentives solve the corners.

Some years later, the planar vault designed by Juan de Herrera under the church choir place (figure 1), meant the zenith of the work on low profile vaults made at the monastery: four main basket arches support a vault which shape has a lot to do with the former mentioned one, with pendentives between the arches and the central planar area.

The aim of this paper is the study of the two mentioned planar vaults, in order to find out something more about how they were built and why certain decisions were made. This work consists of analysing geometry and quartering to pose hypotheses on its constructive configuration and initial tracings. Concerning Juan Bautista de Toledo's planar vault, this work tries to find out something else about the central column and whether it was made

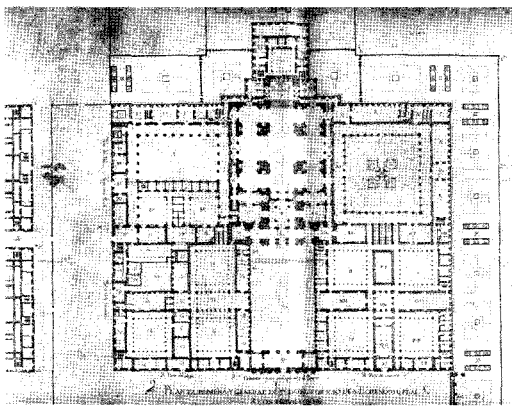

Figure 1
First drawing from the monastery *Estampas*

Figure 2
Planar vault in the monastery basement, under the discarded Noon Tower

from the beginning or not. On the other hand, this work is part of a doctoral thesis about the vaults of the Monastery.[1]

An accurate surveying was specifically carried out for this work, in order to provide reliable data of both vaults. The measurement was done using a laser surveying station,[2] locating a cloud of points —4892 from the *under choir* place and 2032 from the basement planar vault— determining all architectural shapes and joints of the main vaults quartering. It was necessary to take data from several station base points in both areas that were merged afterwards in the same coordinate system locating sharing points between at least two bases. The points from each area were then processed and analysed in a single digital file, where all the drawings showed in this paper were done.

The planar vault in the monastery basement, under the discarded Noon Tower

The first planar vault built at the monastery (figure 2) is located under the initial king's room at the back of the initial church. These rooms are indicated with letters HH and GG in Herrera's drawing in figure 1, and it is a single space at present time, known as the *old church.*

The first mass celebrated at the monastery took place in the initial church on March the 8th 1565 (Villacastín, 1595). Floor centring for the church choir place, just over the king's room, were being placed on January 1566 (Bustamante, 1994, 114); as they should lay on the planar vault we are concerned on, we could think that it was finished at the end of 1565. The work in this area goes on slowly from this moment, in spite of that the king wished to have his room ready as soon as possible: it is being paved on February 1567 (Portabales, 1945, LXIV), almost one year after the beginning of its ceiling centring. Though it may sound strange due to the lack of any reference or document, could a problem arise in the planar vault which made convenient its loading on the central column and the four arches which can be seen at present, being this the cause of the delay in the works of the upper floor? In any case, the vault was built before the death of Juan Bautista de Toledo on May 1567, and the clerk in charge of it could be Lucas de Escalante, who was also responsible for the works of the initial church (Portabales, 1945, LVI).

The drawings of figure 3 describe the current state of the room covered by the planar vault. The plan is almost square (30×31 feet) and it is one of the scarce spaces in this area with a direct access from monk's garden. A square column with 2.5 feet length, decentred with respect to the symmetry axis of the room supports four basket arches of which the design follows the pattern described by Alonso de Vandelvira; the arch which lays on the southern façade loads, amazingly, on the entrance transom. The arches support the vault, approximately 1.5 feet thick,[3] and an intermediate filling can be appreciated between one of the arches and the vault.

In the above mentioned drawings of figure 3 the vault has been strictly represented in its current state without adjusting it to any theoretical geometry or false symmetries, in order to appreciate what could be great deformations. In the intrados there is a central planar zone —with a certain descent in the middle— which does not reach the walls; an intermediate ring starts a smooth transition to the pendentives. In the intersections of the vault with the loading walls, we find four non circular arches. Three out of the four quadrants of the vault show single trace rounded courses, centered in the intersection point between the symmetry axis of the room; in the south-eastern quadrant, the courses are also rounded, but with a displaced center with respect to the previous one and with a more irregular trace for the radial joints. A

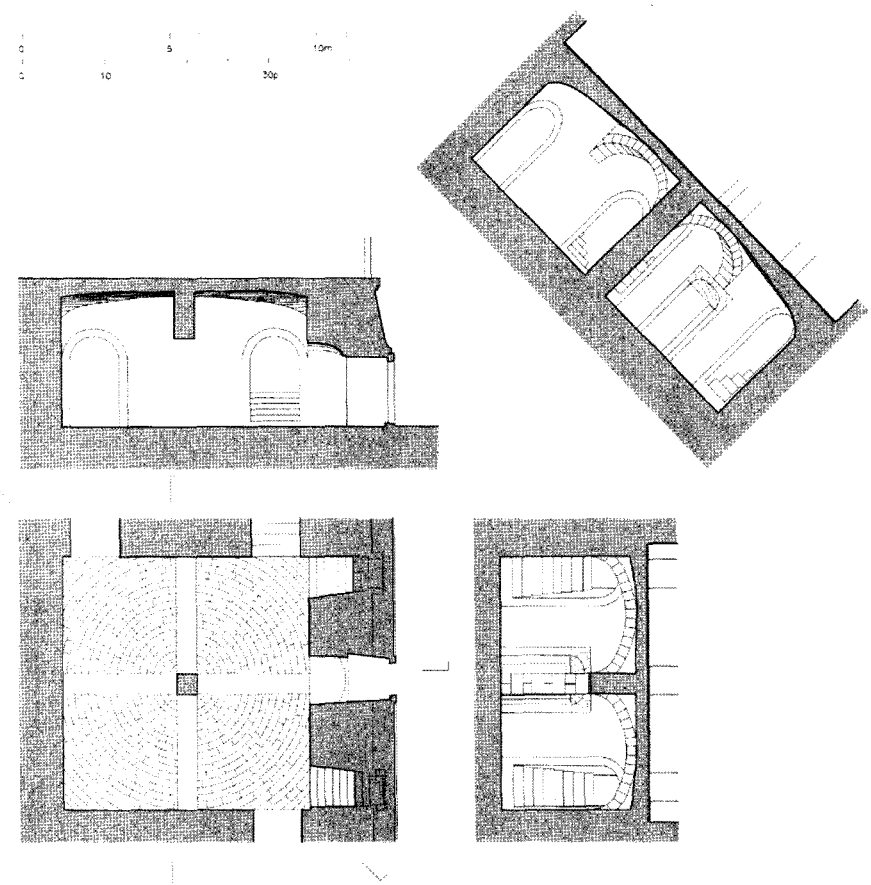

Figure 3
Plan and sections of the room under the discarded Noon Tower at the monastery in El Escorial

certain descent in the diagonal area of each course can be appreciated in all of the quadrants.

The conclusions of this work are summarised in a proposal of which could have been the original tracing of this vault (figure 4): it poses that the central column and the four arches were not in the initial plans. The important delay on the work of the king's private room, placed over our vault and the mistakes in the posing of one of the quadrants in which, in addition, there is filling in the unions with the supporting arches, could allow supposing that the area had to be redone. On the other hand, a column properly built would have been posed in the centre of the room; the solution with the arch loading over the entrance transom from the monk's garden is very strange; the descent in the central area would be difficult to occur in a vault laying on four central arches and, finally, if the construction would have been over column and arches from the beginning there would not be intermediate filling.

The geometry of the vault seems to have been born from its diagonal section, which revolving around a vertical axis generates the surface. The central planar area has been placed at the height of the highest point of the intrados and would comprise the eight central courses visible at present plus another two that are

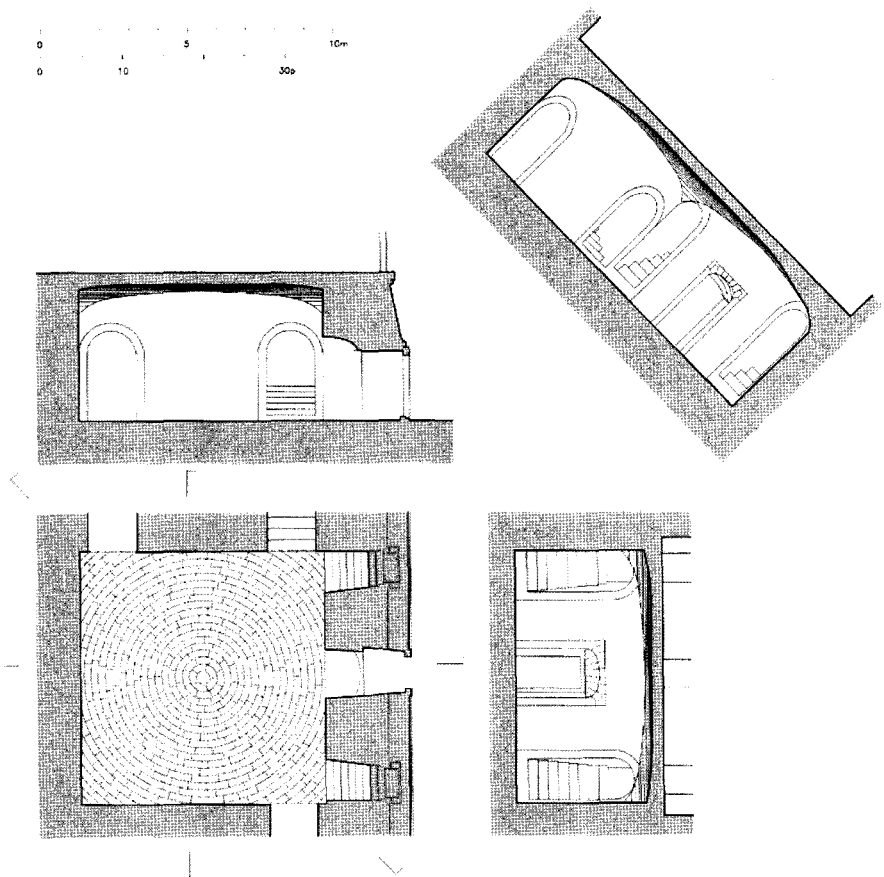

Figure 4
Hypotheses for the initial tracing of the planar vault under the discarded Noon Tower

supposed to be hidden behind the column, including the keystone. A smooth arch initiates the descent in an area of the vault in which the courses do not still reach the walls. The pendentive itself would have a diagonal section formed by a straight line, that would generate a revolving cone, and a final arch that would end the vault in the edges of the four corners of the room. Following this posing, the descent would be of around 7 cm in the centre, and would reach 10 in the thirteenth visible course at present. The laying surface of each course over the previous one could be solved with inverted conic beds, as if it were a transom arch revolving around its vertical axis (Rabasa, 2000, 216).

THE PLANAR VAULT UNDER THE CHOIR PLACE

Under the choir place in the monastery of El Escorial there is a unitary space, like the one of the large temple, following brilliant analysis by other authors (Sigüenza, 1602; Moleón, 1984; Ortega 1999). This paper analyses the set of all vaults, with a special stress on the famous central planar vault which was

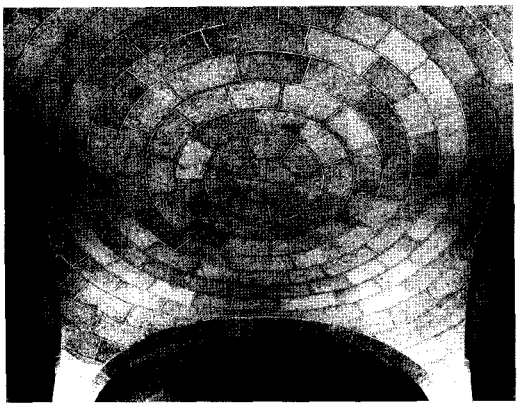

Figure 5
Planar vault under the choir place of the monastery in El Escorial

the second and final attempt to cover a space with a large horizontal stone surface at the monastery (figure 5).

At the end of 1565, the works of the church are divided into ten parties: five to the north of the longitudinal axis and five to the south (Bustamante, 1994, 412). The clerk of works Juan de Minjares is responsible for the whole works. That split tries to balance the work of all teams, each one headed by two stonemason masters. The space under the choir is distributed among four of the ten parties. Francisco del Río and Diego de Cisniega are in charge of one of them, comprising the south-western angle of the church: southern tower, half the façade and the arcade and a quarter of the space under the choir place. The rhythm of the works is not the same in all parties: on February 1581 the Congregation assigns to Cisniega the complete construction of the choir, including the space under the choir place reducing the parties of another three teams which were working in this area.[4] The works of the southern tower of the church go faster than those of its twin, what proves that Cisniega was very efficient. On December 1581, an expert valuation of the towers was done, being already finished by that date.

On March 1582, scaffolds are being made in the space under the choir,[5] in a very difficult area to this purpose, as it was the main entrance to the church work. On September 1582 an agreement for the construction of all the centring is reached with Juan Ramos.[6] On May 1583 the space under the choir was already finished as the measurement of the works is done on the 24th.[7]

The initial aim of this work was to analyse just the planar vault, but later it was decided to study all vaults in the space under the choir place and this unitary space was completely measured and drawn (figure 6). Herrera (1589, 13) describes the space under the choir place: «es quadrado, y tiene mesma forma que el Templo, y haze tres naves por cada lado de su quadro y sirve de cuerpo de la yglesia». The two main naves are covered by basket barrel vaults ; the planar vault with 28 feet span (7.81 m) covers what could be called the transept of this temple and four small sail vaults solve the corners. An intermediate arcade solves the transition between the space under the choir place and the church and we can find in there a transversal barrel vault and a false central sail one.

The five sail vaults we find in this area show an slightly enlarged plan in the direction of the

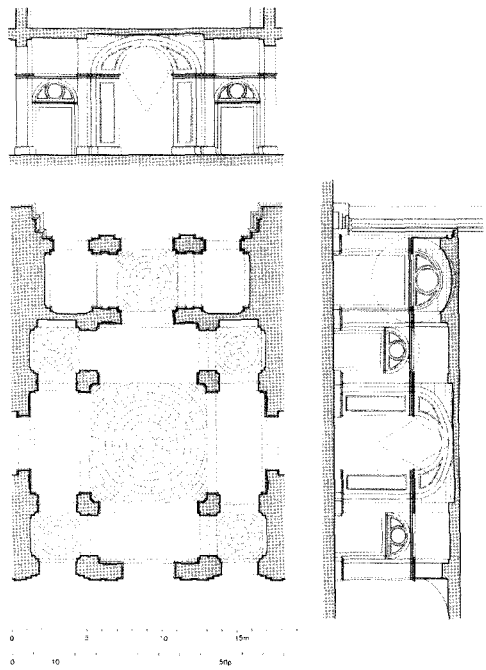

Figure 6
Plan and sections of the under choir place at the monastery in El Escorial

longitudinal axis of the church. The false sail vault mentioned above has an spherical casquete lowered almost 1 feet in height. The planar vault lays on four main arches which also conform the section of the main barrel vaults; those arches fit with enormous fidelity the traces described by Hernán Ruiz. The planar vault has been represented in the drawings of figure 6 in the deformed current state. The geometry of the quartering is perfect in plan, but not in height in which the descent looks very important in the central area and in the diagonals of the intermediate courses. The existence of a course with variable width is amazing: it is the first one laying on the main arches, thus, the highest among the pendentives.

Alonso de Vandelvira draws a vault which could have a lot to do with the one we are studying: it is the *square basket chapel with rounded courses* (figure 7). That vault could be cut by a horizontal plane at the height of the key stones of the main arches, generating a planar vault laid on four pendentives on basket arches but it would create a discontinuity at the start of the pendentives which does not exist at the piece in the space under the choir place. On the other hand, the vault by Vandelvira is a revolving surface: if the diagonal arch is a basket one, the main arches cannot be too and vice versa.

This work poses a hypotheses of initial trace for this planar vault. The solution that, probably, Herrera and Minjares designed, should response to a series of restraints : support on basket arches, diagonal section with smooth transition between planar area and pendentives and horizontal rounded courses. The configuration of the diagonal section becomes then the key point in this posing (figure 8). The central planar area would comprise the six central courses; in the last one, the highest point in the vault at present has been located, at a height of 8.034 m, almost 29 feet. At this height the planar area of the vault is placed. A three sections basket arch completes the diagonal section. The central area independent from the pendentives is drawn as in the planar vault by Juan Bautista de Toledo, initiating a smooth descent that would coincide with the first section of the mentioned basket arch. The vault in this area is

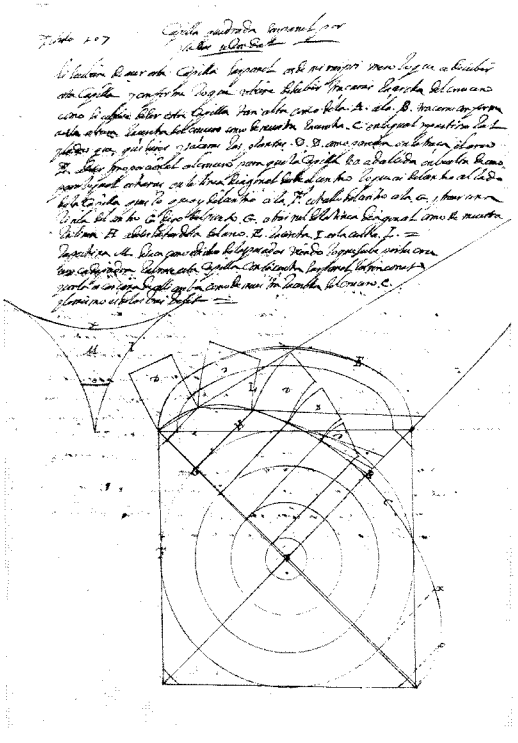

Figure 7
Square basket chapel with rounded courses, in Alonso de Vandelvira's treatise

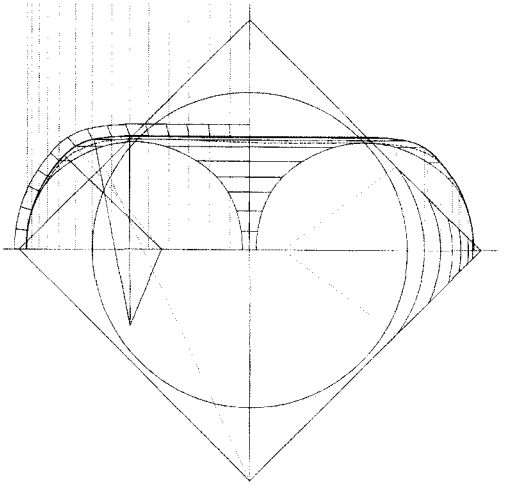

Figure 8
Hypotheses of the geometrical configuration for the diagonal section of the planar vault under the choir place

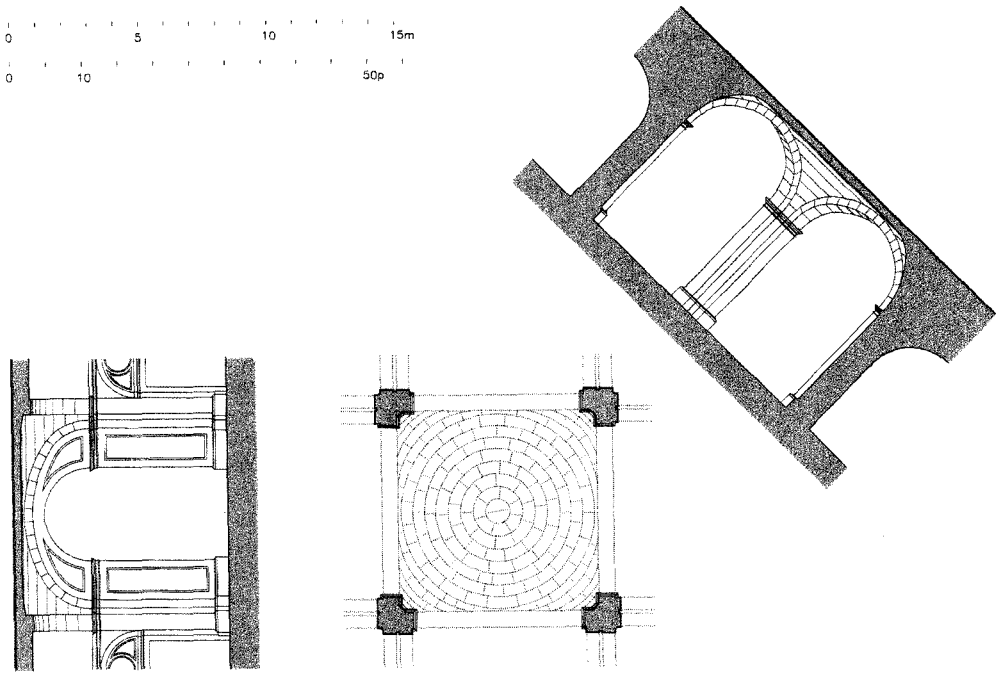

Figure 9
Hypotheses for the initial design of the planar vault under the choir place

formed by the revolving area generated by the corresponding part of the diagonal section; the joints between courses are then complete horizontal circumferences with center in the axis of the vault. In the pendentives, the courses are horizontal circumference arches, which lay on the diagonal section and on the two corresponding main arches and have then their center displaced with respect to the axis. For this reason, the transition course between pendentives and the central area presents a variable width. The surface of the voussoirs of this area is slightly warped and probably carved by approaching.

The current state of the diagonal section of the vault has been drawn with a discontinuous line in figure 8: the comparison between that state and the hypotheses for the initial trace allows a proposal of a descent in the keystone of 9.66 cm. On the other hand, the difference between the height of the choir floor where there is no deformation and the proposed intrados for the trace, gives a thickness for the vault of 28.1 cm. The laying beds of each course over the previous one could be conic, as in the planar vault by Juan Bautista de Toledo. In the case of the space under the choir place, the goodness of this posing would come confirmed by the recent construction of a plaster model of the vault with a scale of 1:10 by doctorate students of the School of Architecture of Madrid, leaded by Enrique Rabasa Díaz: the laying beds between courses are conic ones and the vault stands perfectly well.[8] Fray José de Sigüenza also describes this configuration (Sigüenza, 1602, 454).

The drawings in figure 9 describe the theoretical state of the vault before its deformation happened.

The relationship between the two vaults analysed in this paper is clear. The vault by Juan Bautista de Toledo has a longer span : 8.35 m × 8.63 m, versus 7.80 m in the one by Juan de Herrera. The thickness is almost double, the courses of a smaller width, and above all, a shorter height development. If that vault was a failed attempt as it is posed in this paper, Herrera, pupil of Toledo by that time, learned enough to build successfully the planar vault under the choir

place: he reduced the thickness and corrected the diagonal section arranging a sole central straight line and increasing the height.

Notes

1. *The vaults of the Monastery in El Escorial,* carried on by the author of this paper guided by Enrique Rabasa Díaz, professor at the Madrid School of Architecture.
2. The realization of this surveying has been possible due to the availability of the measurements instruments of the Department of Graphical Architectural Ideation of the Madrid School of Architecture, specially the laser surveying station, and also due to the kindness of the National Heritage Office at El Escorial, permitting all the visits needed to complete the fieldwork.
3. Using the laser surveying station at the monk's garden, points at the *old church* windows were located; then the level of the floor was manually determined from the inside. The whole thick obtained is 0.4682 m: if we discard the pavement, it could be a 1.5 feet thick vault (0.4179 m). There is no visible descent in the church pavement, but the floor vibrates as one walks over it.
4. Manuscript at the Monastery Library Archive, VII–41, transcript by Bustamante, 1994, 501 y 502.
5. Manuscript at the Monastery Library Archive, VIII–8, transcript by Bustamante, 1994, 506.
6. Manuscript at the Monastery Library Archive, VIII–3, transcript by Bustamante, 1994, 506.
7. Manuscript at the Monastery Library Archive, VIII–29, transcript by Bustamante, 1994, 508 y 509.
8. Pedro Martín Gómez (1986) posed a complicated stone-cutting configuration.

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