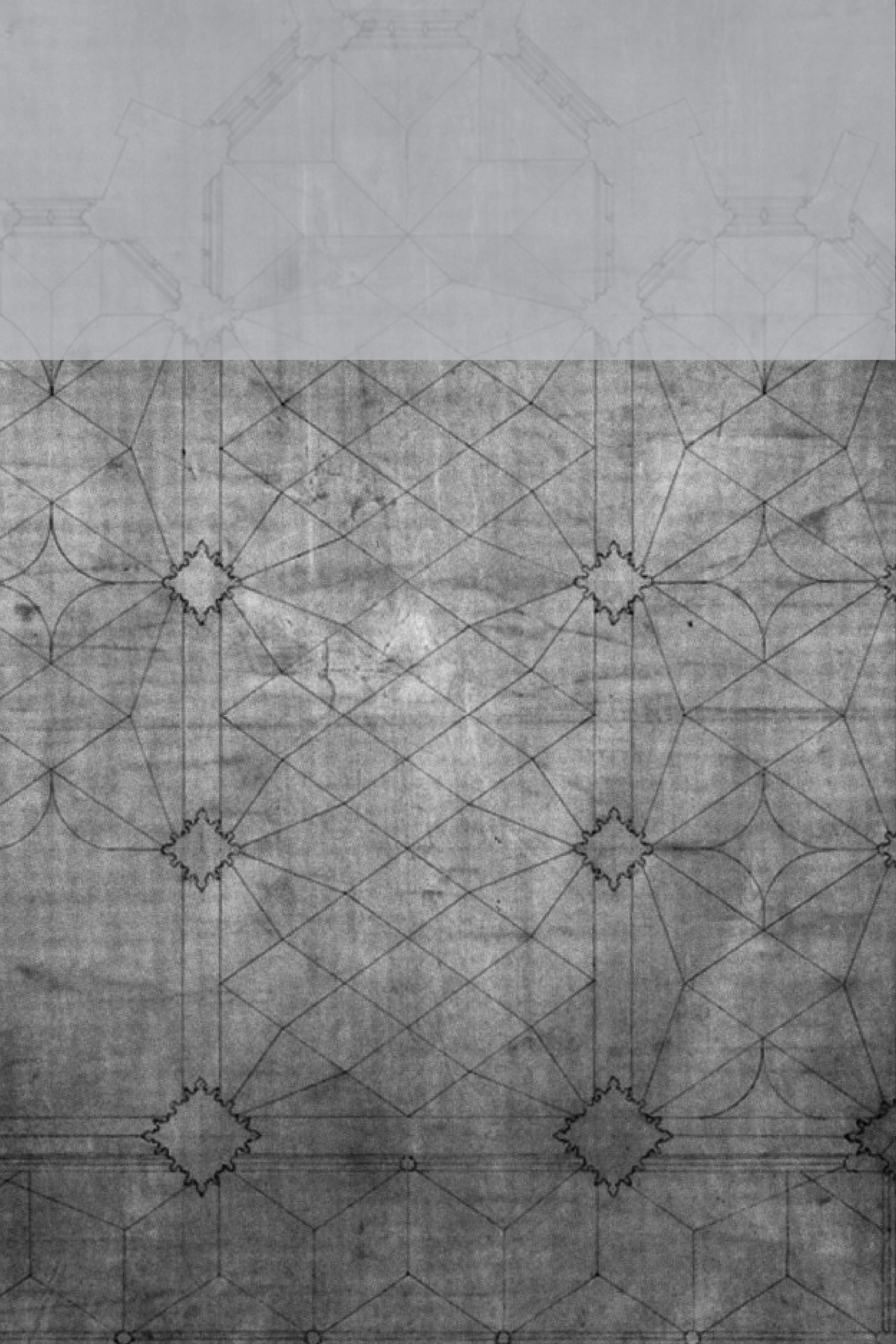

ROBERT BORK

Gothic Vaulting and the Dynamics of Plan Design

I. Introduction: The challenges of "reverse-engineering" Gothic design practice

In the Gothic architectural tradition, the aesthetic character of a building reflects the steps of the design process to an extent rarely seen in other architectural modes. The proportions of Gothic piers, for example, were not standardized like those of classical columns, whose canonical forms were supposedly based on those of the human body. Instead, it can be shown that the proportions in Gothic architecture arose from dynamic processes of geometrical unfolding, whose details could vary considerably from building to building (Bork 2011). Similar geometrical dynamics also govern the format and articulation of other Gothic building elements, from overall ground plans and elevations to details such as buttress sections and molding profiles. For this reason, Gothic architecture can best be understood through the approach known as "reverse-engineering," in which the modern investigator attempts to rediscover and even replicate the steps taken by the original designers. Until recently, however, several major factors have made it difficult to apply this approach effectively.

Among the most significant impediments to research on Gothic design is the simple fact that Gothic builders did not leave very satisfying written records of their methods. This is hardly surprising, since their training emphasized visual more than verbal communication. The so-called portfolio of Villard de Honnecourt, from the early thirteenth century, admittedly includes some short commentaries alongside its architectural sketches, but Villard was probably not a designer himself, and the widely varied contents of the portfolio cannot be construed as a treatise on Gothic architectural practice (Barnes 2009). Most of the more precise architectural drawings produced in the later Middle Ages have no textual glosses at all. Most of the written documents associated with major medieval building projects, conversely, were unillustrated fabric accounts prepared more for the patrons than for the builders. Valuable as they are for dating the buildings and situating them within their institutional and social contexts, they reveal almost nothing of design practice *per se*. It was only in the fifteenth century that Gothic builders themselves began to explain their methods in writing, most famously in the pinnacle design booklets written by Matthäus Roriczer and Hans Schmuttermayr (Shelby 1977; Coenen 1990). As Paul Crossley has suggested, their publication may well have been catalyzed by a sense of competition with the treatises that were then beginning to be published in Italy, including Vitruvius's genuinely Roman *De Architectura* and its most direct Renaissance successor, Alberti's *De Re Aedificatoria* (Crossley 1993). In terms of scope and rhetorical sophistication, however, the Gothic design booklets were no match for their classical rivals. Instead of being written in elegant Ciceronian Latin that would impress educated Humanist patrons, they were written more like recipe books, with step-by-step instructions for pinnacle construction that can hardly be called inspiring.

Authors like Roriczer and Schmuttermayr confronted a fundamental difficulty, one that has inhibited discussion of Gothic design up to the present day: namely, the fact that Gothic design practice is hard to describe in words, or even in concise individual images (Bork 2010). The builders were obviously able to communicate effectively with each other and with their apprentices, as the continuity of their methods and traditions over four centuries amply demonstrates. But their design methods involved the dynamic unfolding of geometrical operations, which could be demonstrated in person more effectively than they could be captured in prose. In writing, precise description of these steps could often become tedious, as one sees in Roriczer's pinnacle booklet (Fig. 1) After establishing a base square ABCD in step one, for example, he explains the next step as follows: "Divide the distance from A to B into two equal parts, and mark an E at the midpoint. Do the same from B to D and mark an H; from D to C and mark an F; from C to A and mark a G. Then draw lines from E to H, H to F, F to G, and G to E, as in the example of the figure drawn here-after […]" (quoted from Shelby 1977, 85). Despite its numbingly explicit detail, Roriczer's text is all but unintelligible without reference to his sequences of illustrations.

Classical designs could be described and illustrated much more economically, since their forms were more constrained by convention, and since their formal logic depended less intimately on the steps of the design process. The publication of illustrated treatises like Serlio's *Libri* thus helped to quickly spread the taste for classical design throughout Europe in the middle decades of the sixteenth century. The publication of Vasari's *Lives of the Artists*, meanwhile, popularized the notion that Gothic architecture was chaotic and lawless. Gothic architectural culture did not succumb immediately to the spread of Renaissance fashions, of course. Some ambitious theorists such as Rodrigo Gil de Hontañón and Philibert de l'Orme even sought to synthesize aspects of these traditions, and some Gothic craft practices survived into the seventeenth century, especially in English and German workshops (Casaseca 1988; Sanabria 1989; Hipp 1979). As time wore on, however, the procedural logic of Gothic design was gradually lost, as architectural theory came increasingly to follow the norms of classical design. When scholars began to undertake serious study of Gothic architecture in the nineteenth century, therefore, they were starting over largely from scratch. Despite these very significant obstacles, the nineteenth century witnessed a variety of ambitious attempts to "reverse-engineer" Gothic architecture. E. E. Viollet-le-Duc, for instance, undertook the rebuilding of many major Gothic monuments, gaining along the way a detailed understanding of many of the period's design and construction methods. In attempting to discern the logic of the Gothic design process, he arrived at a still-plausible overall picture of sequential geometrical unfolding, which he illustrated with examples including the chevet plan of Amiens Cathedral. As Stephen Murray has demonstrated, however, this construction does not quite match the format actually seen at Amiens (Murray 1990). Most authors interested in Gothic geometry in nineteenth and early twentieth centuries, moreover, were far less experienced with actual buildings than Viollet-le-Duc had been.

Geometrical research into Gothic design became rather notorious for diagrams in which thick lines were drawn onto small building plans of dubious reliability. Some work in this genre may include valuable observations, but the imprecision and ambiguity inherent in the testing process make it all but impossible to distinguish the justified conclusions from the flights of interpretive fancy. Much of the early work in this field, therefore, was dismissed in a rigorous critical study published by Walter Thomae in 1933 (Thomae 1933). Three decades later, in his magisterial review of writings on the Gothic period, Paul Frankl wrote in apparent frustration that "The question of what is actually gained by such research becomes urgent. There can be no doubt that Gothic architects made use of triangulation and the like, but the excogitated networks made up of hundreds of lines to determine all points has not been proved and is probably undemonstrable and unlikely" (Frankl 1960, 721).

Perhaps the most devastating critique of this geometrical research tradition came in the early 1970s from Konrad Hecht, whose writings have exercised a chilling influence on the field in the four subsequent decades. Hecht began, it seems, with the best of intentions, seeking to restore historical realism to a field in which fantastic hypotheses had grown unchecked. He may also have been eager to challenge the nationalist legacy of geometrically-minded scholars like Otto Kletzl, who had enjoyed a favored position in the Third Reich (Labuda 2003). Hecht thus opened his major publication in the field, *Maß und Zahl in der gotischen Baukunst*, with a rigorous critical review of previous literature, amply demonstrating the arbitrariness, implausibility, and mutual incompatibility of much that had come before (Hecht 1969–1970). Next, he set out to demolish all the successive attempts to illustrate geometrical proportioning systems in the tower of Freiburg Minster, which had become something of a hobbyhorse for writers in the field. Through careful numerical analysis, Hecht showed that imprecision, ambiguity, and wishful thinking flaw most of these studies. Reacting against the excesses of purely geometrical design theory, Hecht then proposed an even more implausible alternative, suggesting that Gothic designers worked almost exclusively in arithmetical modular fashion. He sought to demonstrate this by proposing module-based analyses not only of the Freiburg tower, but also of the elevation drawings associated with planning of the Ulm Minster tower. Hecht had good reasons to see the examination of original drawings as a useful complement to the study of buildings. To begin with, drawings can be precisely measured far more readily than full-scale buildings. Second, their proportions are those actually intended by the original designer, uncompromised by errors that may have crept into the building during the construction process. Third, such drawings may preserve telltale traces of the draftsman's labor, such as compass prick holes or un-inked construction lines that can reveal the designer's working methods. Hecht rightly observed that such traces are relatively scarce, but he was surely wrong to categorically deny the importance of geometrical planning methods for Gothic design. His densely argued work appears rigorous at first glance, but his purely module-based descriptions fail utterly to explain Gothic architectural practice. Indeed, they are little more than quantified descriptions, which provide no real insight into how the designers arrived at the proportions and articulation strategies they chose.

In recent years, the advance of technology has made it possible to "reverse-engineer" the Gothic design process far more

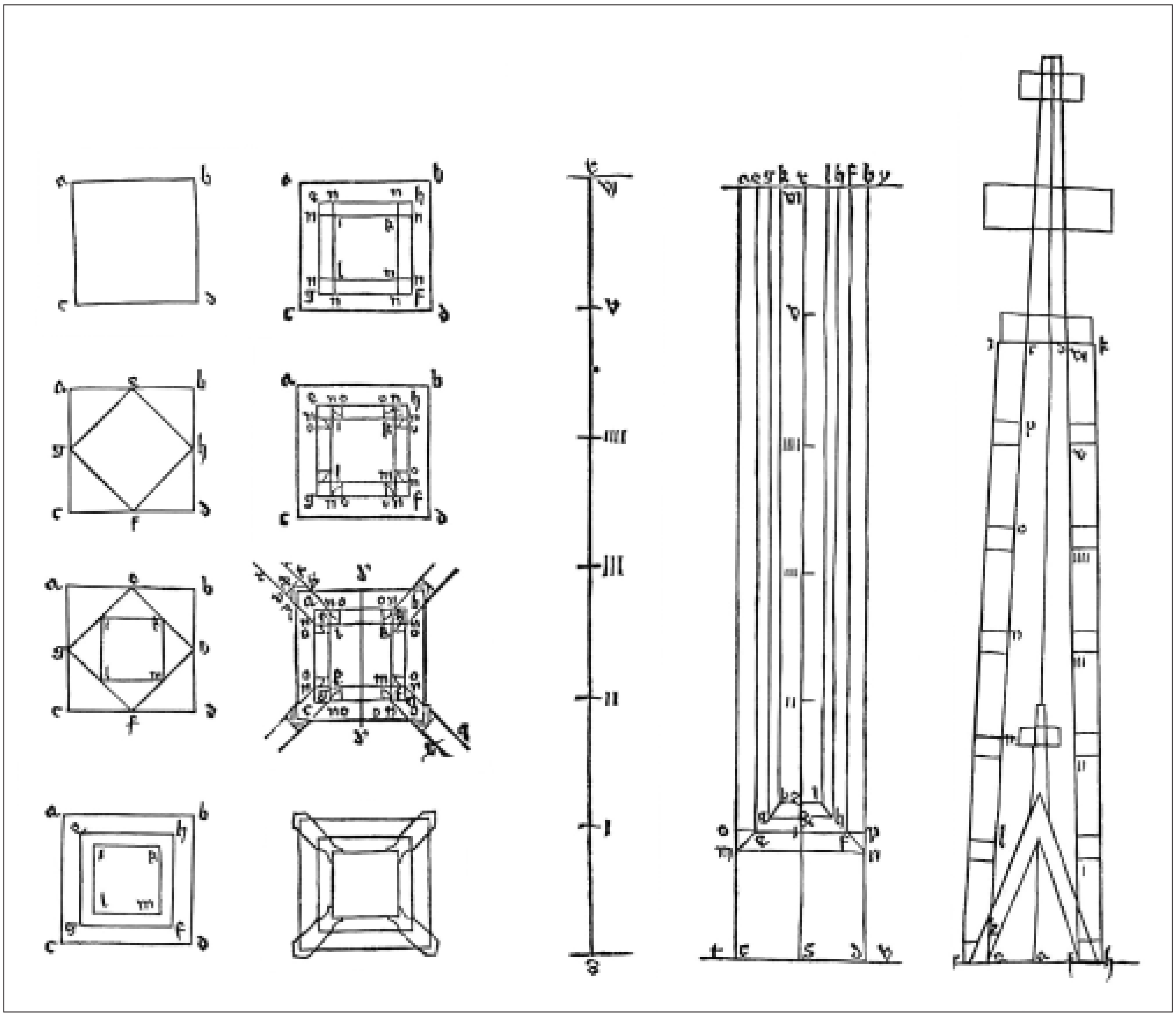

Fig. 1 Steps in the geometrical construction of a pinnacle, after Matthäus Roriczer, *Das Büchlein von der Fialen Gerechtigkeit*, 1486.

effectively than Hecht and his predecessors could. The emergence of laser-based 3D scanners, for example, has begun to revolutionize the surveying of buildings, permitting the rapid and highly precise measurement of entire monuments, including elements such as vaults that would formerly have been very difficult to study effectively, even with scaffolding (Bork, Clark, and McGehee 2011). Actual analysis of such 3D data depends on the use of CAD (computer-aided design) systems, which can be used to compare the measured forms to basic geometrical elements that the Gothic builders could have planned, such as arcs of given radii. When this technique is applied in two dimensions, in fact, a modern scholar can use a CAD system as a digital compass and rule, thereby potentially recapturing the dynamics of the creative process that the Gothic draftsmen themselves employed. This approach can be particularly effective in cases where original medieval design drawings survive, while the scanning of the monuments themselves, combined with more traditional hands-on approaches to building archaeology, can reveal how those ideas were translated into practice. Such work has begun to reveal that rigid arithmetically-based reasoning played a far less important role in Gothic design than Hecht had imagined. Gothic builders certainly used fixed units of measure on their work sites, and in some instances they appear to have used module-based rules of thumb as part of their design process, but in many cases they appear to have chosen dimensions that would approximate geometrically-determined quantities, in a process that Franklin Toker has aptly called "pseudo-modular" design (Toker 1985).

Before going on to see how this approach could be applied to more complex structures, it will be helpful to briefly consider the proportions of the simple pinnacle base described by Roriczer. As noted previously, Roriczer begins by inscribing a rotated square EFGH within the framing square ABCD

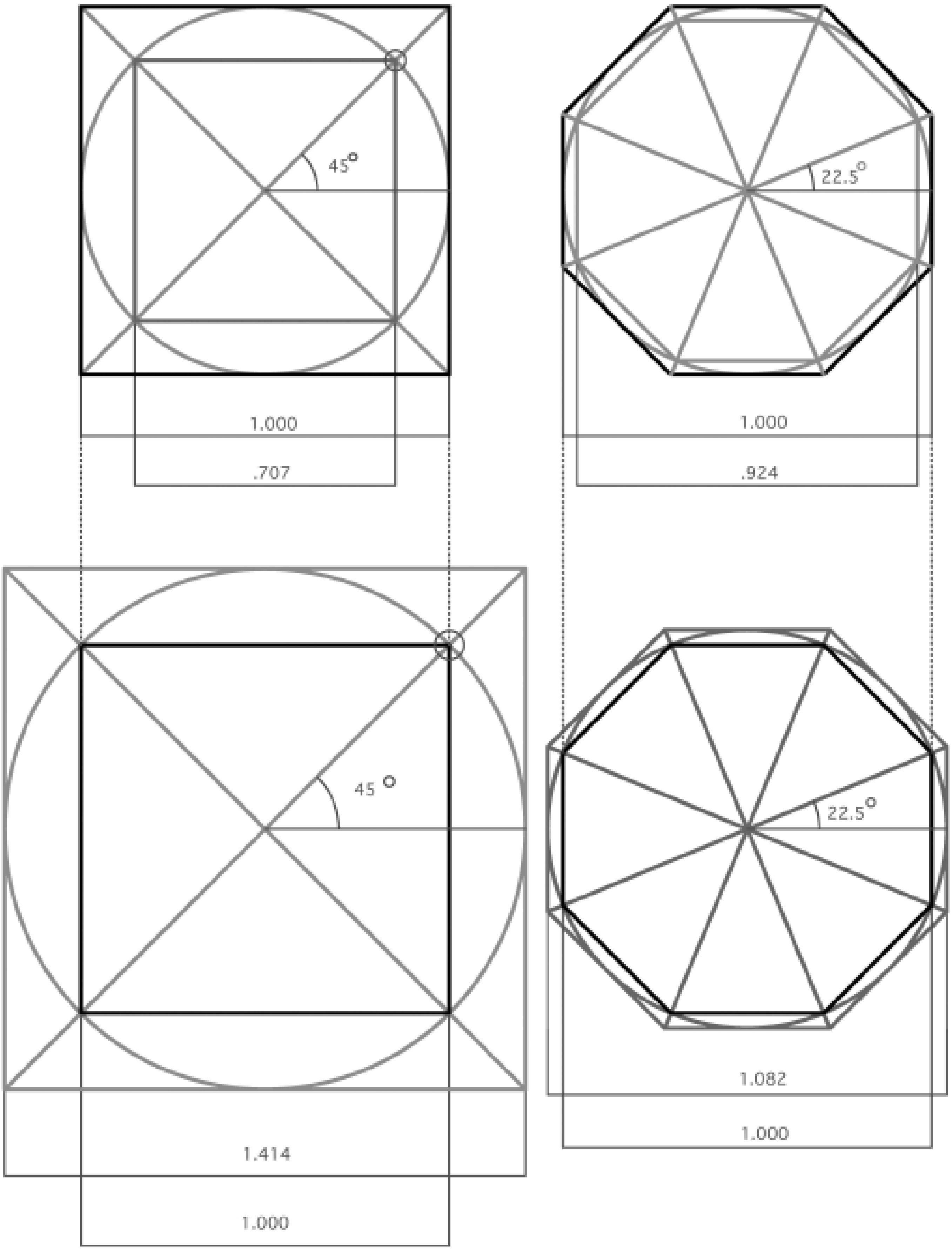

Fig. 2 Proportions resulting from "quadrature" and "octature."

(Fig. 1, left). The area of EFGH will be half as great as that of ABCD, while the lengths such as FG will be shorter than AB by a factor of √2. This irrational number, which arises naturally in the geometrical design sequence, amounts to roughly 1.414. It could therefore be conveniently approximated by the ratio 17/12, or more roughly by ratio 7/5=1.4. These approximations may have been helpful to builders working at full scale, but Roriczer seems to have developed the plan of his pinnacle in purely geometrical fashion. After establishing square EFGH, he rotates it back into alignment with the framing square, as seen in the bottom left of Figure 1. This format can be seen more clearly in the upper left quadrant of Figure 2, where the circle between the two nested squares describes the path that the tips of the smaller square would sweep out as they rotate. In this graphic, the size of the original square is taken as 1.000, so that the side length of the inscribed square is 1/√2, or .707. As the bottom left quadrant of Figure 2 indicates, meanwhile, an analogous process can be used to step outwards to a larger square of side length of √2, or 1.414. Most students of Gothic architecture are well familiar with this process of square nesting, which has become known by a name of its own: quadrature.

Squares, of course, were not the only polygons widely employed by Gothic architects, and they were not the only ones to be nested in this recursive fashion. Many pinnacles have ground plans based on nested triangles or hexagons, for example. It can also be shown that buildings such as Cologne Cathedral have proportions based on the nesting of dodecagons (Bork 2011, 97–99). But perhaps the most frequently employed variant on this theme involved the octagon, a figure often used for the ground plans of spires and apses because it conveniently approximated the closed form of a circle while interlocking directly into the orthogonal frame of a typical Gothic bay system. The proportions that emerge from "octature" are shown in the right-hand half of Figure 2. When one steps inward in octature, the figure shrinks by a factor of .924, which is the cosine of 22.5 degrees, just as .707 is the cosine of the 45-degree angle seen in quadrature. And when one steps outward in octature, the outer framing octagon is larger than the original by a factor of 1/.924, or 1.082. Precisely analogous factors can be readily determined for any other set of nested polygons. As the following discussion will reveal, the presence of such proportions in Gothic buildings and drawings can reveal a great deal about the geometrical logic of their conception. A geometrically rigorous analytical approach can prove particularly helpful in the study of late Gothic vaults, which rank among the most complex products of the medieval architectural imagination. Fortunately, a good number of plan drawings survive, especially from the unrivaled collections of the Akademie der bildenden Künste in Vienna (Böker 2005). Not all genres of vaultare are recorded in these drawings. There are no surviving drawings, for example, to document the planning of the so-called cell vaults that gained popularity in the eastern reaches of the Holy Roman Empire in the decades around 1500. Careful scrutiny of the drawings associated with specific late Gothic rib vaults, however, can shed some light on the strategies of their designers, providing lessons that may prove to have wider applicability.

II. The Steyr plan as a case study of "reverse-engineering"

Consideration of the vault designs for the parish church of Steyr, in southern Austria, can effectively illustrate the value of this analytical method. The overall outlines of the church design were surely determined by Hans Puchsbaum, who initiated its construction in 1443 before going on to take over leadership of the Stephansdom workshop in Vienna. Puchsbaum, however, likely foresaw simpler vaults than those seen in the choir today. The planning for the vaults is recorded in three drawings in the Vienna Akademie collection, which Hans Böker has persuasively dated to the 1460s, attributing them to Puchsbaum's successor Laurenz Spenning. Drawing 16.890v, which was executed on parchment, was probably Spenning's original vault design drawing, on which attention will focus here (Fig. 3). The nearly identical 17.052 and the more fragmentary 17.029 were copies drawn on paper. The scale match between all three versions provides reassuring evidence for the dimensional stability of Gothic drawings (Böker 2005, 203–05, 340, 367, and 25). Further refinements were introduced between the production of these drawings and the construction of the church's vaults, where new patterns are seen in the aisle bays. Adopting a "reverse-engineering" perspective, one can ask how the original planners of the church developed their designs, starting in Puchsbaum's case with a blank parchment. The surviving drawings, although likely produced during Spenning's tenure, provide valuable clues that help to answer this question.

The geometrical seed for the development of the Steyr design appears to have been the octagonal geometry of the main apse, whose overall scale was set by the span between the arcade axes; in the following discussion, the span from the building centerline to the arcade axis will be called 1 unit, for convenience. An octagon framed by the arcade axes thus has face-to-face radius of one unit. A circle circumscribed about this octagon will have a radius of 1.082 units, in accord with the previously described principle of "octature." As Figure 4 shows, this radius corresponds to the distance between the building centerline and the outside faces of the prominently indicated arcade walls in the drawing, while an octagon circumscribed about the circle describes the outer wall surfaces of the main

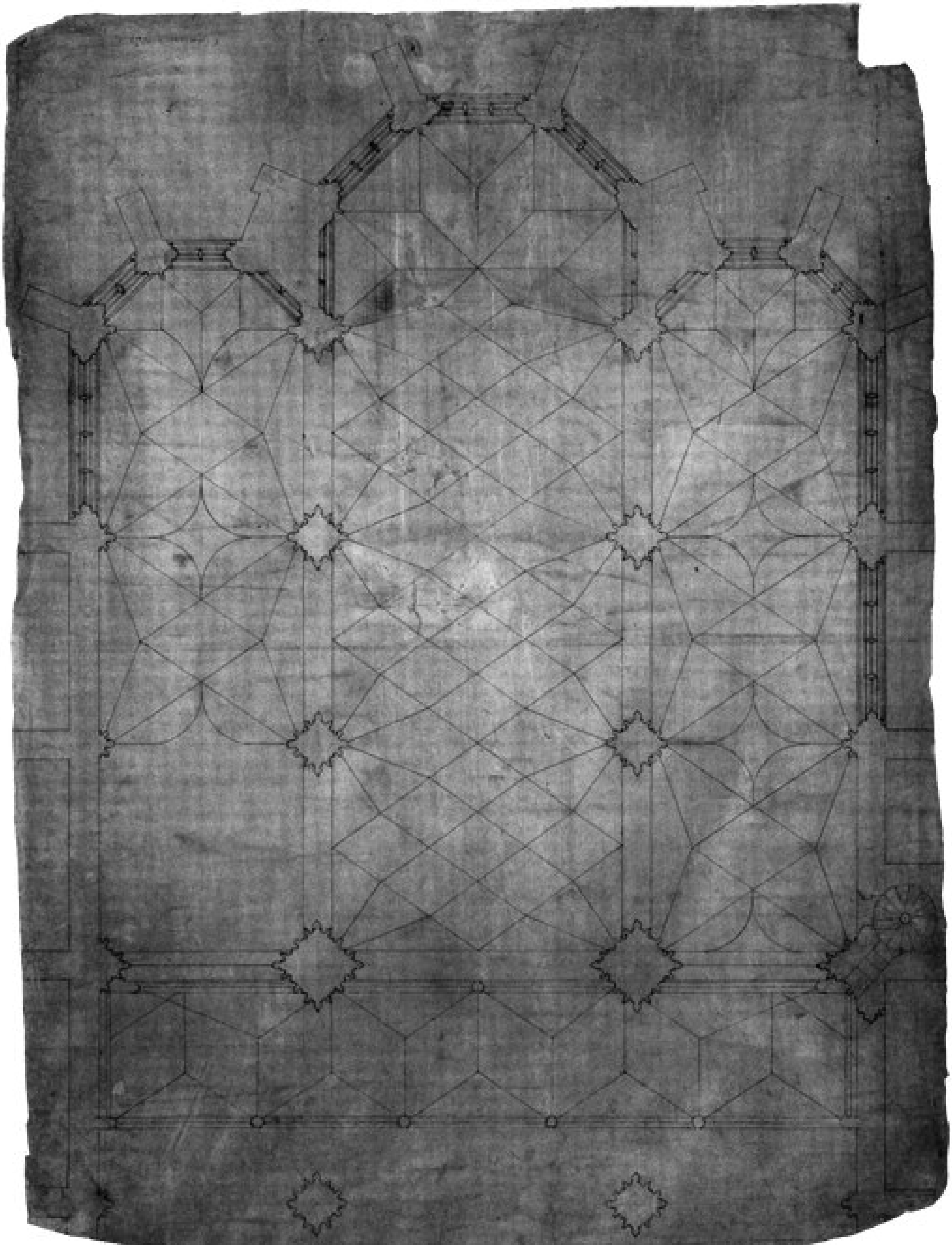

Fig. 3 Drawing 16.890v, showing the plan of the parish church of Steyr. Parchment, 75.7 x 55.5 cm.

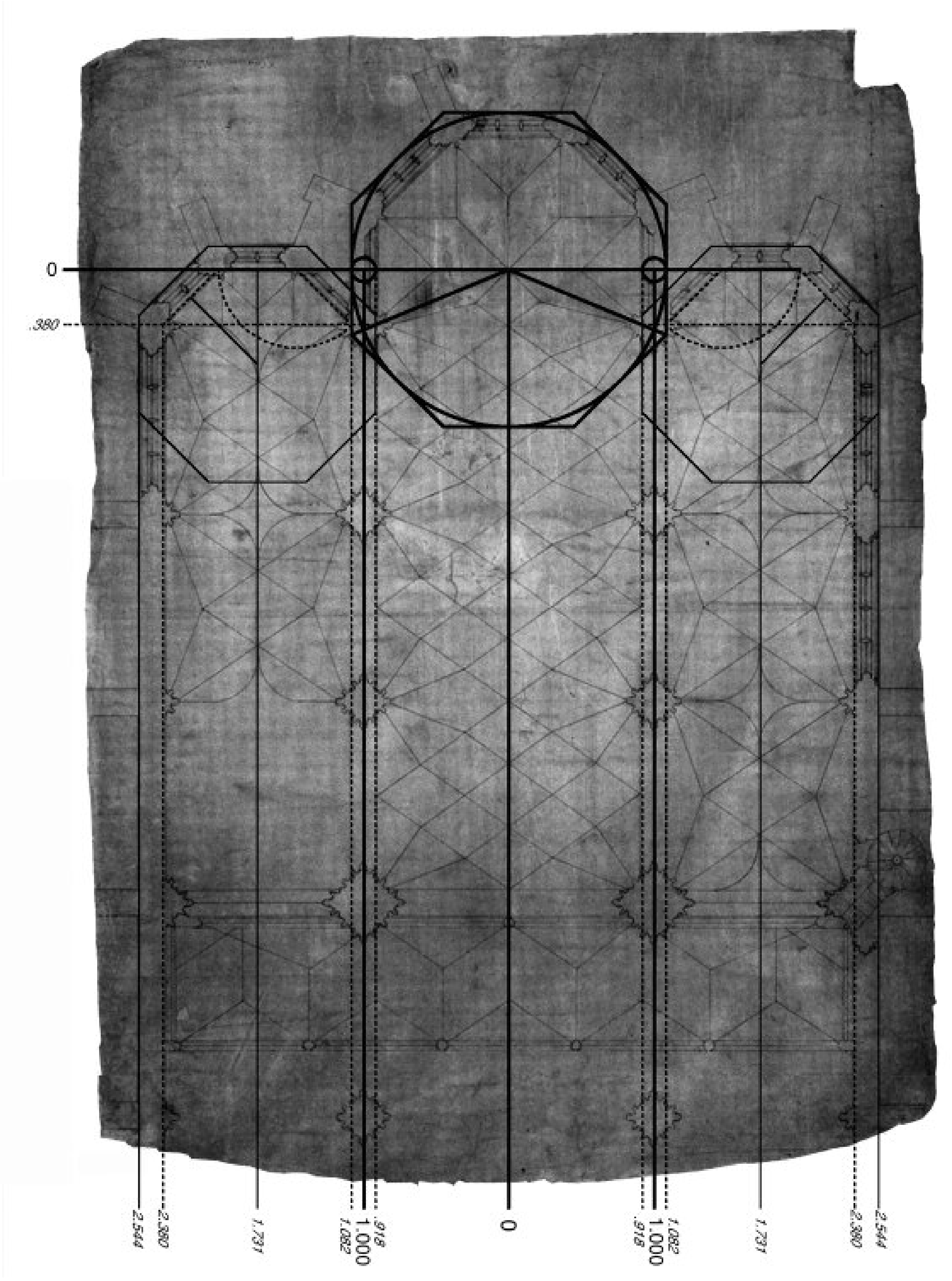

Fig. 4 Hypothetical sequence of early design steps in layout of the Steyr plan.

apse. Figure 5 shows how the overall outlines of the Steyr ground plan could have been developed in a series of simple geometrical steps starting from the east end. In each quadrant of the graphic, the older lines appear in grey, while the newly added lines appear in black. Figure 5a shows the basic octature figure of the apse, with lines extended westward to describe the arcade axes and outer arcade surfaces at distances 1.000 and 1.082 units from the building centerline, respectively. As Figure 5b indicates, the inner arcade surfaces are found by reflection about the arcade centerlines, at a distance of 1.000-.082=.918 units from the building centerline. The line describing this inner arcade surface intersects the ray of octagonal symmetry in the apse composition .380 units west of the octagon's center. If this interval is used to set the facet length in the octagons that define the apsidioles flanking the main apse, then the distance from the building centerline to their centers will be 1.731 units, and the distance to the inner faces of the apsidioles will be 2.380 units. Then, as shown in Figure 5c, the arcade wall thickness can be wrapped around each apsidiole, so that their outer wall surfaces will stand 2.544 units from the building centerline. A simple construction based on the geometry of the east end thus sets all the vessel widths and wall thicknesses. In the Steyr plan, all the bay lengths can be determined by counting equal intervals westward from the apse. As the south or right-hand side of Figures 5d and 6 show, a diagonal starting in the corner of the apsidiole can be bounced from the inside wall surface to the centerline of the apsidiole and back. The point of departure is .380 units west of the apse center, and the first, second and third bounces are 1.678, 2.975, and 4.273 units west of the center, respectively. The first two bounces locate the centerlines of the narrow ribs dividing the bays, while the third locates the eastern edge of the larger transverse arches separating the choir, whose walls had been built under Puchsbaum's guidance, from the nave, which was yet to be constructed when the drawing was made. Since these transverse arches have the same thickness as the walls, they span from 4.273 to 4.438, with their centerline 4.356 units right of the center. The first nave bays are shown slightly longer than those in the choir; more precisely, they are longer by half the width of the wall. The centerline of the first nave piers falls 5.818 units west of the apse center, where the diagonals of the bay intersect the midline of the outer walls, instead of being 5.736 west of the center, where the diagonals intersect the inner wall surface as they would be if the choir geometry were repeated exactly. The main divisions of the Steyr plan, therefore, can all be found fairly easily once the structure of the east end is established.

The wall and pier details evidently designed by Puchsbaum are quite simple in their geometrical structure, as Figures 6 and 7e show. The buttresses of the apse and apsidioles, for example, are perfect double squares in which the side length of each square equals the wall thickness, as measured along the sloping buttress axis. The piers are more complex in their details, of course, but each of them fits into a rotated square √2 greater than the wall thickness. The reinforced piers separating the choir from the nave are half again larger in side length. As the lower portion of Figure 7f shows, the western boundary of the choir screen in the first nave bay can be found by striking an arc from the midpoint of the freestanding reinforced pier through the midpoint of the first nave aisle bay, and swinging it up to hit the arcade axis, which it does 5.390 units to the west of the apse centerline. The margins of the screen are half as thick as the main walls, as the dark lines in Figure 7g indicate. The slope of the ribs in its vault can be found by striking a line from the pier center to the midpoint of this marginal strip, as shown in figures 6 and 7h.

Among the most prominent forms in the Steyr drawing are the high vault patterns evidently designed by Puchsbaum's successor Spenning. The geometry of the main apse vault, surprisingly, is among the simplest in the building. The corners to which the ribs of its star vault converge lie on the circle inscribed within the octagon of the apse's inner wall surfaces, which is shown in Figure 7e. Then, as seen in Figs 6 and 7f, the ribs themselves proceed from these corners parallel or at 45 degrees to the building axes, rather than proceeding directly to the apse center. In the straight bays of the main vessel, one set of lines forms an X subdividing each half-bay, while a second set forms a triangle with its base on the building's axis of symmetry. These two figures intersect to divide each bay into equal thirds, measured along that axis. And, as the lines added Figure 7g show, a smaller and narrower X within the middle third of each bay completes the geometrical armature to which all the ribs are aligned. Here, as in most Gothic buildings, the ribs converge to precise points on the piers, rather than to their centers.

The vaults of the side aisles, which include curved ribs, are perhaps the most complicated in the drawing, especially in their eastern terminations. The first step in the construction of the apsidiole vaults must have been to inscribe a circle within the octagon of their inner wall surfaces, as shown in Figure 7f. This circle also intersects the aisle centerline in a point marked with a small dot in Figure 6. Then, as seen in Figure 7g, a line departing from the shaft bundle at the first regular bay division, 1.678 units west of the main apse center, passes through that point and onwards to the midline of the bay. Reflection of this figure within each bay suffices to locate most of the straight ribs and their intersection points in the aisle vault. As in the main apse, the ribs of the apsidiole proceed out from this circle at multiples of 45 degrees, as shown in Figure 7h. But the curving ribs follow a slightly different structure. The easternmost curved ribs in the apsidiole vaults must have been constructed by locating their end points, con-

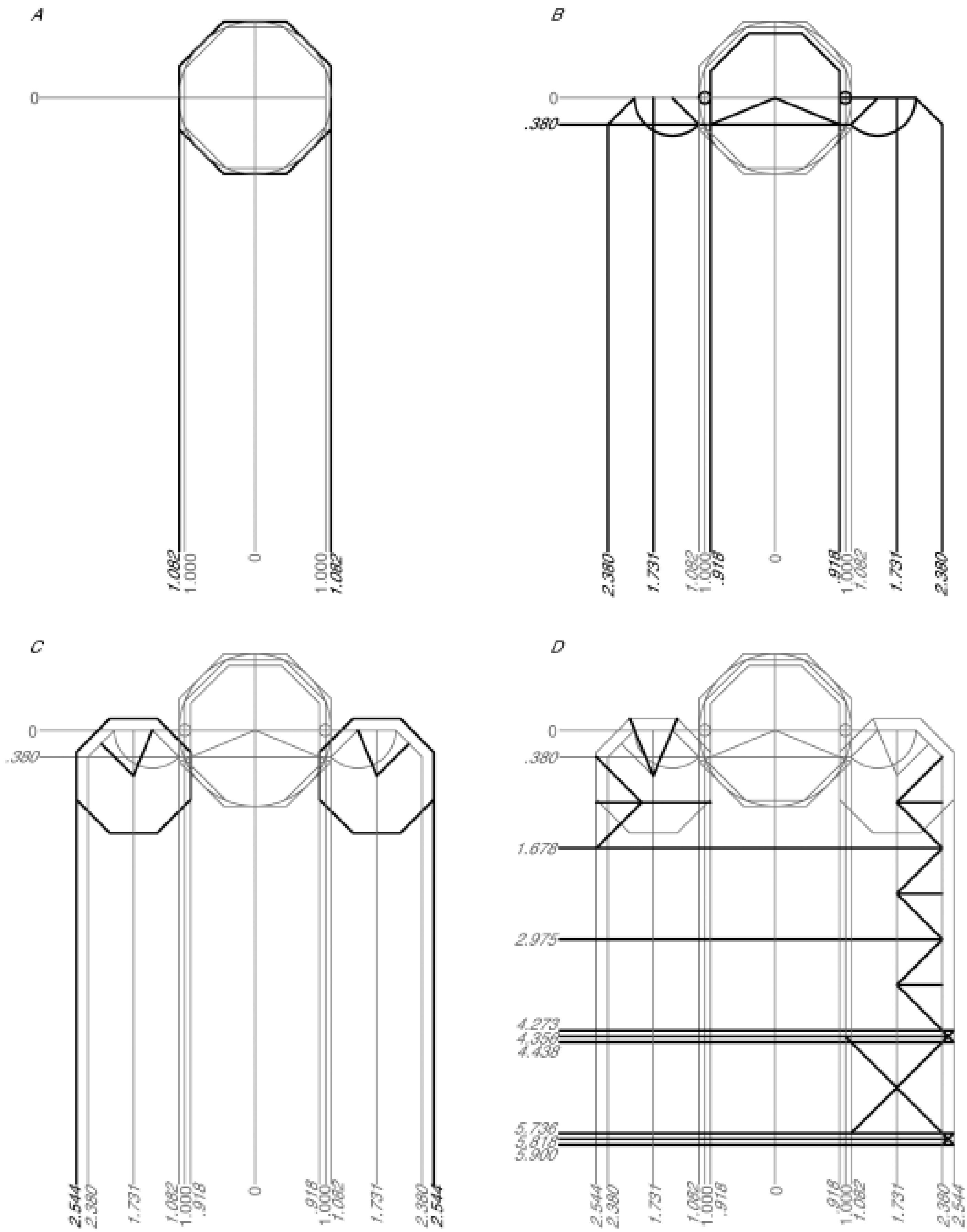

Fig. 5 Drawing 16.890v with overlay of early design steps.

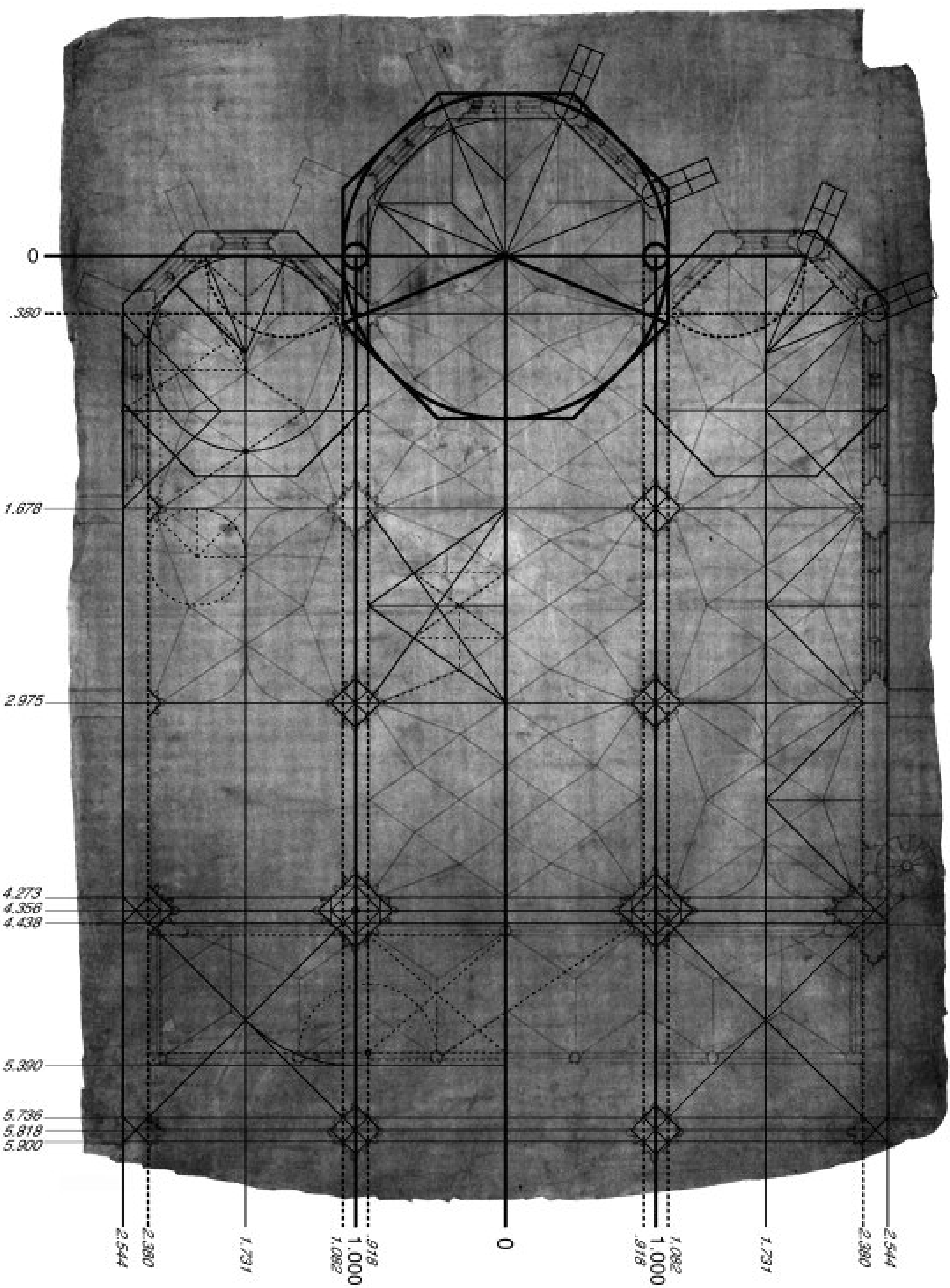

Fig. 6 Hypothetical sequence of early design steps in layout of the Steyr plan.

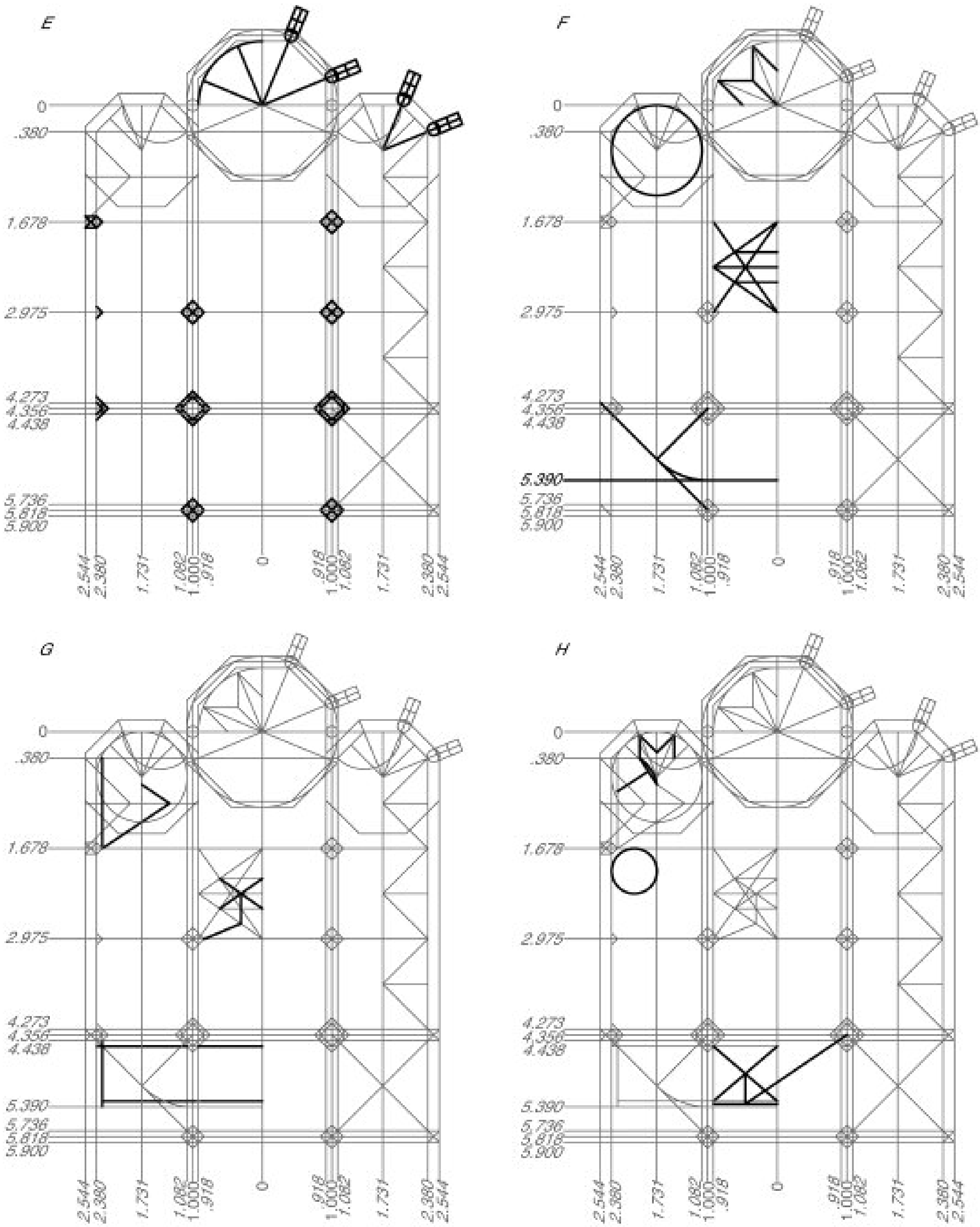

Fig. 7 Drawing 16.890v with overlay of later design steps.

necting their end points with a line like the dotted one shown in Figure 6, and then constructing a perpendicular to that line. The intersection of that perpendicular with the spatial envelope defined by the front edges of the wall shafts became the center point from which the arch was struck. The other curved ribs, which align with the piers, can be constructed more simply since their centers are the centers of each quarter-bay of vaulting, as the complete circles in Figure 6 and 7h indicate.

It is interesting and significant that these details of the vault shown in the Steyr drawing appear to have been conceived independently from the rest of the structure. The design of the walls, piers, and buttresses, which must have been established by Puchsbaum, depend only on the simple "octature"-based geometry of the apse, and its most direct unfolding into the aisles; these steps were already fully described in Figure 5 and Figure 6e. Within this overall framework, Puchsbaum's successor Laurenz Spenning was able to develop the curved ribs and other innovative vault details seen in the drawing. And, when the builders of the church finally got around to completing the vault in the years around 1500, they modified the design yet again, eliminating the curving ribs and introducing rectilinear lozenge patterns in their place. The mutability of the Steyr vault design calls attention to the way that vault patterns were becoming an increasingly free field for creative play in the fifteenth century. Historians of Gothic architecture have, of course, long recognized this general trend, but much work remains to be done in clarifying the more specific dynamics of this development.

III. Placing the Steyr results in context

The geometrical analysis presented in the preceding section represents just one small contribution to a scholarly conversation that can be fruitfully extended in several complementary directions. It would be useful, for example, to have comparable analyses of other closely related plan drawings. The Viennese corpus includes a number of fairly impressive and well-finished vault drawings like those for Steyr, or for the nave of the Stephansdom, along with many other humbler works showing only vault patterns, with no attention to wall articulation or other such concrete architectural details. Some of these may have been produced essentially as student exercises, as Hans Böker has suggested in his catalog of the Viennese drawings (Böker 2005). Even in cases where these plans cannot securely be identified with any known building project, analysis of their geometrical logic could help to shed valuable light on Gothic design practice.

These investigations of medieval plan drawings can be profitably extended by consideration of ground plans based on modern surveys of buildings for which no original drawings survive. It would be particularly interesting, for example, to trace in detail the manner in which vault articulation became increasingly free of wall articulation. In early Gothic design, of course, vault structures were generally quite simple, while the spatial perimeters of the buildings were often fairly complex. Already in the thirteenth century, though, English builders had begun to develop complex vault patterns, as at Lincoln Cathedral, and by the years around 1300 elaborate star vaults had begun to be installed in simply articulated brick churches of the Baltic region, such as the Cistercian abbey in Pelplin. In Bavaria a century later, Hans von Burghausen and his followers developed umbrella-like vaults that stand in arrays conceptually independent of the wall structure, creating what Norbert Nussbaum has called a container principle (Nussbaum 2006; Nussbaum and Lepsky 1999, 218–44). The Steyr vaults described above are less radical in this respect, and even the pioneering cell vaults of the roughly contemporary Albrechtsburg in Meißen do not really incorporate this principle, perhaps because in both cases the wall remained richly articulated. In later cell vaults like those of St. Mary's church in Gdansk, by contrast, the independence of the vault pattern from the nearly featureless brick walls is quite striking. It seems likely, however, that even these late and highly complex vault plans were developed in accord with a process of geometrical subdivision closely related to that seen in the Steyr vaults, especially those of the main choir vessel.

Many of the greatest challenges in the "reverse-engineering" of Gothic architecture, of course, involve grappling with three dimensional problems, even though the original designers appear to have worked largely in two dimensions at a time. Virtually all surviving Gothic design drawings were either ground plans or elevations, and the spatial proportions of Gothic structures appear in most cases to have emerged from the intersection of these two complementary planning modes. Only a few Gothic drawings depict vault curvatures, however, and even in combination with ground plans they provide incomplete information about the full three-dimensional contour of the surfaces in question. For this reason, the geometrically rigorous analytical approach described here for the case of the Steyr drawing can best be extended into the third dimension by careful measurement of actual building fabrics, using tools such as laser scanning that greatly increase the speed and precision of data gathering. Such work has already begun to reveal that Gothic builders at times used multiple radii of rib curvature in individual vaults, which had not previously been assumed (Müller 1989; Müller 1990; Wendland 2009). Another valuable perspective on the design process will continue to come from traditional hands-on archaeological approaches, which can reveal telling details of construction that purely geometrical or formal approaches cannot. All of these perspectives can help to inform the "reverse-engineering" of Gothic design, providing results that can be tested through the creation of new structures at full scale. Several exciting new initiatives of this type, including David Wendland's construction of new cell vaults in Saxony, have underscored the procedural quality of Gothic architectural design, in which forms arose dynamically both through the play of compasses at the drafting table and through the progressive installation of building materials at the worksite (Wendland 2012).

In sum, then, it becomes clear that a rigorous approach based on the idea of "reverse-engineering" can reveal a great deal about the Gothic design process. This point of view deserves particular attention because Gothic buildings emerged from an intrinsically dynamic design process; this means that Gothic architectural order has a very different quality than the more static and more readily understood order of classicism, which was more governed by fixed canons of proportion. The logic of this process has been poorly understood in the centuries since Vasari critiqued Gothic architecture for its seeming lawlessness, and the lingering influence of Konrad Hecht's polemical writings has chilled the climate for geometrical research for the past four decades, especially in the German-speaking world. With the recent flourishing of drawing-based research, building surveying, and full-scale constructional experiments, though, the future prospects for the study of Gothic design practice look bright.

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Abbildungsnachweis

Fig. 1 Geldner, Ferdinand, ed. 1965. *Matthäus Roriczer, Das Büchlein von der Fialen Gerechtigkeit; Die Geometria deutsch*. Facsimile of the first ed. Wiesbaden: Pressler. Anordnung der Grafiken von Robert Bork, Foto: Courtesy Guido Pressler Verlag.

Fig. 2, 5, 7 Graphic: Robert Bork

Fig. 3 Wien, Kupferstichkabinett der Akademie der bildenden Künste, 16.890v.

Fig. 4, 6 Wien, Kupferstichkabinett der Akademie der bildenden Künste, 16.890v. Graphic by Robert Bork