

Villard de Honnecourt, Archimedes, and Chartres

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Villard de Honnecourt, Archimedes, and Chartres

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THE techniques of Gothic masonry construction can best be studied in two ways. The monuments themselves unquestionably provide the best evidence of the procedures that were actually employed, although accurate measured drawings, the sine qua non of this approach, are difficult and costly to make, and they fail to reveal anything beneath the surface of a building, precisely where masons' setting-out marks are most likely to be concealed. One cannot wish that more Gothic churches will be destroyed so historians of architecture may prowling among the ruins, looking for indications as to how they were erected. The second approach comprises the study of the rare texts and documents that have been preserved from the Middle Ages. Foremost among these is the manual of the thirteenth-century Picard architect, Villard de Honnecourt, which contains a set of diagrams of masonry techniques drawn and annotated by an anonymous follower known as Master 2, about 1250.¹ These diagrams sometimes seem very hypothetical, however, and many still hold secrets for the modern reader. Three in particular—the keystones *del tiirc* and *del quint point*, and the so-called Archimedes spiral (p. 40 c–2, d, e in fig. 8)—have never been satisfactorily explained. The last one has the dubious honor of being the single diagram Master 2 did not annotate, but by extraordinary good fortune, similar spirals have been preserved on the bed-face of a capital from Chartres Cathedral.² It is therefore possible to compare the manuscript figure with one that seems actually to have been employed in the construction of a Gothic monument.

1. Paris, Bibl. Nat., fr. 19,093. The standard edition is H. R. Hahnloser, *Villard de Honnecourt* (Vienna, 1935), with bibliography (the page and figure numbering used in the present article follows this edition); see also J. B. A. Lassus, *Album de Villard de Honnecourt*, A. Darcel (ed.) (Paris, 1858); R. Willis, *Facsimile of the Sketchbook of Wilars de Honnecourt* (London, 1859); and *The Sketchbook of Villard de Honnecourt*, Th. Bowie (ed.) (Bloomington, 1959), with pages renumbered.

2. I am indebted to Dr. Peter Kidson, Conway Librarian at the Courtauld Institute of Art, for bringing the piece to my attention and for providing the photograph reproduced in fig. 5.

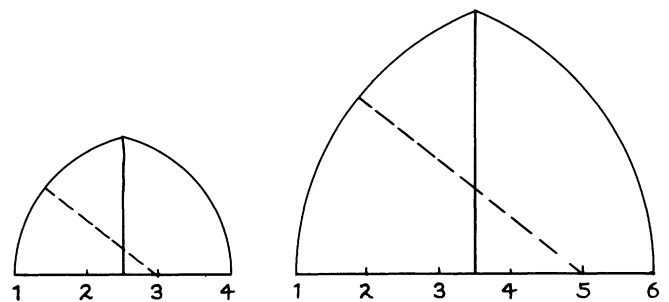


Fig. 1. Traditional third- and fifth-point arches, numbered according to Brutails.

The absence of a caption in p. 40 e is perhaps understandable, since this figure forms an integral step in the procedure of setting out the keystones in the two preceding diagrams. In order to understand the procedure, however, it would seem necessary to revise the terminology for the various forms of Gothic pointed arches that has been current since the Renaissance. Master 2 wrote *clef del quint point* and *del tiirc*, and every modern student of the manuscript has correctly associated these phrases with the keystones of the *quint-point* and *tiers-point* arches. By the traditional definition, one form of the third-point arch is generated from a base divided into three equal units, the centers of the curves being situated one unit in from the ends, while the fifth-point arch has five equal units in the base and the centers are situated one unit in (fig. 1).³

3. The other third-point form is generated around an equilateral triangle; see Hahnloser, p. 115, *et al.* The traditional definitions seem to derive from Italy: cf. Scamozzi, *Dell'Idea . . .*, III, xiv; Philibert de l'Orme, *Nouvelles Inventiones . . .*, xv, and Wotton, *The Elements of Architecture* (London, 1624), p. 51, seem to make this clear; *quinto acuto* was used in this way by Giovanni di Gherardo da Cremona, see H. Saalman, *Journal of the Society of Architectural Historians* XVIII (1959), 11–20.

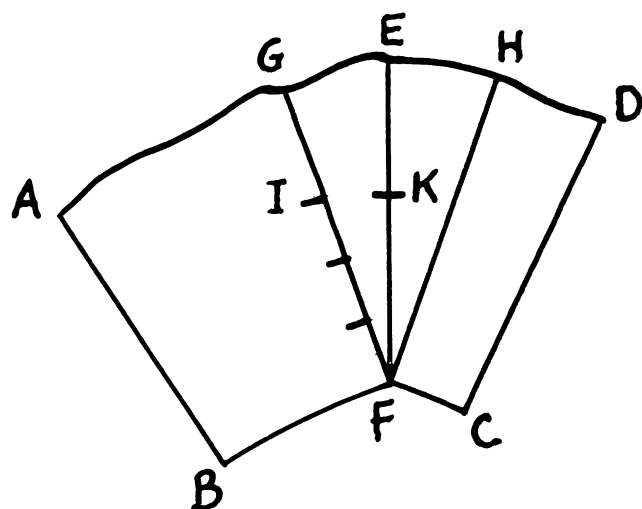


Fig. 2. Third-point keystone, redrawn from p. 40 c-2.

If the arches are constructed from such bases, however, the keystones do not correspond to those in the diagrams, and as Master 2 is not noted for his intelligence or accuracy, it has generally been assumed that the drawings are incorrect or badly proportioned.⁴ If, on the other hand, the diagrams and captions are accepted as they stand, it is clear that our own terminology is at fault. This may be confirmed by the coherence, simplicity, and mathematical foundation of the procedure outlined in the diagrams.

The keystone resembles an ordinary voussoir with a small, triangular section added to carry the extrados up to the peak of the arch (fig. 2).⁵ Prior calculations, perhaps found among the other diagrams of Master 2, have undoubtedly provided the upper and lower curves, as well as the thickness of the arch, and serve as a point of departure for setting out the keystone.⁶ AB, GF, HF, and DC represent the radii of the arch, EF the vertical axis and GEF or GHF the area to be added. In the third-point design, any three equal units are marked off on the radius passing through the peak of the soffit (FI) and another unit of the same size (IK) is laid out perpendicular to the vertical axis, forming a triangle with sides of 3, 1, $2\sqrt{2}$. But the length and position of the vertical axis are the unknown quantities and $2\sqrt{2}$ is incalculable. To find these

4. See, for instance, J.-A. Brutails, '“Tiers-point” et “quint-point”', *Bulletin archéologique du comité* (1902), pp. 273–279.

5. The early thirteenth-century keystone may be a single stone sloping down on both sides from the apex of the arch, or it may be formed by two stones with a common bed lying on the vertical axis of the arch. Both kinds are often found together in compound arches, where each set of voussoirs is staggered with respect to the adjacent ones, in order to insure a better bond. Thus the keystones of each component arch are alternately a single stone and twin stones separated by a vertical bed, as, for instance, at Bourges Cathedral. Brutails (p. 276) misquotes Choisy on this point.

6. E.g., p. 39 r or p. 40 g.

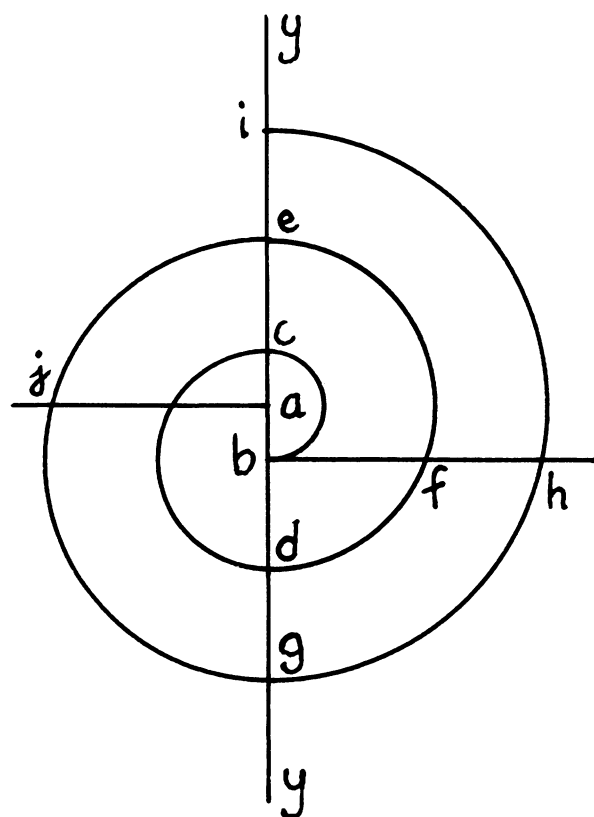


Fig. 3. Spiral, with transversal axes added, redrawn from p. 40 e.

distances, one need only draw the 'Archimedes' spiral shown in the adjacent figure of the manuscript (fig. 8 e).⁷

The spiral of Master 2 is not a true Archimedes spiral, which is generated by moving parts, but is made of semicircles drawn from two centers lying on an axis (fig. 3 y). The construction is simple. Let the first center be *a*, the radius of the first semicircle \widehat{ab} ($=1$), and the second center *b*. Then *cd* forms the second semicircle, with $r=2$, \widehat{ad} the third semicircle, with $r=3$, and so on. If a line perpendicular to *y* is projected from *b*, it intersects the third semicircle at *f*, and $bf=2\sqrt{2}$, the incalculable dimension required for the third-point keystone. That such a line is not shown in the diagram merely means that it was not necessary to draw it in, for the mason's square (represented in fig. 8 b) could simply be laid along *y* with *b* in the corner, both *bf* and *ba* marked on it, and the instrument then transferred to the stone and the marks used to complete the setting-out of IK and KF. The ordinary mason did not in fact have to know he was dealing with an irrational number.

The fifth-point keystone is equally simple. In view of Master 2's caption, the marks in 40 d must be taken to represent five equal units. The incalculable side of the

7. Viollet-le-Duc's explanation of the spiral as a means of calculating the various ribs of the vault is difficult to accept, if only in view of the considerable size of the latter. *Dictionnaire*, vi, 442.

triangle is $2\sqrt{6}$, or bh on the spiral, while the shortest side is still 1, or ba .

Willis noted that the third-point keystone could only be situated above an arch that in modern times would be called fourth-point, that is, with the base divided into four equal sections and the centers located one-fourth of the way in from each end.⁸ Instead of questioning the terminology, he decided that the draftsman must have intended the three units of the diagram to represent four spaces. It would seem, however, that Master 2's terminology, as well as his diagram, may have been perfectly correct. The points of the base should not be confused with the spaces they mark off and they must be counted starting with 0 at the end, and not 1, as in the Roman method; then the third point from the left, for instance, forms the center for the left-hand arc (fig. 4). In other words, the radius of the *tiers-point* arch is $\frac{3}{4}$ of the base, just as the radius of the *quint-point* arch is $\frac{5}{8}$,⁹ and the mason could set out either keystone merely by knowing the name of the arch it was to crown.

The procedure noted in shorthand by Master 2 is therefore completely logical, and it has some interesting consequences. If the position of the centers is constantly increased by 1 and the number of base divisions by 2 ($2/2, 3/4, 4/6, 5/8, 6/10, 7/12 \dots$), a series of arches and keystones is formed for which the spiral will continue to provide the unknown quantities ($\sqrt{3}, 2\sqrt{2}, \sqrt{15}, 2\sqrt{6}, \sqrt{35}, 4\sqrt{3} \dots$), while the short side of the keystone triangle remains 1.¹⁰ And as the number of divisions across the base increases, the spiral accommodates only the lower arches.¹¹ The verification of such a limitation in the monuments of the first half of the thirteenth century in northern France would be a most valuable contribution to our knowledge of Gothic techniques. What will probably always remain unfathomable, however, is how the Gothic mason, generally considered to be ignorant of more than the simplest mathematical calculations, came to use the system.

The use of the spiral in setting out a keystone made it unnecessary to trace the arch at full scale, a step that must often have been difficult in the limited area available in the thirteenth-century lodge. This tends to confirm the conclusions that can be drawn from several other diagrams of Master 2.¹² But the connection of the manuscript

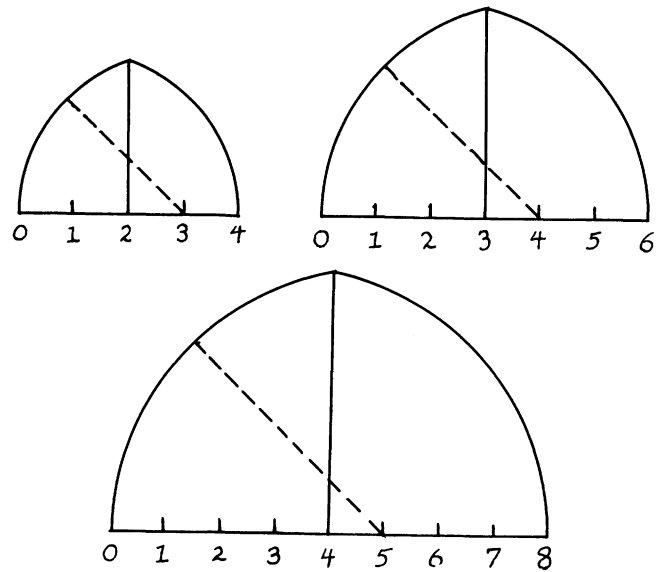


Fig. 4. Third-, fourth-, and fifth-point arches, numbered in the presumed thirteenth-century manner.

figures with actual working procedures would remain highly theoretical, were it not for the fact that several similar spirals are preserved on the stone from Chartres Cathedral, giving us a fair idea of their size in real practice.

The stone at Chartres originally served as a capital for one of the piers of the south transept porch (figs. 5 and 6). It now measures about 168 by 78 cm. and represents a bold design, in that the upper corners form clusters of five small, almost independent capitals, of which three rested on isolated, monolithic shafts. Even with the small load of the porch vaults resting upon them, the clusters seem to have broken off, and this is undoubtedly why the stone was replaced. It is now preserved in the chamber of the south tower.

On the lower bed of the capital are traced the normal axes that were used to set out the plan of the piece, in addition to some inexplicable lines (fig. 6). There are one axis in the center, three to the left, a short one delimiting the small half-capital to the upper right and a transversal one reaching to the half-capital on the opposite side. The spirals are located on the central axis and on a now-lost axis to the right. Since two of the spirals (B, C) are incomplete, the original stone was probably larger when they were traced (at least 168 by 92 cm.). And the coincidence of the central axis of the capital with the axes of spirals A and B seems overly fortuitous. It is more likely that the capital was intended to be cut from a stone sufficiently large to allow the mason some leeway in its setting-out and execution, that the central axis was drawn at an early moment as a reference mark, and that the stone was then used as a tracing surface in the shop before the final

8. Willis, *Facsimile . . . Wilars de Honnecourt*, pp. 141–142.

9. These proportions were already noted by Brutails, p. 277.

10. Obviously certain multiples of the original series, such as $6/8$ and $8/12$, can also be used, but a number of possibilities, such as $5/6$, $7/8$, and $7/10$, are excluded because the short side of the triangle would be greater than 1.

11. This obtains both in the original series and in the acceptable multiples, e.g., $8/12$ and $9/12$, but not $10/12$. Brutails' conjecture that the third-point may indicate the more obtuse, and the fifth-point the more acute, arches, is therefore incorrect (p. 278).

12. Cf. Robert Branner, 'Three problems from the Villard de Honnecourt manuscript', *Art Bulletin* xxxix (1957), 61–66.

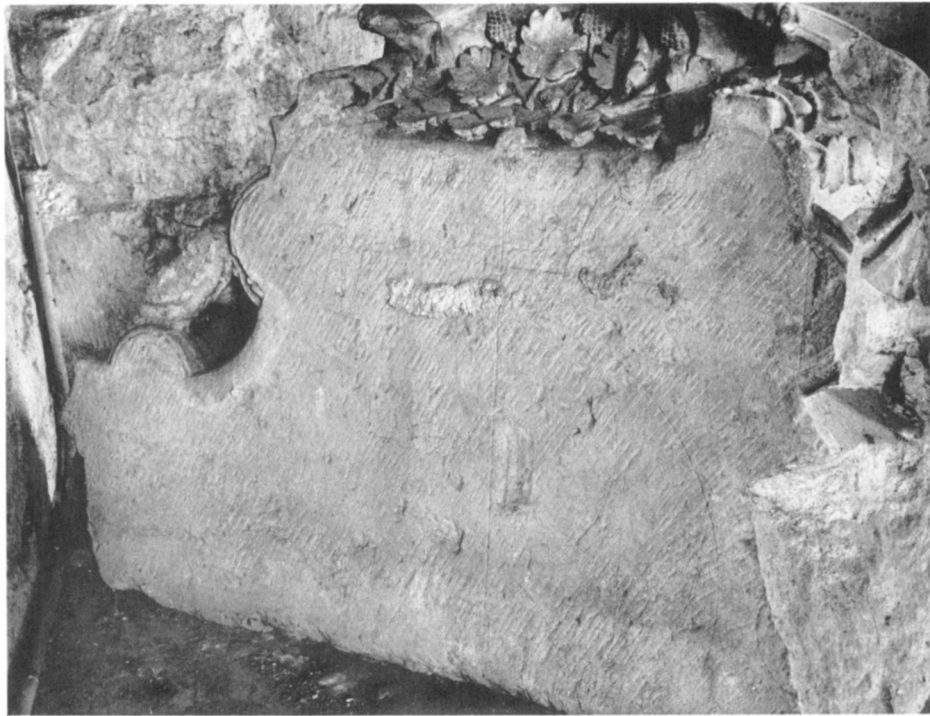


Fig. 5. Capital, from south transept porch, lower bed, Chartres Cathedral (courtesy Courtauld Institute of Art).

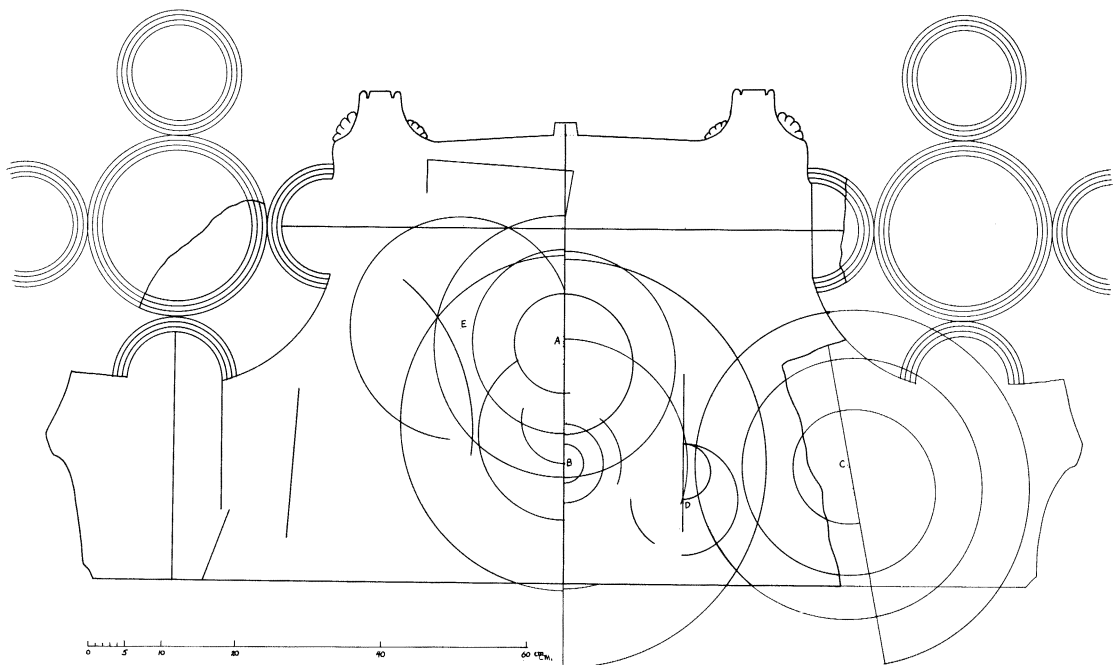


Fig. 6. Capital, from south transept porch, lower bed, Chartres Cathedral. Measured drawing: dark lines indicate extant portions, light lines indicate reconstituted portions (axis of C hypothetical).

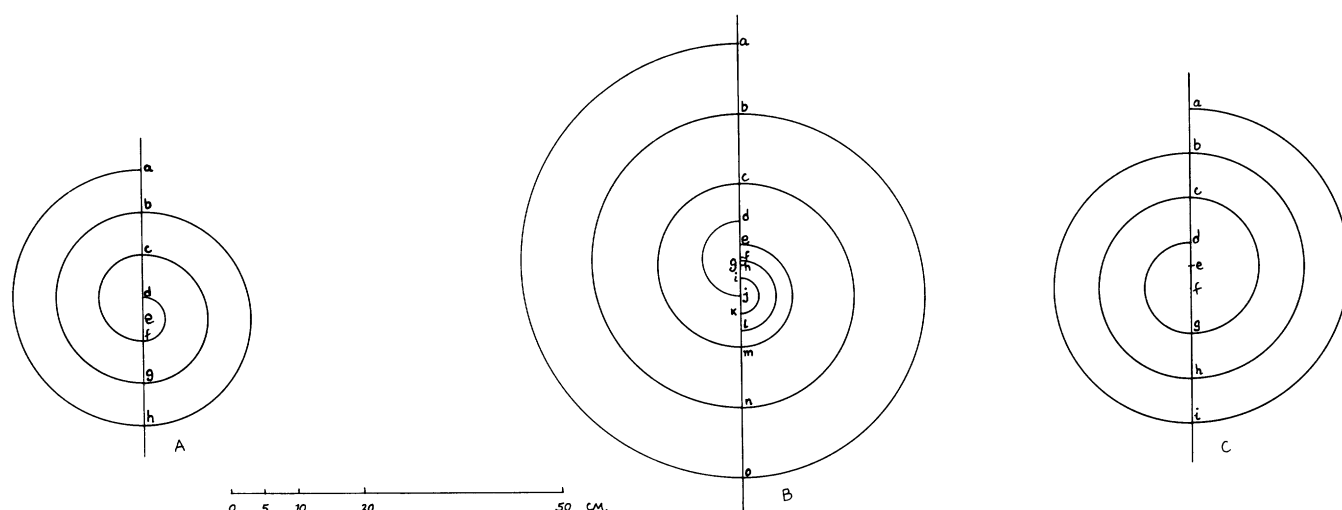


Fig. 7. Spirals from capital, Chartres Cathedral.

cutting and the sculpture were made. This span of time in turn suggests a kind of mass production whereby a number of similar pieces were rough cut and only partly finished in one operation. The capitals of the porch piers are in fact composed of sixteen pieces, seven of which are identical with the one in question and eight of which are smaller, but alike, one to the other.

All the lines on the capital are lightly engraved and in some cases they seem not to have been completed, for obviously they could not have worn off here. Many of them, such as D and E, some of the arcs in B, and perhaps one of the fragmentary axes, are unrelated to either the spirals or the capital and seem at present to have no logical explanation. Furthermore, there is a fundamental difference between A and C, and B. In the first two, the second center is taken midway between the first center and the circumference (fig. 7 C, *e*), rather than on the latter (*b*). Thus the internal relationships of each spiral are reduced by half. This is the same construction as the one used by Dürer, although he constructed the spiral in reverse, starting with the largest semicircle and working inward.¹³ It is just as effective in setting out a keystone as Master 2's system, for where the incalculable side of the triangle is $\sqrt{2}$, the second radius is $3/2$. And the mason's square could be used to mark off the distances, although it would first have to be slid along to the other center. In B, on the other hand, Master 2's system is used. Extra semicircles (*ik*, *gl*) are fitted into the initial one (*em*), however, and

the semicircle on the left (*mc*) was probably drawn from the center *h*, approximately halfway between *e* and *j*, making this part of the spiral a variant of the system of A and C.

The real dimensions of the spirals have only a general importance for the dimensions of the keystones, since the relationship between the two is proportional. In actual operation, however, too small or too large a spiral would be inefficient: the former would lack accuracy, the latter might exceed the surface of the block from which the keystone was to be cut. The initial radii at Chartres are quite small but the maximal sweeps are large, and the presence of three separate spirals may reveal a search for the most efficient size. Furthermore, the spirals are poorly drawn. The centers of A and B form small, irregular holes in the stone, as if the sharp point of the compass had frequently been set in them, and they are not consistent, varying up to 1.7 cm. from the true centers.

At Chartres, the arches of the south transept porch seem to conform to the fourth-point design, in the terminology proposed here, and the keystones would therefore have been set out on the same system.

Interesting as the spiral and the keystones are, they seem at first glance to have nothing to do with Villard de Honnecourt, since the set of figures on the top of p. 40 was drawn by Master 2.¹⁴ The latter is known to have effaced portions of the manuscript in order to enter some of the diagrams, however, and the faint marks at the top of the page consequently take on a new importance (fig. 8). Under ultra-violet light they can be seen to represent the remains of five figures (fig. 9): M, a right triangle of unknown meaning at the present; N, a keystone similar to

13. A. Dürer, *Underweysung . . .* (Nürnberg, 1525), fig. 6; cf. M Steck, *Dürers Gestaltlehre der Mathematik und der bildenden Künste Mathesis universalis*, 1 (Halle, 1948), pp. 25–26. It was also used by Juan Arfe y Villafañe later in the sixteenth century. *Varia Commensuración para la escultura y arquitectura*, 1, i, 9, 7th ed. (Madrid, 1795), pp. 5–6.

14. Hahnloser, *Villard de Honnecourt*, pp. 195–198.

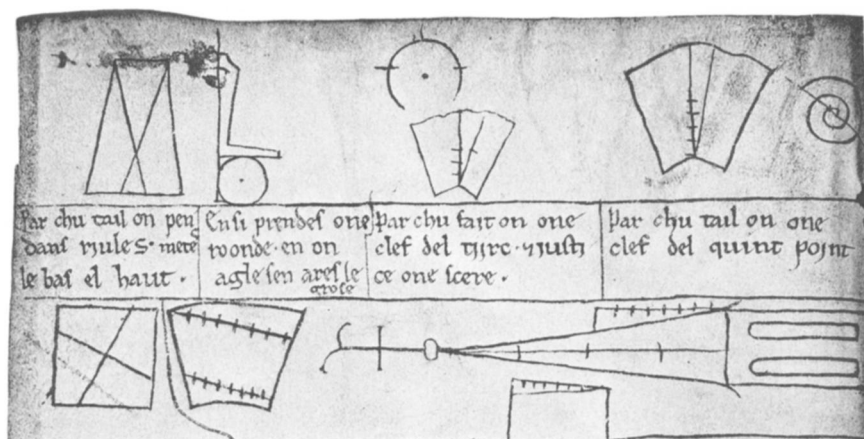


Fig. 8. Paris, Bibl. Nat., fr. 19,093, detail of page (from Omont, *Album de Villard*, pl. xl).

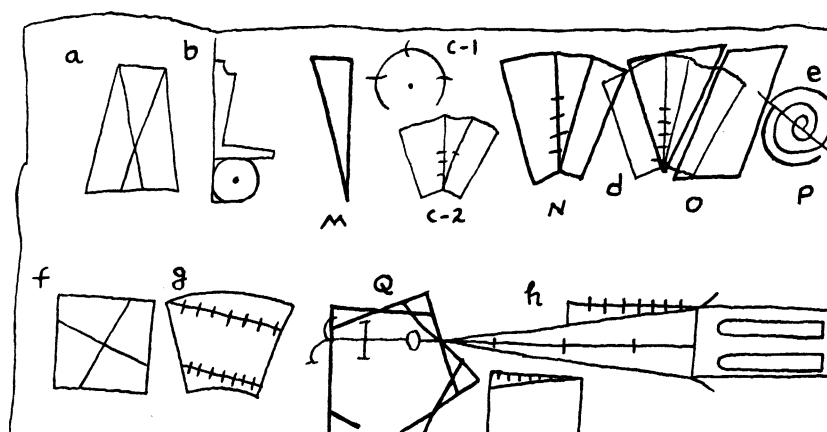


Fig. 9. Sketchbook of Villard de Honnecourt, detail of page with palimpsested figures in heavy lines (redrawn).

c-2 or d, on which there seem to be four marks indicating the fourth-point system; O, a triangle and trapezoid, in all probability designating still another keystone design; P, an extra semicircle on the spiral, e; and Q, the pentagonal tower repeated in p. 41 c. N and P are of particular importance, since they indicate the first draftsman knew the keystone technique and the uses of the spiral.

The alignment of these palimpsested figures in bands resembles the work of Master 2, but it is doubtful whether he would have drawn them, only to efface them and redraw some of them in other places. It is possible that they were the work of the evanescent Master 1, who perhaps wrote the now effaced text on p. 39.¹⁵ But it is more likely that they were the work of Villard himself. He seems occasionally to have moved his own figures around, for p. 41 h repeats the effaced diagram found between the

pear tree and the plan, at the top of the page. And even if he was not preoccupied by scholastic models to the same extent as Master 2, he was also given to aligning small figures across the page (cf. pp. 36–37).

Villard is known to have visited Chartres, where he drew the rose window and several figures from the south transept porch, among which was probably the engaging lion of p. 48, as Kidson has recently suggested.¹⁶ While it is not possible to prove that he learned the keystone technique there, the presence of the fourth-point arch in the porch and the fourth-point keystone in the manuscript suggests that this may have been the case. Villard's trip to Chartres would therefore have taken place shortly after the porch was begun, very probably in 1225.¹⁷

16. P. Kidson, *Sculpture at Chartres* (London, 1958), pp. 55–56.

17. Preparations for the construction of the porch seem to have been underway in 1224, when a lean-to on the site was demolished; see L. Grodecki, 'Chronologie de la cathédrale de Chartres', *Bulletin monumental*, no. 116 (1958), pp. 91–119, with bibliography.

15. Cf. Robert Branner, 'Note on Gothic architects and scholars', *Burlington Magazine*, no. 115 (1957), pp. 372, 375.