

## GEOMETRICAL MODELS OF STELLAR VAULTS

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**Abstract.** This work contains the overview of geometrical models of the gothic vaults, with special consideration of stellar vaults. Consecutive development forms are presented, beginning with the easiest three-arms through four-arms, and then six-arms, eight-arm stars and finally complex stellar-network vaults. Examples are illustrated by the asymmetric vaults and vaults with and without diagonal ribs. Vaults which appeared at the end of Gothic, and were the heralds of Renaissance, are also presented (crystal and curvilinear vaults).

**Key words:** stellar-ribbed vaults, crystal vaults, stellar-network vaults

### 1. Introduction

In Poland there are large numbers of historical structures, which include Gothic vaults with a very diverse geometric construction. Inaccessibility to these objects, difficulty to take measurements and the lack of precise plans are the main reasons why different hypotheses concerning their real geometric shapes were put forward in the past. On very few objects precise photogram metric survey has been conducted. Because of high costs of measurements there is still lack of such research studies for majority of Polish historical buildings. A process of vault building was usually documented by drawing respective views or cross-sections, by taking photos or providing iconographic materials. However, the views by themselves don't give complete information how the vaults were constructed as the same view of the vault pattern can have various spatial solutions. There can be a vault with ribs (stellar-ribbed) or without ribs (crystal). The single vault can be found in small-size chambers or interiors (e.g. chapels) as well as in monumental ones; adjusted to severe bay with different size and shape (square, rectangle); they can be found separately (e.g. in chapels) and in connection with the same or other vaults. Figure of star was changing constantly. At the beginning there were four-arm stars, and then six-arm, eight-arm and many-arm stars which further turned into stellar-network vaults. The role of the star in a vault was changing. Initially it was playing a central role (it was filling all the bay/span) and later it started to play the role of the accent in a network of more and more scattered divisions (almost invisible).

### 2. Stellar vaults

Stellar vaults appeared around the middle of XIV century. They were created by division of area of cross-ribbed vault to smaller parts with a series of shorter ribs located symmetrically to diagonal ribs and creating a figure of the star with triangular spatial areas of squinches. First examples of these vaults had figures of four-arm stars or six-arm stars, and in further phases, due to the concentration of ribs, there were created diverse constructions of multi-arm stars.

In literature the term of 'stellar vault' is used in various non-similar meanings for different variants of vaults, different in context of spatial modeling of 'calotte' (intrados).

1/ First variant of its meaning is used for a form of intrados with a rib construction which creates figure of a star. Usually it is applied as a dome-shape or a sail-shape with a lunette (Fig.1a)

- 2/ In the second variant this definition can mean a barrel modeling of roof with rib construction in shape of a star described on surface of a cylinder or a barrel (Fig.1b).
- 3/ In the third variant the term means also intrados formed as a cross-ribbed vault (with lunettes which reach the key course) with a stellar pattern of ribs (Fig.1c).

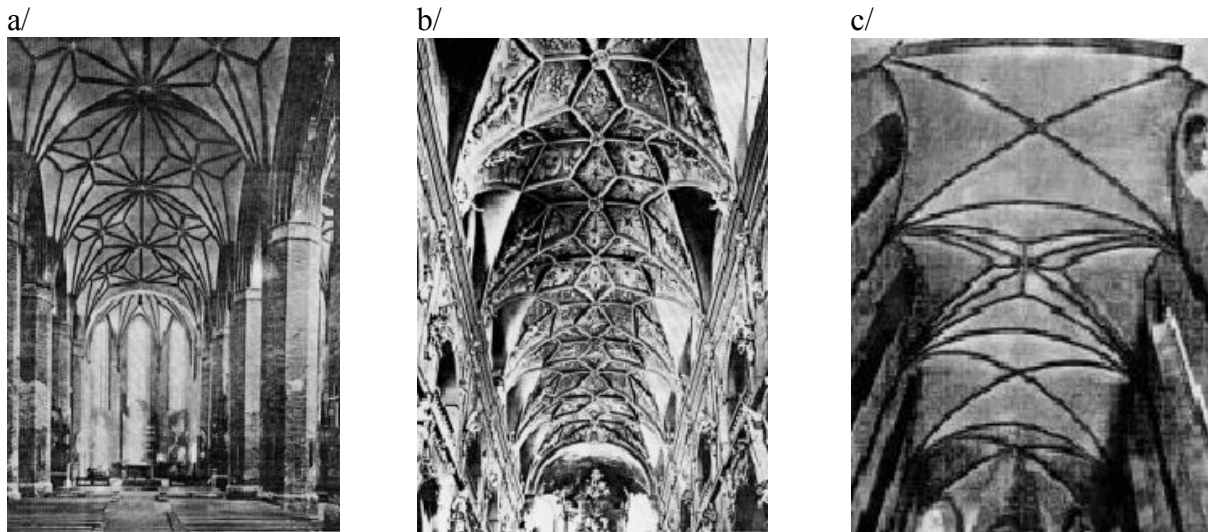


Fig.1. Stellar vault a/ parish church in Braniewo b/ parish church in Kłodzko  
c/ church in Chełmno

There are several forms of stellar vaults: with diagonal ribs (Fig.2), without diagonal ribs (Fig.3), warped forms, with stellar construction added to diagonal (Fig.4). This division is important regarding vault static. There is a belief that diagonal ribs were strengthening construction and securing strength. From comparison of application of vaults with and without such ribs comes conclusion that these without ribs were created only in lower aisle with smaller span, very rare in basilica system and from the static point of view their application in the hall systems was more favorable.

Especially interesting are warped forms of vaults because of asymmetric configuration of ribs, which create the illusion of being a taut in a wind sail. This idea was innovative because it implemented the element of dynamism, concern, figure asymmetry, effect of anxious rhythm and intrados waving.

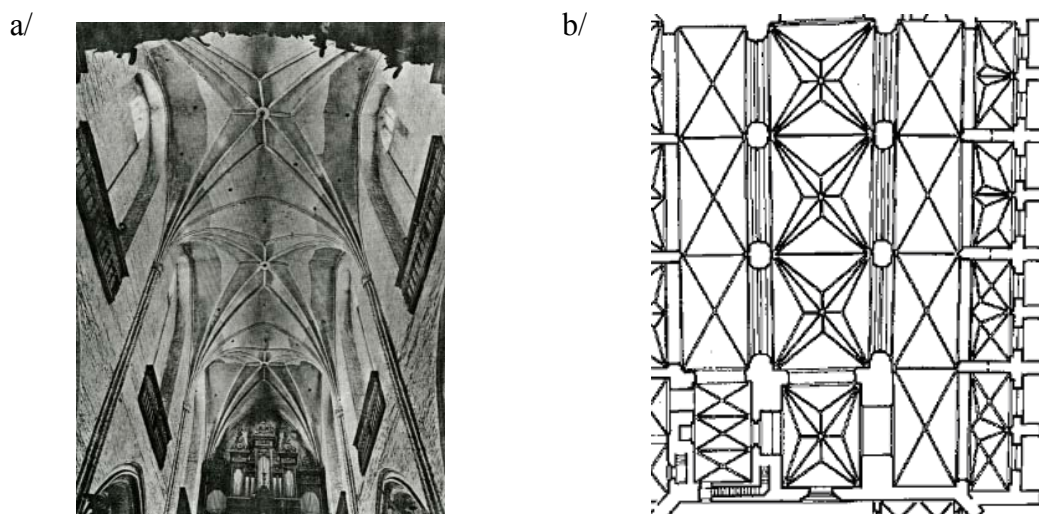


Fig.2. Stellar vault with diagonal ribs –church in Toruń  
a/ view of interior b/ plan of vault

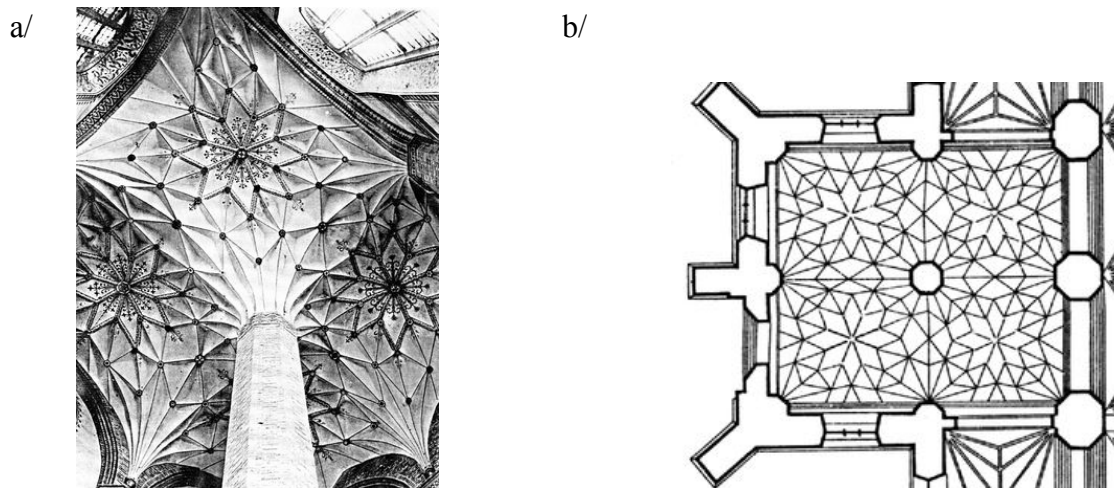


Fig.3. Stellar vault without diagonal ribs - Cysters church in Pelplin  
a/ view of interior b/ plan of vault

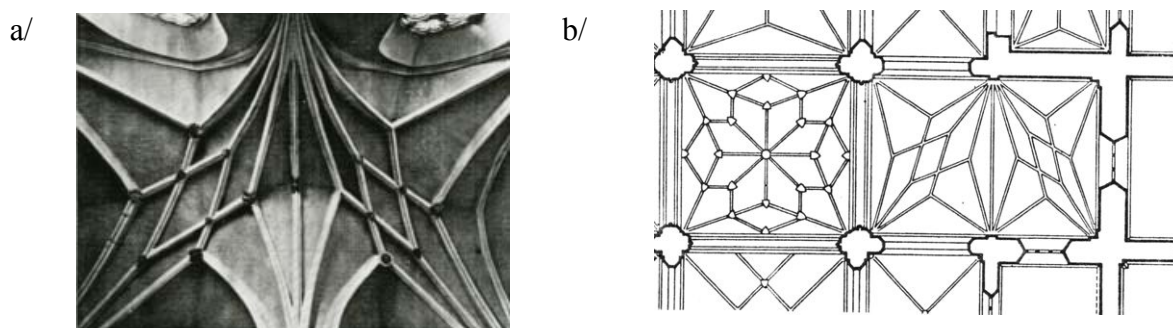


Fig.4 Stellar asymmetric vault in church in Strzegom  
a/ view of interior b/ plan of vault

The paintings on stellar vaults together with advantages taken from chiaroscuro produce special esthetical impressions. In small interiors they do not give as good composition impressions as in large interiors. They were often treated experimentally to explore new and innovative forms. The most favorable effect they give is a structure of repetitive severy bays, situated high and observed in perspective as a sequences (rhythm) in a full view of a vault. Depending on the structure of a vault (longitudinal or transverse – means how star arms are situated in a bay to navy axis) it gives different artistic accents. Spatial construction is usually underlined with architectural shape (keystones, brackets, ribs) and accented with polychrome (ribs were painted in a contrastive way as well as the squinches were also painted).

The top view of a vault creates a figure of a star and consists of segments with different lengths depending on the way it was planned in a particular view. Less often we find curvilinear shapes, i.e. circular and elliptical parts of a star. The shape of the star keeps symmetry which has at least 2 perpendicular symmetry axes crossing each other in the middle of star.

The shapes of the star which can be found in radial vaults can be as listed below:

- four-arm – the most common in aisles (Fig.5a),
- six-arm – existing in naves and aisles (Fig.5b),
- eight-arm (Fig.5c),
- linked (Fig.5d),
- radial with a net of small ribs (radial-net),
- crystal – construction - analogical to the vault with ribs used in aisles.

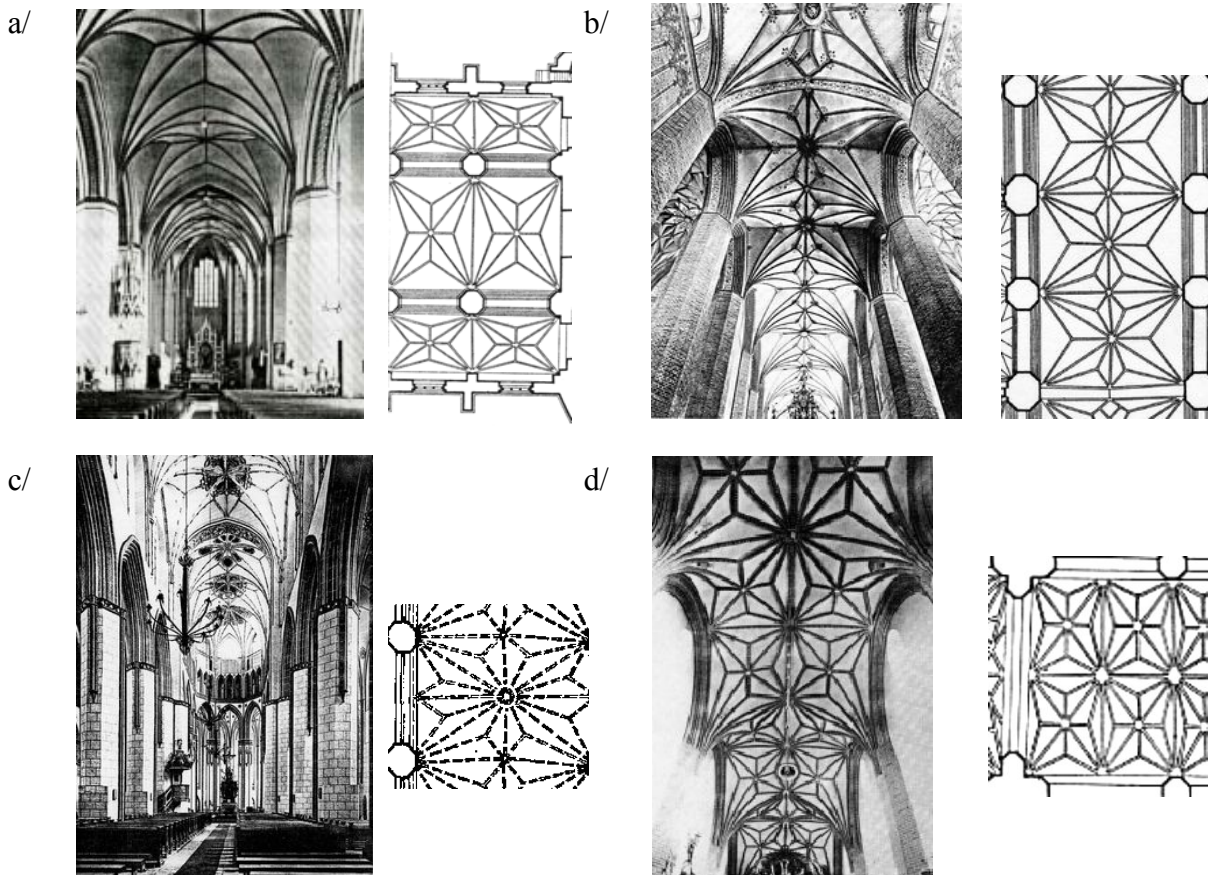


Fig. 5. Stellar vault with figure of star a/ fourth-arm – church in Trzebiatow b/ sixth-arm – church in Pelplin c/ eight-arm – NMP church in Stargard Szczecinski d/ linked with other – church in Orneta

### 3. Stellar-network vaults

Network vault is a kind of a ribbed vault with an extensive system of ribs where the pattern is similar to the net which surrounds equally the whole barrel. It creates a joint cover for several severy bays, most often in form of barrels with a lunette. Ribs are conducted in a constant, transverse manner.

Spatial variants of the network vaults with regard to the structure of the vault are divided into the following groups: a constant barrel, a constant barrel with a lunette, a sequence of the dome-shaped vaults with joint ribs and two severy bays (Fig.6). The structure of the last group is similar to the barrel as it consists of a sum of the ‘concave’ surfaces creating a constant barrel but having in the top part the raise of the arch.

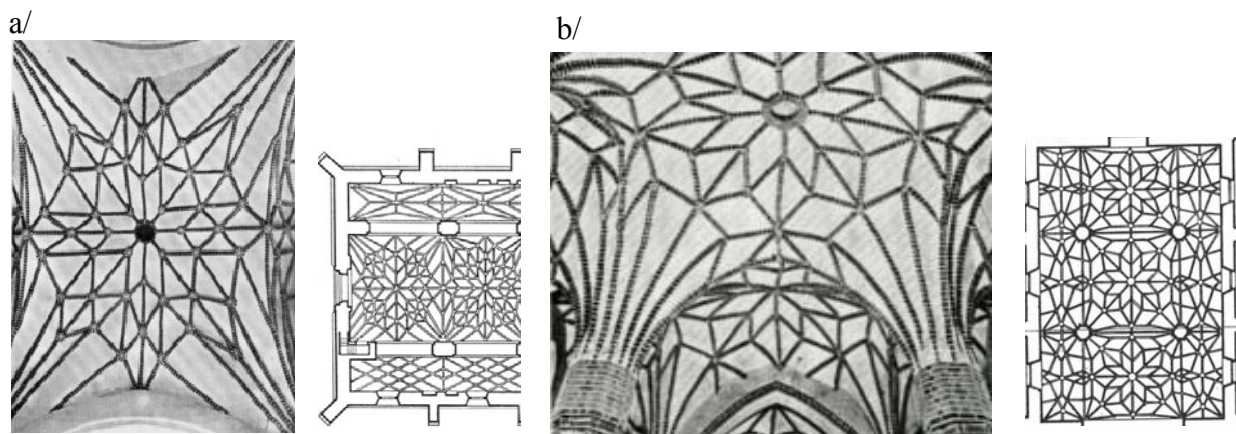


Fig.6. Stellar-network vaults a/ parish church – Wizna b/ parish church – Kleczew

#### 4. Curvilinear vaults

Curvilinear vaults are considered to be of a transitional form between Gothic and Renaissance structures. This is a version of decorative vault inspired by new Renaissance trend.

The main characteristics are the following: soft plasticity, smooth profile of the ribs which were curved in three dimensions; circular form of ribs; callipered forms surrounding the ceiling; intertwining, meandering, going down, nearly reaching the floor.

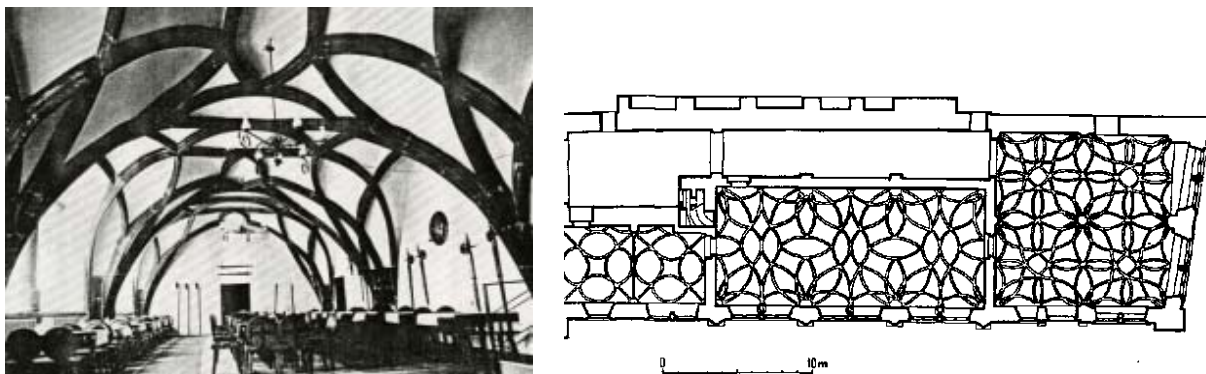


Fig.7. Curvilinear vault in town hall in Lwówek

#### 5. Crystal vaults

Crystal vault comes into existence as a derivative of a rib vault. Ribs are replaced with sharp intrados curves. The views of crystal vaults are similar to those which were used before stellar vaults. They are only enriched with a net of small spatial divisions of all fields between intrados curves. The name reminds of crystal surfaces, which are cut sharply with concave walls similar to inverted pyramids.

The basic principles for building crystal vaults do not differ very much from the ribbed vaults construction. Analogical method is used to construct figure ribs and intrados curves. Different is just the construction of a squinch. We can usually find prismatic pyramidal shape instead of oval or concave surface between the ribs. Classification of crystal vaults can be conducted according to significant differences in intrados modeling - cylindrical or spherical. These vaults cover smaller width spans than the ribbed vaults do: maximum up to 7.5 meters. Smaller widths relate to the lack of ribs as there appears decrease of the structural strength and rigidity.

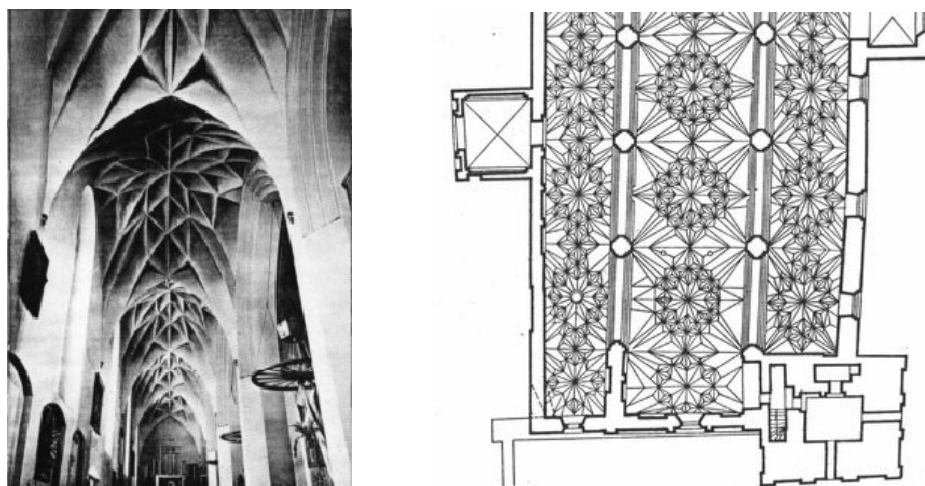


Fig.8. Crystal vault in Kętrzyn church

## 6. Conclusions

Gothic vaults are dominant in mediaeval interiors; they constitute an important component of construction and composition. Early forms usually had constructional character while the late-Gothic forms usually took diversified and more decorative (ornamental) forms. We can find large diversity of design and variety of forms even in a single structure, which is often related to different phases of the construction process. Development of forms was striving in direction of being more decorative, wider (range, scope) and higher. Geometric construction is expressively shown in ribbed vaults, which are additionally accented with the color and the texture. Ribs in late-Gothic vaults get thickened and create nets or completely 'get lost' in the complex crystal vaults. In Poland stellar vaults have become the most popular while the most significant technical skills and artistry can be found in curvilinear vaults.

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## MODELE GEOMETRYCZNE SKLEPIEŃ GWIAŹDZISTYCH

W Polsce występuje duża liczba zabytkowych obiektów zawierających sklepienia gotyckie (gwiazdziste) o bardzo zróżnicowanej budowie geometrycznej. Ich niedostępność, trudności w dokonaniu pomiarów, brak precyzyjnych planów są powodem wysuwania różnych hipotez co do ich rzeczywistego kształtu geometrycznego. W nielicznych obiektach sporządzono dokładną, fotogrametryczną inwentaryzację sklepień. Ze względu na wysoki koszt pomiarów brak takich badań dla większości polskich zabytków. Zazwyczaj budowę sklepień dokumentują rzuty, ewentualnie przekroje, zdjęcia lub materiały ikonograficzne. Jednak sam rzut nie daje pełnej informacji o budowie sklepienia. Bowiem ten sam rzut wzoru sklepienia może mieć inne rozwiązanie przestrzenne. Może on oznaczać sklepienie z żebrami (gwiazdzisto-żebrowe) jak i bez żeber (kryształowe). Tam sam rodzaj sklepienia może występować zarówno w małych, kameralnych wnętrzach jak i monumentalnych; dopasowany do przęsła o różnych wymiarach i kształtach (kwadrat, prostokąt); występując osobno (np. w kaplicach) oraz w połączeniu z takimi samymi lub innymi odmianami sklepień. Rysunek gwiazdy zmieniał się i przekształcał. Początkowo były to gwiazdy czteroramienne, następnie sześć-, ośmioramienne aż po wielopromienne przechodząc w sklepienia gwiazdzisto-sięciowe. Zmieniała się rola samej gwiazdy w sklepieniu. Początkowo pełniła rolę centralną (wypełniała całe przęsło), stopniowo malejąc, aż do roli akcentu w sieci coraz bardziej rozdrobnionych podziałów (zagubiona, prawie niewidoczna).