

Late German Gothic Methods of Vault Design and Their Relationships with Spanish Ribbed Vaults

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Despite the differences among the Late Gothic vaults in different European countries in the 15th century, masons travelled throughout the continent, maintaining an ongoing exchange among the different lodges. The Spanish case is particularly significant, as a great number of masons from Europe arrived to Spain during the 1440s and 1450s; for instance, Pedro Guas from Brittany and the Coeman family from Brussels settled in Toledo, while Juan de Colonia travelled from Cologne to Burgos. These masters brought with them the advanced knowledge and the technological improvements used in Their countries, which would appear in the vaults created in Spain from that moment on. This hypothesis is supported by the fact that some Late Gothic vault models found in central Europe were also used in Spain.¹

One of the most significant characteristics of German Late Gothic ribbed vaults is the presence of ribs that intersect one another in the *tas-de-charge* above the springing. This is illustrated in some manuscripts from the German area, like the *Wiener Sammlungen* [15th-16th centuries], and the *Codex Miniatus 3* [c. 1560-1570], also known as the *Dresden Sketchbook of Vault Projection* (Bucher 1972). This solution is developed in Spain by Master Simón de Colonia in the final decade of 15th century. One of his masterpieces is the rectangular vault in the Antigua Chapel in Seville Cathedral, designed in 1497; this present paper analyzes this significant vault and its geometric construction, in relationship to the German vault construction system reflected in these manuscripts.

The vault of the Antigua Chapel has two striking characteristics: the first is the design of the vault plan, which is divided in four rectangles, each reproducing a *tierceron* ribbed vault with five keystones;² the second is the aforementioned ribs that intersect in the *tas-de-charge*. These two characteristics can also be found in one of the vaults illustrated in the *Codex Miniatus 3*.

Research work on Late Gothic vault construction is usually restricted to a single country or region, and no comparative studies have been carried out in order to prove a potential transfer of knowledge. This present paper, which compares a German-appearing Spanish vault with the theoretical German vault construction system, is intended as a starting point for further research on this field.

Simón de Colonia and the Spanish Late Gothic ribbed vaults

Simón de Colonia was born in Burgos around the year 1450. His father, Juan de Colonia, had arrived in Burgos ten years earlier, recruited by the bishop of Burgos during his trip to the centre of Europe looking for masons who were expert in building towers.

Once he had dealt with his father's unfinished works after his death, Simón began to work on his own vaults, developing the classical cross-ribbed Gothic vault into much more complex and sophisticated designs. The particular characteristic of his vaults are the ribs springing separated from the wall that intersect one another in

the *tas-de-charge*. In this, Simón's design was original. In central Europe, some contemporary vaults can be found with similar layouts. This leads us to believe that the arrival of European masons in Spain favoured the entry of new designs and technological solutions. The fact that it was Simón de Colonia, and not his father, who proposed these new layouts is striking; we wonder if he might have travelled to central Europe.

Simón's first and most famous interlaced *tierceron* vault is located in Burgos: the Condestable Chapel [1482-1492]. It is an octagonal plan vault in which the half of the *tas-de-charge*s springs from a corbel and the others from a pilaster. In each one, two ribs spring separately and then cut through one another in order to arrive to a secondary keystone. From these keystones the layout of the ribs reproduces a *Sterngewölbe*. A similar layout is also found in one of the designs included in the *Wiener Sammlungen*.

In 1495, Simón was in Toledo working with Juan Guas in San Juan de los Reyes (Dominguez 1993). We believe that during his stay in the city he also developed the vault of Juan Guas's Memorial Chapel located in the church of Santos Justo y Pastor [c. 1497] (Fig. 1). This vault has a small rectangular plan with a design that recalls the four vaults located in the middle of the aisles of Astorga Cathedral, also attributable to Simón (Gómez 1998). However, the *tas-de-charge* is different in Toledo, with two ribs that intersect one another without diagonal ribs.

Afterwards, he arrived to Seville to take over as Master Mason of the Cathedral. Due to his frequent absences he was later replaced by Alonso Rodríguez. Nevertheless, he still had time to lay out the Antigua Chapel in the Cathedral and its Sacristy.

He also worked in Cordoba, where he carried out the interlaced *tierceron* vault in the Hospital de San Sebastián. Here the vault has diagonal ribs, so there are three ribs intersecting in the *tas-de-charge*. The layout of this vault is similar to what is shown in the *Wiener Sammlungen* (fol. 17.020) and the *Codex Miniatus 3* (fol. 3v) designs, as well as several contemporary German vaults: Gwandstein [1518], the aisle of Ulm Cathedral [1502-1507], the Basilica of St. Ulrich und Afra in Augsburg [end of the 15th century]

and St. Kastor and Liebfrauenkirche in Koblenz [1486-1487] (Bürger 2007) (Fig. 2).

Simón also went to Valladolid hired by the bishop of Palencia. It has been assumed that during this time he developed the Inmaculada Chapel in Palencia Cathedral (Gómez 1998). Historians suggest that in some cases Simón provided the layouts of the vaults and other masons built them. It has to be taken into account that Spanish masons didn't know the technique to develop these outstanding *tas-de-charge*, so Simón must have been involved in the construction process. The rectangular vault of the Inmaculada Chapel has no diagonal ribs either, and in the *tas-de-charge* one rib seems to pass ahead the other as in Toledo, Cordoba and Seville. The design of the vault also recalls that of Toledo and a German vault in St. Georgskirche in Nördlingen [1505].

There are also two vaults in churches found in the area between Burgos and Palencia in which

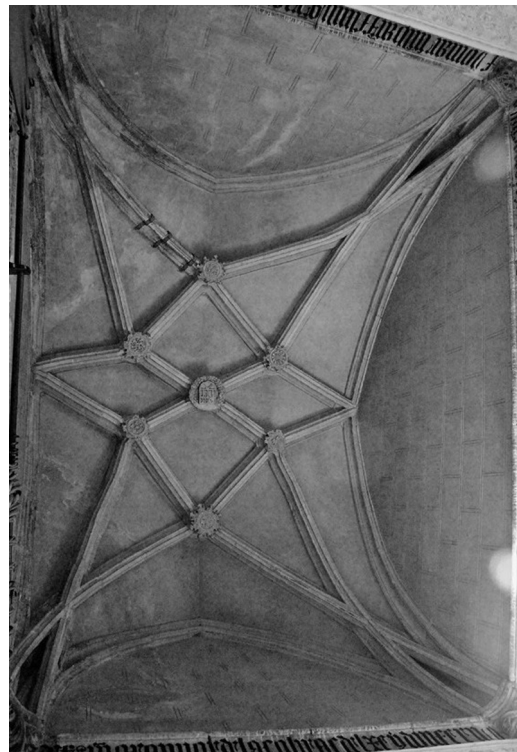


Fig. 1: Juan Guas's Memorial Chapel.

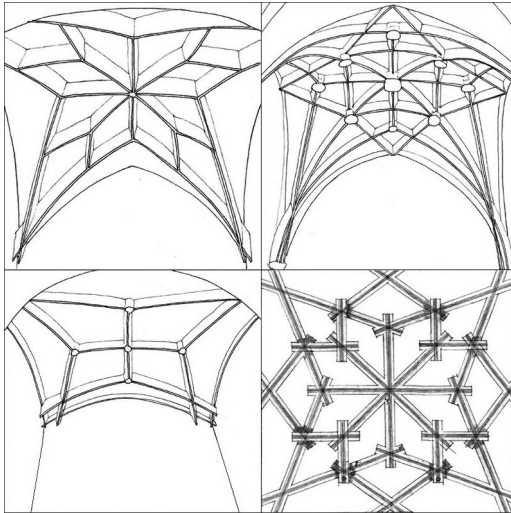


Fig. 2: Similar layouts in Spain and Germany: Gndstein, Hospital de San Sebastián, Sacristy of Antigua Chapel, *Codex Miniatus 3* (fol.3v).

Simón might have been involved. One is located in the southern access to the transept in the church of Santa María del Campo,³ and the other is situated in the church of Santa María la Real in Sasamón. Neither of them has diagonal ribs.

Spanish and German design of Late Gothic ribbed vaults

A Gothic ribbed vault is composed of a mesh of ribs, which intersect in the keystones, and the webs, which fill the space between ribs. Aside from their widely discussed structural value, one of the main constructive functions of the mesh of ribs is the geometric definition of the form of the vault. The increasing complexity of Late Gothic vault designs required absolute control of the position of the keystones and the curvature of ribs. The geometric procedures that explain “how to derive the elevation from the plan” varies from one country to another and could be the *secret* of the masons, protected by the proceedings of the Meeting of the Lodges in Regensburg [1459] (Bucher 1972, 527).

Contemporary Spanish documents regarding Late Gothic ribbed vaults are scarce.⁴ These docu-

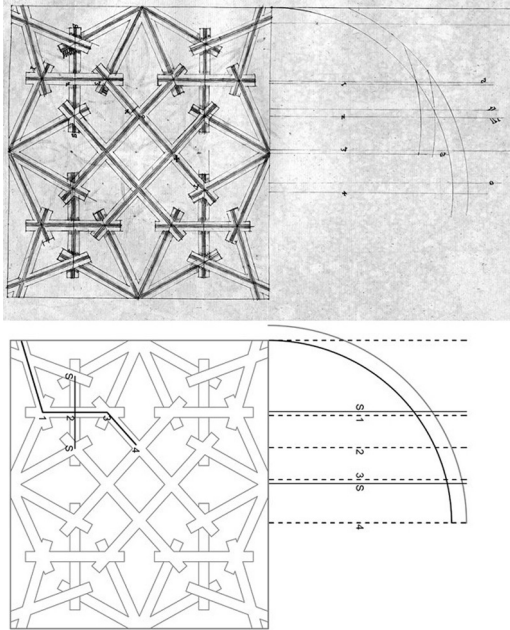
ments usually represent a *tierceron* ribbed vault with five keystones related to the elevation of the ribs, with little or no explanation given.⁵ This predominance of a simple *tierceron* vault doesn't correspond with the reality of Spanish Late Gothic construction.

The definition of the form of a Spanish ribbed vault is based on the diagonal ribs, which are seldom omitted. From this starting point, there are different solutions which can be classified by means of the ridge; the most common solutions are those with a horizontal ridge [*rampante llano*] and with a curved ridge [*rampante Redondo*] (Chueca 1951; Palacios 2009). Whatever the solution chosen, the form of the vault is independent of the plan of the ribs. On the other hand, the number of contemporary documents on Late Gothic vault construction in central Europe is much larger; Their plan designs are more complex and reflect Their constructive variety.⁶

The construction of the form of German ribbed vaults is based on three different procedures (Müller 1990). The first and second ones rely on a previously determined regular surface on which the vault plan is projected, giving the position of the keystones and defining the form of the vault, which is independent of the plan.

In the third method [*Prinzipalbogen*], the control of the height of each point of the plan is done by means of a semicircular arch, which is not necessarily a rib of the vault. There is a relation between the rib plan and the form of the vault, but the same vault plan can result in different vault forms, depending on the *Prinzipalbogen* chosen, and on a certain number of decisions that the mason must make (Bucher 1972).

The *Codex Miniatus 3* is the only contemporary document exclusively devoted to describing the construction of Late Gothic ribbed vaults; all the drawings reproduce the vault plan in relationship to the elevation of half a semicircular arch which involves the use of the *Prinzipalbogen* method (Bucher 1972). As far as we have been able to check, these designs don't reflect vaults actually built, except for the aforementioned fol. 3v. Nevertheless, the vaults in the *Codex* illustrate some features found in many Late Gothic ribbed vaults in central Europe: direct intersection of the ribs, interlacing of the ribs above the springing,

Fig. 3: Codex Miniatus 3, fol.2. *Prinzipalbogen* definition.

the usual lack of diagonal ribs, use of curved ribs and a swastika-like design of the plan.

We have already mentioned the similarities between the vault in Antigua Chapel and the vault shown on fol. 2 of the *Codex* (Fig. 3). In contrast to the vault in Seville, this vault has no diagonal ribs and its form is controlled by a *Prinzipalbogen*, as explained in the figures (Fig. 4).

The Antigua Chapel in Seville Cathedral: Analysis of the vault

The main objective of the analysis has been to study which design process and geometrical conditions were taken into consideration by Simón de Colonia (Fig. 5). For that purpose, it was necessary to ascertain the dimensions and position of each rib through a topographical measurement (Fig. 6). It has not been possible to check the lack of verticality of the walls. However, in this case the walls do not seem to deviate much from true vertical, and it is reasonable to think that the

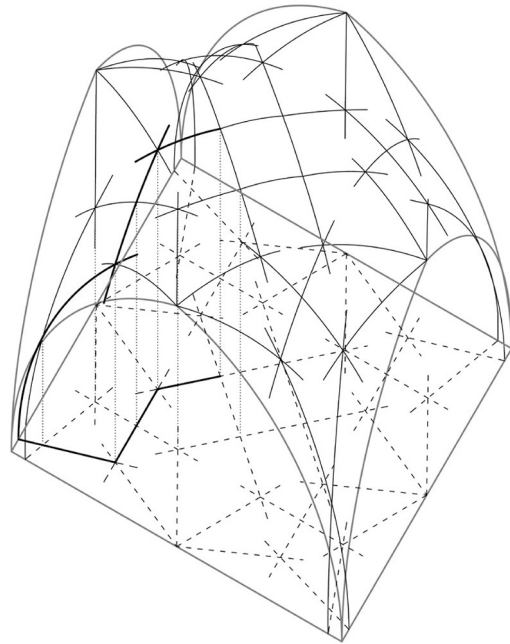


Fig. 4: Construction of the form of the previous vault.

geometry of the vault has not changed to a great extent over the course of the years.

The wall ribs of the vault define a quadrilateral shape that may be fit into a rectangle which measures 13.80×10.42m. The ratio they form is 1.324, very close to 1.333, equivalent to the ratio 4:3, which is a standard *sesquitercia*. Taking into consideration not m. but the unit of length usual at that time [the Castilian foot, equal to 0.279m.], the whole vault rests on a rectangle of measuring 49.5×37.25 ft.

From the main rectangle, the design process of the vault could have been as follows (Fig. 7). The diagonal lines are drawn directly, corresponding to main diagonal ribs, which also define the central keystone. Secondary keystones [M, N, O, P] could have been determined by two ways: either the designer could have defined numerical distances from both sides of the rectangle [14.5+20.5+14.5 ft in the north-south direction; 11+15.25+11 ft in the east-west direction], or a geometrical development could have been used, first tracing a circumscribed circle to the

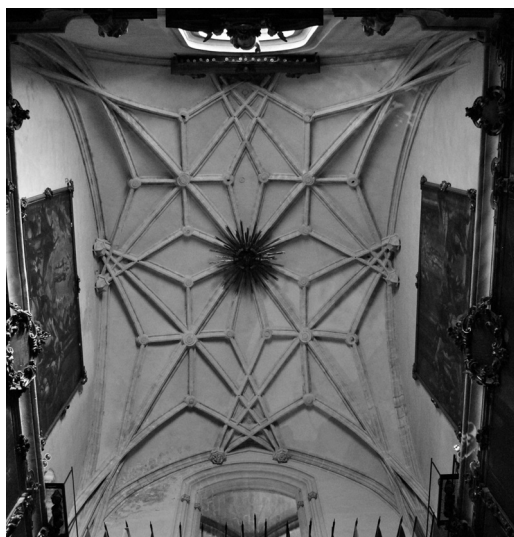


Fig. 5: Vault of the Antigua Chapel.



Fig. 6: Result of the topographical measurement of the vault.

rectangle, and second, dividing its diameter into eight parts. A similar thing happens when laying out the stars at each quadrant of the vault. The keystones M1-M4, N1-N4, O1-O4 and P1-P4 could have been defined by a pair of numerical distances from both sides of the rectangle, but secondary rectangles could also have been drawn. They would have been the basis of stars drawn by linking each corner with the medium point of both opposite sides.

After designing the plan of the vault, some basic decisions had to be made regarding the volumetric

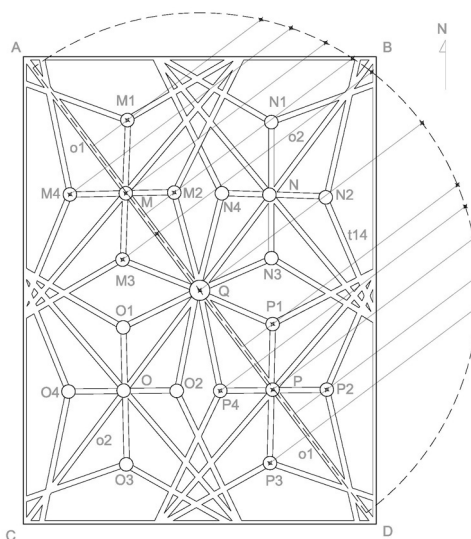


Fig. 7: Plan of the vault.

shape of the vault. The usual Spanish late Gothic method of defining the vault consisted in first setting the height of the vault. All the ribs begin at 52.5 ft from the floor, while the central keystone is located at 86 ft. Second, it was usual to set the diagonal rib as a semicircular arch. To define the overall shape of the vault, the designer used to set the form of both ridges, which gave the height of the secondary keystones. Finally the curvatures of the ribs were fixed to arrive at these points; when possible, some of the ribs were laid out so that their curvatures would be the same.

In the vault of the Antigua Chapel, there are no ridge ribs. Moreover, the ridges measured do not follow a circular line; they seem to have irregular shapes. It can also be pointed out that there is no clear intention to give all the ribs the same curvature; nevertheless, there are some similarities between groups of ribs. In light of these facts, a basic question still remains: which were the variables used to define the volumetric shape of the vault?

As previously mentioned, some German manuscripts (*Codex Miniatus 3*, *Wiener Sammlungen*) use an arch which gives the position of all the keystones and crossing of the ribs [*Prinzipalbogen*]. This method has been applied to the analysis

of the vault (see Fig. 7 again). Considering the diagonal ribs [o1, o2] as *Prinzipalbogen*, the heights of some main keystones [M, N, O, P, Q] are determined directly by their belonging to them. To know the theoretical height of the secondary keystones [M1-M4, N1-N4, O1-O4, P1-P4], their horizontal positions have been projected with a perpendicular direction to the rib's line until it reaches the arch; this point defines the height of the keystone. Comparing these values with the actual measured heights, it must be pointed out that there is a clear correspondence between them. There is only a big difference in keystones M1, N1, O3 and P3; however, the difference is always the same. This fact is the main argument for the hypothesis that the designer used this method, although he decided to modify it to locate four keystones. With this change he elevated their positions in order to obtain a more regular surface, and it made possible to use the same curvatures at the springing.

The springing is one of the most critical points of the vault. When the ribs do not intersect at the beginning but higher, three variables must be managed: the curvature of the ribs, the intersection point, and position of the keystone where the ribs arrive. In this case, the curvature of the ribs could be previously defined; the keystones are also previously fixed. That might be the cause of the irregularity of the ribs' junction: they do not intersect at a single point (Fig. 8). Once again, the skilful architect employed several geometrical resources [such as the vertical supplements], to reduce the irregularity of the springing, which is hardly noticeable when the vault is seen from the floor.

The vault shown in the *Codex Miniatus 3* has a basic design quite similar to the vault in Seville. However, there are two main differences: in Seville, the vault has diagonal ribs [which could be a Spanish feature], but all the ribs also intersect at their beginning, while the ribs shown in the *Codex* only intersect in the corners of the vault.

The analysis of the vault at Antigua Chapel sheds light on some important facts regarding its design process. The plan is fit to a 4:3 rectangle, which was a standard numerical ratio. Apart from this, it is not clear if the author used a numerical method or a geometrical process to determine the



Fig. 8: Springing of the vault.

position of the ribs. Since both ways were possible, it is reasonable to think that he first developed the overall design following a geometrical process; second each point could have been determined by a whole numerical distance from the border of the rectangle, in order to make the full-scale layout of the plan easier.

According to the volumetric form of the vault, it can be pointed out that in both cases [Seville and *Codex*] there is a definition of the heights of the keystones through the use of a *Prinzipalbogen*. In the first case, this arch is the diagonal rib – as it is shown by some German authors (Müller 1990; Nussbaum and Lepsky 1999) – while in the manuscript this arch does not physically exist, so that the keystones are determined using a previously defined path through the mesh of ribs. However, in both cases the volumetric form of the vault is strongly linked to the design of the plan.

Although there are some differences between them, it is reasonable to think that Simón de Colonia knew of a method that was rarely used in Spanish territory [but quite common in Germany], with which he defined the height of each keystone individually. In fact, this method had a very important constructive advantage: it was

quite easy to fix all the keystones in Their places [on a wooden structure] and then to built short ribs between them. Many times no wooden centring was needed, and the transmission of orders on the work site was easier than in those cases in which the volumetric form of the vault was defined by using the curvatures of the ribs. More than a simple copy of a plan design, the analysis shows a relationship to the whole design process, a transmission of technological knowledge from Germany to Spain.

NOTES

1. The design of Juan Guas' asymmetrical vault at the cloister of Segovia Cathedral [1473-1491] can be found in the *Frankfurt Lodge Book of Master WG*, and in the *Wiener Sammlungen*. There are at least seven more different vaults constructed in the 15th and 16th centuries with this design: S. Ildefonso's Chapel in Zamora Cathedral, St-Gausbert chapel in Cahors Cathedra, Bebenhausen Abbey, Glauburg Chapel in Peterskirche in Frankfurt, the Church of Sta. Eugenia in Villegas [Burgos], St. Bartholomäus Cathedral in Plzeň and the Church of St-Nicolas-Tolentino in Bourg-en-Bresse. We would like to thank Professor Miguel Sobrino for the discovery of San Ildefonso chapel.
2. This type of vault, the result of dividing a vault into four parts and repeating the same design in each part, can also be found in contemporary German documentation and in several vaults constructed throughout Europe.
3. We want to thank Alberto Calderón González for the discovery of this vault.
4. The manuscripts preserved in Spain which contain information on ribbed vault construction are: Anonymous manuscript attributed to Pedro de Albiz [ca. 1510]; *Cuaderno de arquitectura de Hernán Ruiz el Joven* [1545-1566]; *Colección de trazas de monte de Alonso de Guardia*

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[1566]; *Compendio de arquitectura de Rodrigo Gil de Hontañón* [ca. 1540], in Simon García, *Compendio de arquitectura y simetría de los templos* [1681].

5. The stone-cutting manuscript of Alonso de Vandelvira also contains the design of three ribbed vaults, but they are actually Renaissance sail vaults with ribs. The construction of the form of Spanish ribbed vaults has been analyzed by Rabasa (1996; 2000) and Palacios (2003; 2009).

6. The manuscripts and printed treatises on ribbed vault construction preserved in central Europe are: The *Lodge Book of Wolfgang Rixner* [15th and 16th centuries] (The *Wiener Werkmeisterbuch*); The *Wiener Sammlungen* [15th and 16th centuries]; *Von des Chores Maß und Gerechtigkeit* [c.1500]; *Unterweisungen von Lorenz Lechler* [1516] and the *Treatise of Jacob Fatch* [1593]; The *Codex Miniatus 3* [c.1560-1570]; The *Frankfurt Lodge Book of Master WG* [c.1560-1572].

The construction of the form of central Europe late Gothic ribbed vaults has been analyzed by Bucher (1972), Müller (1990) and Nussbaum and Lepsky (1999). These investigations are usually based on the analysis on the construction described in contemporary documentation; for a study of the application of this theoretical methods to real vaults see Martín (2011).

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