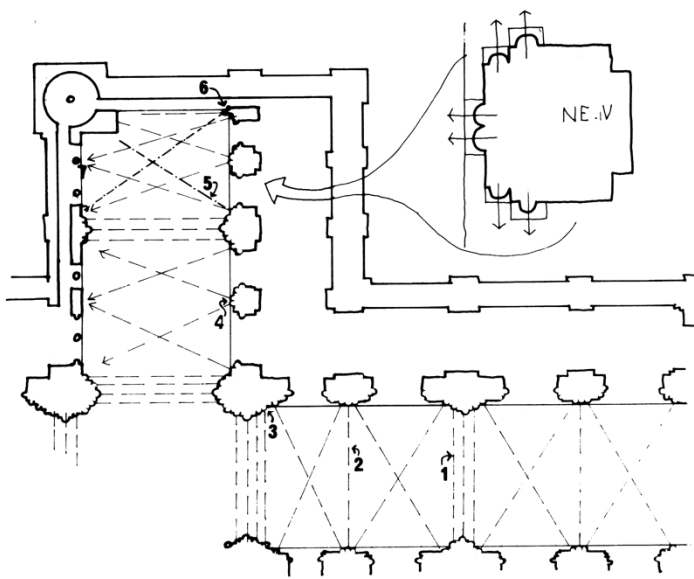


## The Rib Vaults of Durham Cathedral

Adapted from *Gesta*, xxii 1983, 135-145.

In 1899, Bilson, in discussing the original vaults over the choir of Durham Cathedral, remarked that "there can be no question of a sexpartite vault here, for the date is much too early for this kind of vaulting."<sup>1</sup> I wonder if this statement may have been an afterthought, since his drawing suggests the opposite, above. Over the capitals on the left he noted in dashed lines the edge of the twelfth-century stonework which had once



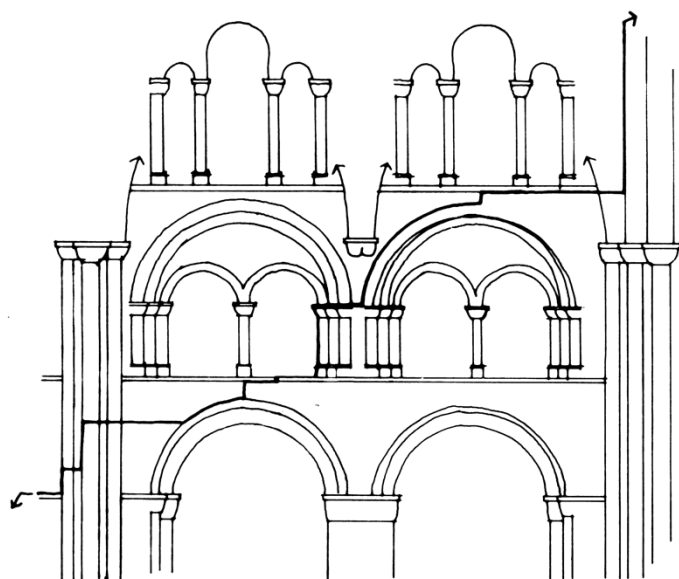
supported the underside of the cells of the original vaults. When these vaults were replaced in the thirteenth century,<sup>2</sup> the cells of the new vaults were set a little higher and the gap in the walling was filled with new ashlar that does not match the older masonry.

At gallery level there are more supports for the main transverse arches than for the intermediate ones; there being five shafts over the compound pier to support the transverse arch, and three over the drum to support much lighter arches [above left].

The edge of the masonry that once supported the old cells, even when minutely examined on site, usually disappears behind the Purbeck shafts of the new vaults. However, the outline can be made out in some places, as in one particularly clear corner [above right]. The remaining traces show that the outline of the cell of the twelfth-century vault was irregular, where the curve on each side of a four-part vault would be equal on each side. These follow a shallow curve against the heavy arches of the doubleau, and are set vertically, or stilted, over the intermediate pier. If the original had been a four-part vault symmetrically placed across the bay, then the outside of the cells would have followed the same curve against the wall on both sides. The lopsided geometry shown in Bilson's drawing, which is confirmed on site, is produced by only one type of vault - a six-part one.<sup>3</sup> Also, there is no way it might be argued that the arrangement of shafts under the choir vaults was more suitable to a four-part than a six-part vault. I cannot help thinking that Bilson was aware of this, for his drawing so clearly shows it. Had he been talked out of it?

The history of this part of the building seems to explain what actually happened.

There is a major break in the construction after the second bay of the nave. This is most clearly observed in the aisle vaults, where the ribs and arches of the choir and the first two bays of the nave follow the same templates, while to the west the ribs are all adorned with chevrons [below]. The joint can be followed in the thick line up the face of the wall over the arcade arches until it meets the floor of the tribune. Here the joint moves eastwards to include the first pier. The dimensions of the piers to the west are different than this one. Also, they are built of an orange stone instead of greyish-green. In the clerestory level, the joint lies one further bay to the east alongside the arch of the crossing.

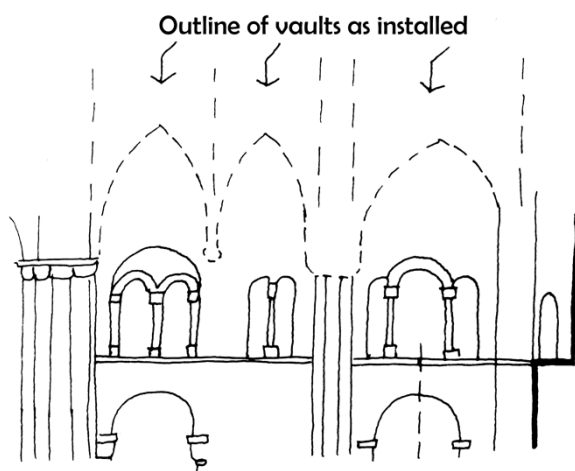


In addition to the matching details in the aisle vaults, there is further evidence at tribune level that the first bay of the nave was erected with the choir: the lowest courses of the eastern tribune piers are built of a dull brown, medium-grained sandstone, of even colour and texture, without masons' marks on any of the stones. Above lies a variegated greyish-green stone, fine-grained to the point of waxiness, and with masons' marks on almost every fourth stone. On the eastern side of the transept the joint between these two materials steps down until in the end bays it meets the floor.

The large windows in the terminal walls of the transepts were inserted in the mid-fourteenth century, but originally there were passages on both the tribune and clerestory levels. Since the staircases on the western sides of the transepts would have given access during construction, it would have been logical to build them at the same time as the choir. The upper level of grey stone continues on the western side from the floor level, exhibiting the same masons' marks as found in the east. The first piers in the nave tribune are also built of this grey stone.

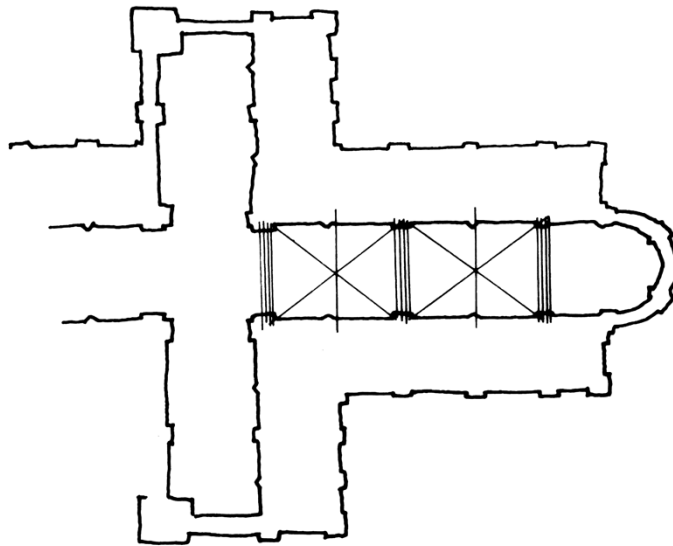
There are six or seven grey courses on both sides; above that the stone type changes again. The capitals under the choir vaults were carved in this third layer, and with them the ribs begun for a six-part arrangement. These three changes suggest that three masters were involved in the construction between the laying-out of the tribune shafts and the start of the vaults. The changes in the details and the dimensions of the piers, arches, and other elements confirm that different templates were produced for the workmen employed on each layer, showing that site control and quarry source changed together.

All three masters seem to have followed different designs for the vaults. The first, building in brown stone, set the faces of the choir tribune walls in from those of the arcade arches underneath, and on that ledge supported additional shafts, one on either side of the compound piers and three over the drums. I presume that those alongside the compound piers were to support diagonal ribs, and that the three intermediate shafts were for two ribs and one transverse arch, perhaps with the same section as the ribs. Around the corners in the transepts, this central shaft was left out, perhaps to support a vault more like those in the nave. Here the central transverse arch would have been omitted, not because of the span-for between the wall faces the spans of the choir and transept are virtually the same-but because of the bay. The transept bays are some 1400 mm narrower than those of the choir, and the master may have thought that the more acutely inclined ribs would have left too little space between them for another arch to be inserted.



But on the opposite (western) side, in the wall laid out by the second master, the plan for the transept is quite different. This master omitted the rib shafts altogether. The only shafts are those continued up from the floor. There is a narrow passage between the inner and outer skins of wall, with three openings through the inner skin. The first reflects the void of the tribune extending back from it into the nave; the second is a pair of openings placed with little apparent relationship to anything else; while the third matches the windows and is flanked by two smaller openings like the previous pair, [above]. They relate to the nave tribune and the external wall at this level and, unlike the eastern openings, do not relate to the vault. The design reflects horizontal rather than vertical thinking, and is as typical of buildings with wooden roofs as the east is of ribbed vaults.

Therefore, the master who laid out the eastern tribune wanted a four-part rib vault, which was abandoned in the transepts by his successor. This second master was in time succeeded by a third who also altered the design by reinstating the ribbed scheme and changing it to six-part.



Although it is usually thought that the six-part vault was specifically evolved to reflect the alternating piers on a square bay plan, the arrangement implied in the choir tribune shafts—the use of thick transverse arches over the compound piers, and light arches (or none over the drums, as can be seen in the nave) is just as sympathetic [above]. The narrower transverse arches would have merged into the vault like the diagonal ribs, giving little if any emphasis to the intermediate bay, while the thicker transverse arch would have dominated, articulating the space into the same two-bay modules found in the arcade piers. Though the masters may not have known it, six-part vaults discharge relatively small lateral loads.<sup>4</sup>

The third master changed this paired four-part arrangement into a six-part one, possibly because he feared that the additional ribs may otherwise have been too dominant by covering a much greater percentage of the vault surface. The same reasoning that led to the omission of the shaft for the central transverse arch in the transepts may have led to the use of six-part vaults in the choir. The original scheme seems to have been considered more successful, for it was reintroduced in all the later vaults. In addition, there were structural problems.

There are a number of ways to determine the height of a vault.<sup>5</sup> In barrel and most groin vaults a half-circle is drawn across the nave, with the centre placed on the same level as the capitals. The height of the vault would then be half the width of the nave. As more rib vaults were built, and the masters became accustomed to setting them out, the circle came to be placed diagonally across the space so that the ribs followed a semicircle. Such rib vaults were higher than the first as the length of the rib was greater than the transverse arch, and the transverse arch had to be distorted or pointed to increase its height to match the ribs.

The height of the clerestory wall shows that the crown of the vault was determined by the semicircle through the transverse arch, and not by the larger circle drawn along the diagonal of the rib. The ribs, being sixty percent longer than the transverse arches, would have had to follow a flattened arc. The marks on the wall indicating the stilt show that the ribs were sprung vertically, so that they would have been almost level at the crown. Flat arches, however shaped, are not as stable as circular or pointed ones, and in this case may have formed a line of weakness in the vault, not of strength. Was this why the vault was in danger of collapse only a hundred years later? This danger did not result from movement in the walls for though the buttressing is minimal, there has been no movement in them, for I have plumbed the walls with some care and, allowing for the shaving of the exterior, there is no evidence for movement. The extent of the shaving can be seen in the corners against the transepts, and the window depths show that a constant amount was cut back along the whole length of the wall. It is therefore probable that distress in the vault came from distortions within its own geometry.

These early rib vaults were built up layer by layer in solid masonry, and not in the later technique where the ribs were erected first and the cells laid later, supported on the ribs. This was more economical, as major centring was required only for the ribs. The mortar bonds between the ribs, cells, and walls ensured that the thrusts were transferred homogeneously as in a shell.<sup>6</sup>

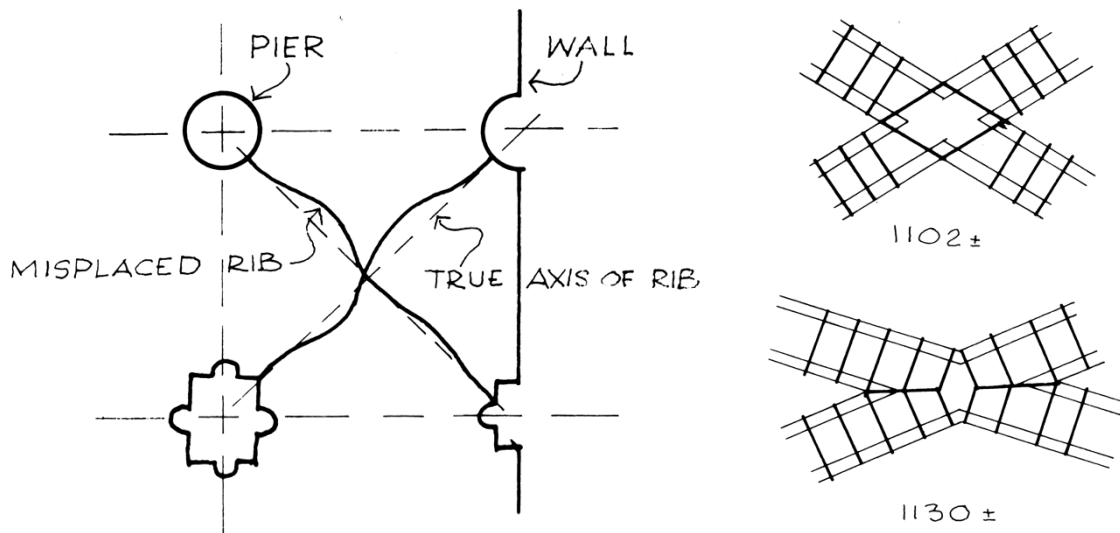
Groin vaults, on the other hand, are pure mass, packed solid to the level of the crown. The mass was not a filling laid over the cells, but was constructed with and as part of the vault. It was incredibly heavy and solid, and its undersurface formed the face of the vault's cell. Since the mortar was soft, the entire mass had to be supported until it had begun to set. Formwork would, one suspects, have been needed under the entire surface.



The rubble and mortar would then have been placed over this layer by layer, until the summit was reached, each layer extending across the bay, and the amount of stonework required increasing with height.

Few groin vaults were made of ashlar, but rather of rubble with a plaster finish. It is not technically easy to finish the plaster neatly along the crease. The material is soft, the position for the workmen fatiguing, and the lighting invariably inadequate. I suspect that few groin vaults were finished with the same neatness and precision found in their supporting piers. The rib provided a solution to this problem. It acted as a cover mould, neatly completing a difficult junction between different surfaces. It was a builder's constructional device applied to a traditional and proven vaulting technique.

This can be shown in two items which demonstrate that the ribs of Durham were not seen as being structural arches, but as part of the surrounding vault mass, which was to be erected with it, layer by layer. In



some of the nave aisle vaults the ribs are serpentine in plan rather than straight [above left]. This is not a distortion stemming from curves of different radii, for the bays are square. The cause can be read in the boss, since the junction between it and the abutting ribs was cut to suit the angle at which the misplaced rib actually met the boss—which is not the same as the angle it would have made if the rib had not moved. The boss was therefore cut and placed after the ribs had moved and were presumably incapable of being realigned. This would have happened only if the ribs had been laid up with the rest of the vault, locked into place by the adjoining masonry, and so it was impossible to adjust them afterwards. In other words, the ribs were built as part of the groin, layer by layer, and not as separate structural elements.

Secondly, examine the bosses to the rectangular bays of the high vaults. In the square bays of the aisles this observation does not show up clearly, though it is noticeable in the aisle rib vaults in the north transept of Winchester Cathedral. The junction between the boss and each rib has been cut parallel to the sides of the flanking ribs, and not true to the rib it supports. The upper boss is typical of those in the aisles and the high vaults, while that below appears only in the sixth bay of the nave [above right]. This is not how an arch is built, for if the ribs had been erected first, the voussoirs would have simply slipped to the side. Only the mass filling of the vault holds them in place. Hence, the rib was not conceived as part of the structure.

This may be seen in all the rib vaults of Durham with one exception: the boss in the sixth bay of the nave. Here the joints were cut true to the voussoirs. Was this when it was first realized that the rib may have acted as an arch, and should therefore be built like one? Was this the beginning of the process which led to an understanding that if the rib was an arch, it could be erected separately from the rest of the vault? If so, that realization could be dated to the early 1130s, one generation after the rib was first introduced. It would not have taken long after that for the masters to have realized that the ribs could be built first, and that what lay in between was capable of being supported during construction on these ribs. The lighter this layer was, the better, and so the cell was born, and with it one of the essential structural innovations of the style we call Gothic.

Any assessment of the dates for these vaults must be founded on the three documents which relate to the early history of the cathedral.<sup>7</sup> Since Bilson's investigation over a century ago, the dates of 1104 for the high vaults of the choir and 1130 for those of the nave have been generally accepted. A refinement of those dates may now be considered.

1) The first document is Simeon of Durham's *Histori Dunelmensis Ecclesiae*, written ca. 1104-1107, which states that the decision to build was made by Bishop William of Calais in 1092, that the first trenches were begun on 29 July 1093, and that the first stone was ceremoniously laid on Thursday, 11 August of that year.<sup>8</sup>

2) The second is the continuation of Simeon's history by an anonymous author writing not long afterwards. He relates that after Bishop William's death in 1096, the monks carried on with the works and that:

(a) when Bishop Rannulf Flambard arrived in 1099, the building work "had been made as far as the nave" (*quam usque navem*),<sup>9</sup>

(b) the remains of St. Cuthbert were transferred to their proper resting place in the shrine prepared for them on 29 August 1104, and

(c) Rannulf "erected the nave and its surrounding walls up to the vaults" (*usque testudinem*). Because the continuator used the word *testudinem*, it is assumed that he was referring to the vault rather than to the roof, since the word's root meaning is "tortoise," or "shell." Today, however, we speak of erecting the shell of a building, which includes the roof. Does *testudinem* then refer to the start of the vaults at their springing, to their completion, or to some point in between? The physical evidence shows that the vaults were erected after the adjacent walls, and probably after the roof, and that at least two campaigns were required for their erection. I am, therefore, inclined to think that the textual passage refers to the uppermost courses of the walls of the nave, the roof and the vault itself being built afterwards, for it also tells us that:

(d) the nave was completed by the monks between 1128 and 1133, no doubt including the mass of the vaults and the plaster that covered them, and

(e) work on the building proceeded quickly or slowly, depending on the flow of money.

3) The third document is William of Malmesbury's *De Gestis Pontificum Anglorum*, written some decades later.<sup>10</sup> He recounts the miracle that occurred when St. Cuthbert's remains were about to be transferred: "Everything was ready for the translation of the body into the new choir, the choir of the monks, the altar and the tomb. They were only waiting for the wooden materials which were supporting the recent vault of the presbytery (*presbyterium*) to be gently removed." During the night before the translation, the centring fell without damaging the vaults or other parts of the building. This was quite a fortunate accident, as normally the striking of centring is a tricky operation, and if not done properly would distort the freshly built vaults.

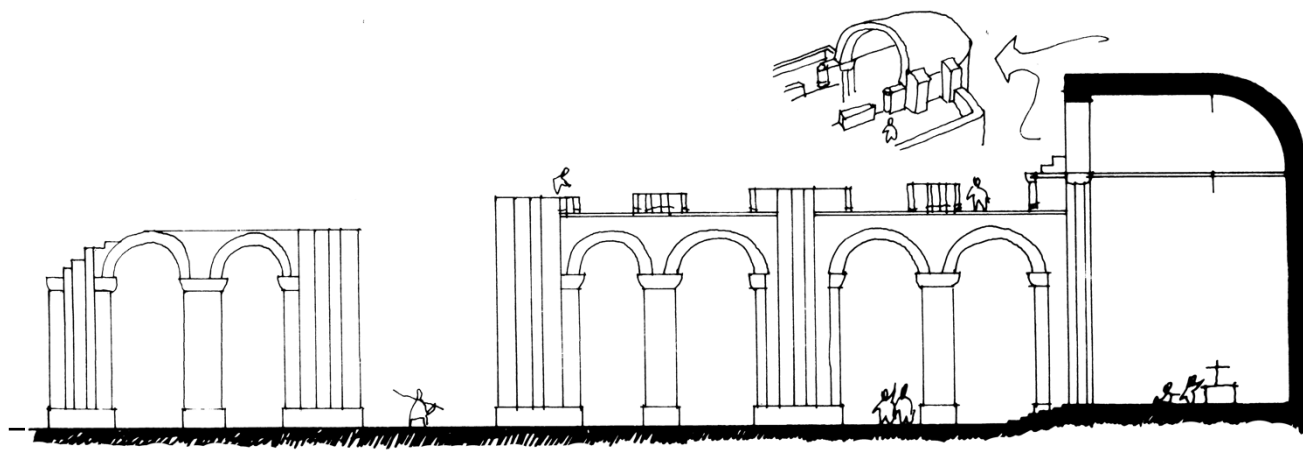
This is all the documents reveal about the construction of the cathedral, or its dates. None of them refers to any particular high vaults, save, by inference, those of the nave, nor do they specifically say that work was begun at the eastern or the western end-although the arrangement of the joints along the aisle walls shows that work did begin in the east.

As far as Simeon's evidence is concerned, the relics could have been translated under a temporary roof before the building was complete. In fact, any part of the building could have been opened to worship under a roof of canvas or hides at any convenient stage, and it is only Malmesbury's specific reference to a vault which shows that some of the stone covering had been completed by 1104. But which stonework?

It has been assumed that Malmesbury was referring to the high vaults, but that is not necessarily so. He says that the vault was over the *presbyterium*, which means the more easterly part of the choir. Though Malmesbury is reputed to have been careful about his facts, he would have heard his story second hand, and may not have been thorough in determining exactly which part of the choir was meant. His description could have fitted any part of the eastern end, even the aisles - though if it had been the aisles, the centring would have blocked the approaches to the tomb, rather than the tomb itself, which is in the apse at the east.

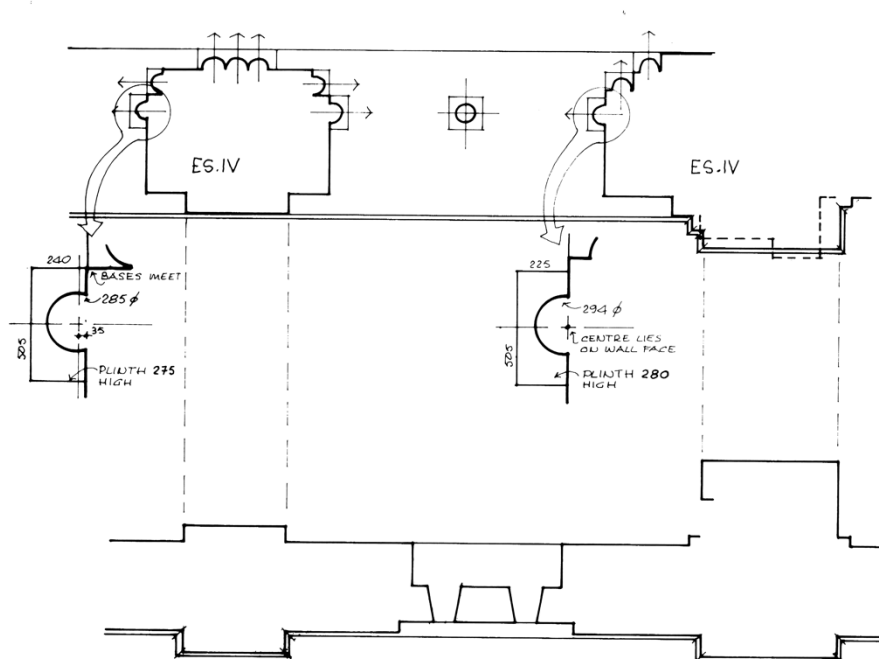
What, then, can we make of his words that 'everything was ready'? Can it mean 'everything' in the building, or 'everything' for the liturgical ritual associated with the translation? For the building, Malmesbury was being imprecise, since 'everything' was manifestly not 'ready'; the centring was still in the way. The shrine of St. Cuthbert, to which he refers, was not located in the main vessel of the choir, but in the apse. Therefore, it seems more reasonable to interpret his words as meaning that the centring was under those vaults which lay directly over the tomb, and that this is the *presbyterium*.

Indeed, when we consider that from 1096 onwards the bishop's income had been diverted to the king's needs, and that the monks had to complete the work from their own resources, we should not expect them to



have built in the quickest manner. To have constructed the whole of the eastern end with the crossing, the first bays of the nave, and the bulk of the transepts in eleven years, under such restricted financial conditions, would have been too extraordinary an achievement. I am therefore persuaded that the vaults referred to by Malmesbury are those over the apse and that they were set at the level of the tribune, and no higher [above].

There are two reasons for placing the apse vault at the tribune level. The bases and dimensions of the lateral shafts that are detailed [below], and the dimensions of the piers show that the ES.IV pier supporting the apse was set out to a different template from the other piers in the tribune. I think that this pier and at least the springing of the apse dome, were both the work of the master who built the vaults over the aisles. Also the shape of the flashing over the tribune roof suggests that it may have been continued over the vault of the apse.



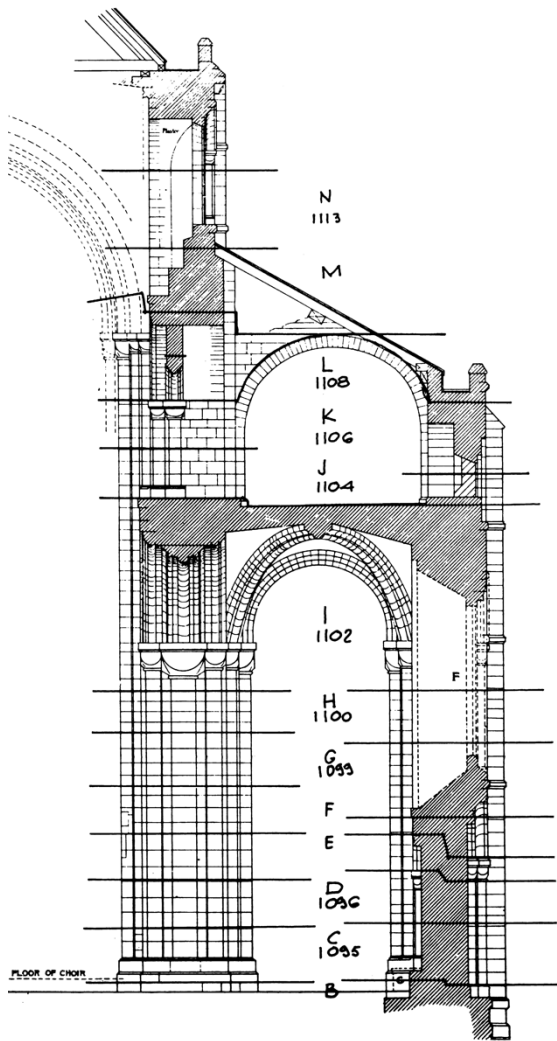
Placing the apse semi-dome at a lower height than the rest of the choir was not uncommon, and many Continental examples are known, such as Cluny III. These show that the semi-dome could have been sprung from as low as the arcade capitals or from as high as partway up the tribune walls. In either case, as my sketch shows, this vault could have been completed before the rest of the tribune.

To summarize: the texts provide just four crucial facts: that the building was begun in 1093, that the nave was under way by 1099 and was completed before 1133, and that some centring was in place somewhere in the east by the middle of 1104.

In order to relate the vaults to these dates, I have analysed the building sequence in the same way as I did at Chartres, but found it much more difficult to come to firm conclusions.<sup>11</sup> Complete as the building is, and relatively unrestored inside, there are few mouldings and almost no carved capitals, and half the evidence was hacked away in the disastrous exterior renovations of the late eighteenth century. Yet what evidence there is seems to point to many campaigns, some small and some large. As Simeon's continuator wrote, the work proceeded *modo intentius modo remissius* which, being freely translated, might be said to read 'by fits and starts.'<sup>12</sup>

Indeed, like Chartres and so many other earlier medieval monuments, work proceeded when there was money, and the men had to be sent away when there was none. Without entering into the vexing problem of architectural control, the evidence at Durham unequivocally shows that the workers were changed often, and with them the stone they used and the templates they followed. I am not yet satisfied that this evidence is precise enough for publication, and its examination would be too detailed for this article, but it was sufficient to divide the eastern half of the cathedral into sixteen campaigns, and the western into at least twenty. Some of the earlier ones overlap, since the sequence of bases, the changes to the geometry of the plan, and the small changes within the wall arcades, along with stone types and masons' marks, suggest that by campaign six the work had reached the foundations under the western doors, and the sills to the windows in the choir.

Further work on the west then seems to have been abandoned - coinciding with the interregnum between Bishops William and Rannulf - and the monks seem to have concentrated on the choir. There are many small campaigns and one very large one in which all the vaults in the eastern aisles and two bays in the nave were



laid up. Around the apse, this included the first piers of the tribune [next page]. Work on the west – to the west of the joint shown at the bottom of page 2, does not seem to have recommenced until the choir was vaulted. The evidence for these statements comes from the following data:

1. The bands of different stone, as discussed earlier, the masons' marks on them, and the different coursing heights.
2. Within the stairs, the stone types, marks, window shapes and positions, door plans, lintels, openings, and tread heights, etc.
3. The bases and arrangement of piers at all levels and the geometry used to set them out, the shape of the torus moulds, and the direction of their placement. along with the heights of the stones in these courses.
4. The templates used for the mouldings, especially in the wall arcades, windows, ribs, and the many varieties of drum patterns and chevrons.
5. Significant changes to repetitive items like wall buttresses, window widths, shaft diameters, impost heights, etc.

From these observations I conclude that it took some thirty campaigns to complete the cathedral. The eastern aisle vaults were erected in the ninth campaign, with the start of the half-dome over the apse. The high vaults over the choir were begun in the twelfth, the western nave aisle vaults in the eighteenth, and the nave high vaults, involving a number of masters, occupied the last three or four campaigns.

The importance of Durham as the only Norman building whose starting and finishing dates are known may make it worthwhile to estimate the dates for each part. While not completely accurate, these approximate dates may help to put these vaults into a clearer perspective.

Of the thirty campaigns which occupied the forty years of construction, the last three or four (being the nave vaults) can be dated to 1128-1133, and the first nine or ten (to the apse vault) to 1093-1104. In between, we can attempt to estimate the dates for each part by relating the total number of campaigns to the available years. If the large campaign in the choir aisle vaults took more than one year, and the rest are given an annual



dating, then these vaults would have been started in about 1102, and the centring under the apse, as documented, would be 1103-1104. Arranging the remaining sixteen or so campaigns over the intervening 24 years would not be too difficult and, allowing for a modicum of error in each attribution, I would suggest the following chronology for each of the Durham rib vaults:

eastern aisles	1101-1103
apse semi-dome	1103-1104
choir six-part	1108 ribs begun, finished 1113±.
north transept	1113-1118
south transept	1115-1120
western aisles	1115-1118
nave springing	1125
nave vaults	1128-1133

In explanation for these dates I would add:

**The six-part in the choir:** It would have taken longer to build each of the high vaults than those in the aisles. They are larger, the amount of surrounding walling and filling is greater, and their materials would have taken longer to lift. The first date refers to the springing, and the last estimates the date for the roof.

**The north transept:** The walls of the south transept were built before those of the north, as can be seen in the relative heights of certain details around the transept stairs. The corners of the buttresses around the stairs are transformed from squares to octagons, through a glacis. In the south this occurs above the roof line, but in the north it begins at the springing of the clerestory windows, with a blind window in the space below the glacis. From this we should conclude that at the level of the clerestory the walls of the south were ahead of the north.

**The south transept:** As Bilson has shown, the southern clerestory was built for a wooden ceiling. I think the ribs on the north had already been begun when this decision was made, because there are correspondences of stone types, marks, and a few details between the transept vaults and the western bays of the nave which suggest that: the ribs and their chevrons in the nave aisles can be linked to those in the southern clerestory; the nave aisle piers and walls below their capitals relate to the lowest courses of the northern clerestory; and the upper parts of the nave aisle vaults, especially as seen within the western staircases, relate to the walling inserted over the southern clerestory vaults. However, the roof over the southern transept does not seem to have been in place when it was decided to insert the ribs. Main roofs and their lead covering are enormously heavy. If the roof had been in place, some part of the axial pier would have had to have been left to support it, otherwise the clerestory may have become unstable. But, in fact, the pier necessary to support this roof was cut out in its entirety to make room for the new ribs. This suggests that the decision to install the vault was made after the small barrel vaults over the passage had been built, and before the roof was pitched. From the chevron patterns on the southern clerestory ribs, I ascribe the vault to the team which was laying identical stones over the arches of the nave tribune, in about 1115.

**The nave springing:** The transverse arches were begun as semicircular arches. After the clerestory walls were built and the roof pitched, the transverse arches were erected, but to a pointed section which I would date to ca. 1128. Was this one of the earliest examples of a roof being placed before the vault was constructed, as became common later? Was it the first of the pointed rib vaults?

**The chevron mouldings:** The earliest are those over the western doors, to be dated about 1108. The next set of chevrons appeared in the nave aisles about 1115, and the south transept high vaults in the same year. Was it by picking out the rib as a separate decorative item that these masons came to see that it could also be thought of as an arch, distinct from the rest of the vault mass? It would not be unreasonable to assume that this realization took quite a long time, for masons had by tradition conceived the vault as a homogeneous lump of masonry, integral with its filling and tied into the adjoining walls. To conceive of the rib as an arch, and the plastered soffit not just as the underside of a mass, but as a shell supported by the ribs, required an utterly new point of view.

On the issue of who decided to use ribs, the story of the transept walls suggests it was the builder's decision, rather than the client's, for it may have been considered of no more importance than whether a cover mould was to be used around a door frame. The decision to use ribs, or even their arrangement, may have been the master's own personal and private affair. I doubt he thought that ribs were the major innovation that we see today. That was to come later, with the invention of the cell.

In conclusion, ribs were for the first time set into the groin vaults of the Durham aisles about 1102. Within a year or two the bases of the choir tribune piers show ribs were to be continued into the high vaults. This four-part scheme was changed to a six-part one around 1108. These early ribs were not structural devices, but constructional, and their potential supportive functions were not appreciated until around 1130.

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1 Bilson, "Beginnings", and "Durham Cathedral"; Bony, "Durham" and "Diagonality and Centrality". The  
quotation is from Bilson, "Beginnings," 312.

2 Fowler, *Rites of Durham*, 149, from an indulgence dated 1235 from Hugh of Northwold. Muniments of the Dean  
and Chapter of Durham, Misc. Chart. 1512 in J. Raine, *Saint Cuthbert* (Durham, 1828), appendix 7 and 10 1 -03.

3 Following Malcolm Thurlby's opposite arguments in "High Vaults" and "Building of a cathedral" I re-examined  
the site, took the photo 16-3, and am convinced that it was a six-part vault.

4 Taylor and Mark, "The Technology of Transition."

5 Frankl, *Gothic Architecture*, ch. 1.

6 Alexander, Mark, and Abel, "Medieval Ribbed Vaulting".

7 I am indebted to Dr. Martin Snape, Paleographer and Archivist to the Cathedral Chapter, for translating the Latin  
texts, and for having the patience to continue to debate with me their precise meaning until we were both  
satisfied. Snape, "Durham."

8 *Symeonis Monachi Opera Omnia*, ed. T. Arnold, Rolls Series, No. 75, 2 vols. (London, 1882, 1885), 1, 128-68;  
11, 220-36.

9 *Ibid.*, 1, 140-68.

10 *Willelmi Malmesbiriensis Monachi de Gestis Pontificum Anglorum*, ed. N. E. S. A. Hamilton, Rolls Series, LII  
(1870), 275-76.

11 James, *Contractors*; James, *Master-masons*.

12 *Symeonis* 1, 139.