South German Late Gothic
Design and Building Praxis

A survey and ongoing parametric modelling study of Late Gothic vaults, chiefly in Swabia, Bavaria, Saxony, and Bohemia

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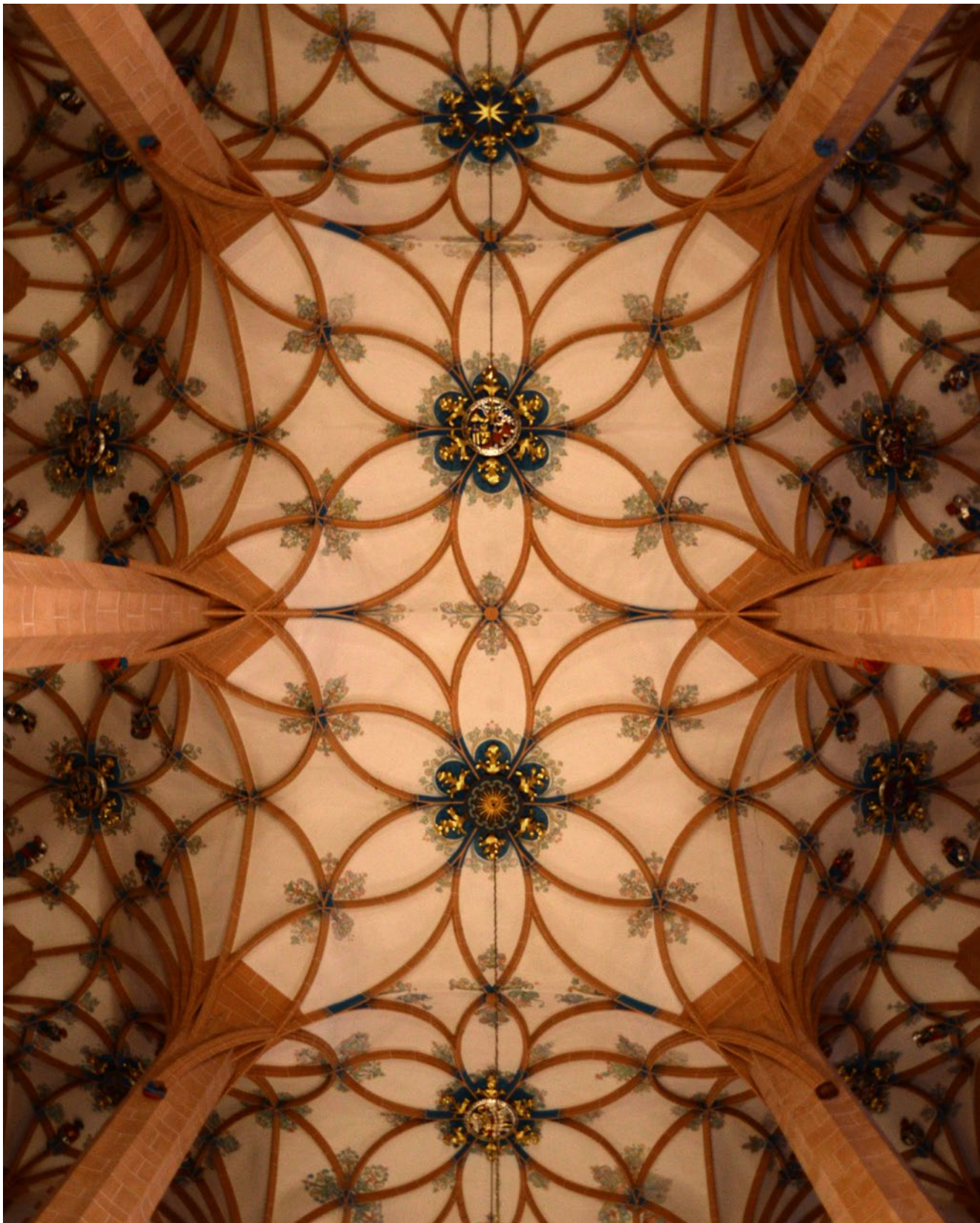

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Cover image: Vaults of St.-Annen-Kirche, Annaberg-Buchholz. Jacob Haylmann, 1517–25.

South German Late Gothic Design and Building Praxis

The aim of this research is to test hypotheses regarding the design and building praxis of German Late Gothic masons, particularly as applied to the execution of complex vaults

1

Introduction

This report documents a survey of Late Gothic vaults, mostly concentrated in Swabia, Bavaria, Saxony, and Bohemia and dating from the 14th to the mid-16th century, undertaken in the autumn of 2014. These rich and formally inventive figured vaults epitomise the German Late Gothic—particularly of the South—and are the output of a sophisticated tradition of strict but immensely productive rules of modular progression and procedural geometric form-finding, applied in the absence of what Renaissance and later architects might recognise as theory.

In the waning of the Gothic style, Ross Anderson has observed a "fundamental change in the nature of making, from a pre-theoretical understanding in the Middle Ages in which guilds and ateliers are embedded *in* culture, to a Renaissance shift of understanding to the liberal arts and the attendant emergence of theory and the self-conscious making *of* culture."[1] The German Late Gothic in particular was regarded by the architect and eminent historian of the Gothic Paul Frankl as the fullest expression of the design praxis which defined the style from the start.[2]

Included in the survey of seventeen buildings were the parish church of Schwäbisch Gmünd (begun in 1317, with a choir by Heinrich Parler) and St. Vitus Cathedral (of which Peter Parler was *Baumeister* from 1352), elements of which mark the inauguration of the German Late Gothic; as well as the Vladislav Hall (1493–1503, by Benedikt Ried or Rejt), also in Prague Castle, and St.-Annen-Kirche in Annaberg (vaulted by Jacob Haylmann between 1517–1525), which are amongst the highest achievements of the Late Gothic masons. A full list and map of the buildings surveyed can be found on pages 27–28. Spot level measurements of keystones in the vaults of selected buildings for which I have been able to obtain sufficiently accurate plans can be found on pages 91–108.

Though the work of Late Gothic masons—particularly German—remains understudied, recent research has cleared away some of the mysticism and wayward speculation which had clouded the subject, and arrived at new insights through: the hermeneutical study of rare and often overlooked primary sources in the form of drawings, lodge books, treatises or manuals, guild ordinances, contracts and accounts, masons' marks, floor tracings, and so on; the detailed measurement of Late Gothic architecture using modern surveying technology and subsequent analysis through physical and digital models; and experimental archaeology, particularly by reconstructing vaults at scales of 1:5 or 1:1 using tools, materials, and methods believed to be faithful to Late Gothic practice. While in Saxony, I had the great pleasure of meeting Dr. David Wendland of the Technische Universität Dresden, who has reconstructed a ceiling of prismatic (diamond, cellular or ribless) vaults found in the Albrechtsburg at a scale of 1:1, in the soft brick used in Mediaeval times. (See pages 23–26.)

Through this research, a picture has emerged of a practical body of craft lore perfectly attuned to the Gothic project; which was, in the words of François Bucher, "the spatial realisation and imitation of laws which were thought to govern the universe as well."[3] In it, we see a thoroughgoing emphasis on relative proportion and geometric interrelationships between constituent elements, and a radical lack of interest in absolute scale until the last moment in the design process, when some length

1 Shrine of St. Sebaldus, Sebalduskirche, Nuremberg; Peter Vischer the Elder and sons, 1508–19

had to be assigned to the module which governed the whole design (such as the width of the choir). This is because measurements were considered to be "dirty within the context of geometry which is an affair of forms in the mind", "*ars*" rather than "*scientia* ... which buttressed the most deeply seated creative philosophy of the great architects."[4] But it must also be because of the architects' tools to hand. Elsewhere, Bucher warns that "[w]e cannot allow ourselves to forget that the architect's primary tools consisted of a straight-edge, a square, a compass, and a divider." "Rules including the construction of any inscribed polygons were based on the use of these instruments. Thus we almost always deal with design precepts which had lost any connection with theoretical geometry or mathematics."[5] In the Late Gothic, this process yielded a style of fractal scalelessness which privileged formal inventiveness over gigantism, and culminated in the detail of baldachins, finials, and column bases; in micro-architecture such as sacrament houses, pulpits, and tabernacles; in figured vaults; and typically not in the buildings themselves as it were, which, "in a strange reversal of reference, became mere shelters for micro-architecture."[6]

The aim of this project is to test hypotheses regarding Late Gothic design and building praxis, particularly as it was applied to the execution of complex vaults. The survey documented in this report will serve as the basis for an ongoing model-making study, in which parametric definitions of vaults will be created which capture the procedural logic of Late Gothic designs rather than only represent their formal outcome. Besides being an aid in efficiently testing various hypotheses on how a given form was arrived at, parametric modelling can generate a speculative range of design options from which a Late Gothic mason might plausibly have chosen, which may yield insights into his design priorities. Particular attention is paid to the *Prinzipalbogen* (principal arc technique), a method of deriving the three-dimensional form of vaults based on a two-dimensional plan without projecting points in the plan onto a predetermined regular surface. Digital proof-of-concept models are used to demonstrate the potential of research-by-model to 'reverse engineer'[7] Late Gothic vaults and identify where the *Prinzipalbogen* or other form-finding techniques have been used, how these techniques helped the masons efficiently negotiate complex formal and construction problems, and how difficulties posed by the application of these techniques were resolved.

A more general benefit of this research will be the insights it may offer into "one of the fundamental architectural dilemmas: the difficulty of being both certain and free." Anderson writes, regarding the rules of Gothic design, that "[e]very rule carries with it the eventual prospect of reduced liberty, a tension constituted in the dialogue between conditions and possibilities."[8] This is as true of design today as it was in mediaeval times.

This report, interactive panoramas of the surveyed buildings, and future models and findings will be published to: http://spaetgotik.org

2

The German Late Gothic

This report is concerned with Late Gothic vaults in southern German and Czech lands built between the early 14th and mid-16th century. These vaults belong to a coherent and unique Late Gothic readily differentiated from other national Late Gothic styles such as the French Flamboyant or English Perpendicular, though German masons were substantially influenced by contemporary developments in English vault design.

The style is generally reckoned to have been inaugurated by the Parler dynasty of masons: in particular, by Heinrich Parler's work in the parish church of Schwäbisch Gmünd (begun in 1317),[9] and his son Peter Parler's innovations in St. Vitus Cathedral in Prague Castle, where he was *Dombaumeister* from 1352. Nevertheless, these examples should be treated as symbolic markers, as the transition from High to Late Gothic in German lands was less marked than in France or England.[10] Dating the end of this stylistic period is an even more fraught exercise, as is defining its geographical limits.

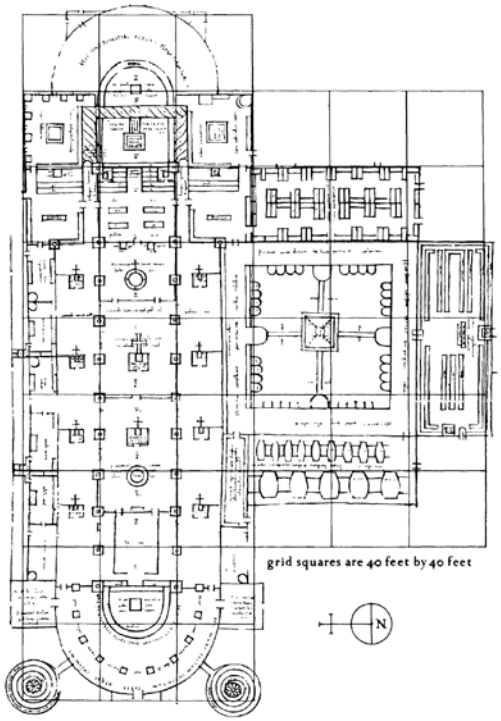
For the purposes of this report, the unsatisfactory label "the German Late Gothic" will be used to refer to this style, in recognition of its importation to Czech lands by the Parlers (of Swabia before they were known as the Junkers of Prague) its prominent development in Bohemia by Benedikt Ried (or Rejt, now generally regarded to have been a German fluent in Czech)[11] and by Anton Pilgram (an Austrian) in Moravia. Bohemia in particular was home to a significant minority of ethnic Germans until modern times, despite the Hussite Wars of 1419–1434 which pit (Bohemian Czech) Hussite armies against often German crusaders.

The label is unsatisfactory because it excludes contributions made to the style by Czech masons (as well as those of other Slavic cultures) such as Matěj Rejsek (1445–1506), whose work includes elements of the Powder Tower in Prague (1478–1483) and St. Barbara's Church in Kutná Hora (1489–1506); as well as eliding distinctions between the Late Gothic of the northern and southern German lands. The North, where stone was scarce, was the territory of the Brick Gothic (*Backsteingotik*). As Bartel Ranisch's documentation of vaults in Danzig[12] cited elsewhere in this report shows, complex and characteristically Late Gothic vaults were to be found in the North as well, but this report is primary concerned with examples in Swabia, Bavaria, Saxony, and Bohemia, where the most developed figured vaults are generally clustered. It should be noted however that a study of prismatic vaults in particular would warrant a wider remit, to include lands further North and East including on the Baltic. It was also not uncommon for German masons to travel further East than Bohemia to destinations such as Buda, where Benedikt Ried likely received his training.

Finally, even the order of the words "Late" and "German" are significant, as "Late German Gothic" emphasises the continuity of the German Gothic tradition, whereas "German Late Gothic" situates the style as a local instance of the International Gothic. There is truth in both nuances.

High and Late Gothic

Certain tendencies differentiate the High Gothic, whose home is the Île-de-France, with the more international Late Gothic generally. These include an increasingly profuse articulation of details such as column bases and



2 "St. Gall, plan, detail (after W. Horn)." In: François Bucher, "Medieval Architectural Design Methods, 800–1560," *Gesta* 11, no. 2 (1972): 37.

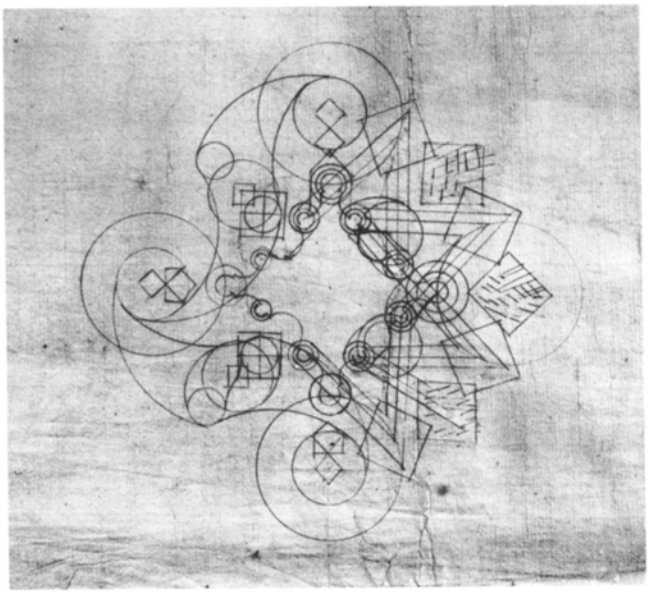
cross-sections, baldachins, finials, and other sculpture; a turn towards micro-architecture such as sacrament houses, pulpits, and tabernacles and away from formal innovation in the church itself, as it were, except in vaults; a naturalistic turn in ornament, particularly in the mature Late Gothic; an investment of creativity in the design of increasingly complex vaults, particularly in German and Czech lands, and sometimes at the expense of the articulation of the exterior; and increasingly sophisticated but in some ways more relaxed rules of geometric progression.

In the Late period, Gothic design praxis based on modular progression and procedural geometric form-finding appears to have reached its final culmination. Relative proportion and the geometric interrelationships of constituent elements enjoyed primacy over absolute scale, producing an especially scaleless and fractal Gothic in which the human body was theoretically incidental. It would be speculation, but not so far from the truth, to describe Late Gothic masons as working towards a vision of an ideal architecture governed by a divine geometry which could be manifested at any scale but only ever approximated in stone. Bucher has suggested that "to exaggerate one might say that a single finial preserved from a crumpled tower could suffice for a reasonably close reconstruction of the total structure, provided its position within the system were known."[13]

Bucher also makes a distinction of particular interest to this report between "additive" and "dynamic" modular progression.[14] The additive approach is epitomised by the plan of St. Gall (ca. 817–23), an early Gothic plan of a hypothetical ideal cathedral which evinces "square schematism,"[15] and in which, for example, the width of the dormitory beds can be derived by halving the basic module (the square defining the crossing of the church) four times.[16] The dynamic modular progression used to design more complex Gothic structures is instead characterised by the procedural rotation and inscription of squares and other polygons. This dynamic mode of design, more evident in the Late Gothic, can yield results of mystifying complexity. The additive approach generally produces round multiples of the building's module, whereas the dynamic approach will result in irrational factors and dimensions. That the masons considered the "arithmetic implications … irrelevant"[17] is significant.

> *Before late Gothic construction began, the parts of the building were carefully correlated. The procedure was based on the standard practice of a derivation from each other of lengths, shapes of profiles, mullions, etc. in a logical sequence. About fifty preserved drawings explain this process, which was highly complex and is not yet clear in spite of the fundamental work by Paul Booz. Sequences of parts based on a master square from which every structural and decorative member was derived were a part of every late Gothic sketch book, and were also kept in lodges for educational purposes.*[18]

Of the "over 2,200 mediaeval plans and designs as well as theoretical treatises and working drawings"[19] Bucher studied before writing the paper quoted above, only "about a dozen"[20] contained a scale. Bucher continues:



3 (Right) "Initial check for a tabernable. (Vienna Akademie)." In: François Bucher, "Design in Gothic Architecture: A Preliminary Assessment," *Journal of the Society of Architectural Historians* 27, no. 1 (1968): 67.

The geometric systems had many levels. They governed the making of template and thus the mason's chisel. They provided the grid on which plans, elevations, and details evolved and thus also the means to re-experience the creative process at will.

Each of the systems produced a logical, repeatable, and reasonably flexible approach, controlled by the unchanging laws of geometric progression. Thus planning also reflected the absolute order of the world as represented in cosmological schemes showing inscribed figures representing the orderly perfection of the universe."[21]

The Late Gothic in German and Czech lands

The German Late Gothic is set apart from other Late Gothic styles by its unusual emphasis on formally and structurally complex figured vaults as a primary medium of a church's expression, and perhaps to some extent by the hall church (*Hallenkirche*) type, in which transepts and clerestories are eliminated and the vaults of the nave and aisles are made level or nearly level with each other. These features are epitomised in St.-Annen-Kirche in Annaberg, vaulted between 1517–25 by Jacob Haylmann, who was *Baumeister* from 1513 and a pupil of Benedikt Ried. The double-curved ribs of its looping floral vaults, which reprise those of the Vladislav Hall and St. Barbara's in Kutná Hora, are particularly emblematic of the Late Gothic in German and Czech lands.

The style in question was the subject of Kurt Gerstenberg's 1913 work, *Deutsche Sondergotik*, or *German Special Gothic*. In it, Gerstenberg argued that the style was decisively defined by a sense of unified space (*Einheitsraum*) unique to German *Hallenkirchen*. In the words of Paul Crossley, Gerstenberg "evoked an essentially non-European and Nordic racial identity as the driving spirit of German creativity." "His nationalist stereotypes—Germanic 'slowness,' 'irrationality,' and a sense of the 'limitless'—all of them quintessentially embodied in the picturesque spaces of the German hall church, struck a deep, atavistic chord in German art historiography in the interwar years."[22] The label "*Sondergotik*" has fallen sharply out of use since the Second World War,[23] and Gerstenberg's work has been substantially criticised as a nationalist project based on cherry-picked examples.

Crossley and Kavaler give much credit for this revaluation of Gerstenberg to Norbert Nußbaum and his seminal *German Gothic Church Architecture* of 1994. But the difficulty of drawing lines through Central European history is made quite apparent upon reading Hans Böker's much more critical review of the English translation. Conceding the importance of the Nußbaum's work in recovering the German Late Gothic from obscurity, Böker finds Nußbaum's criticism of Gerstenberg tepid, and levels a damning accusation at Nußbaum for his "exclusive use of German place-names without an indication of their present official form—especially for the eastern regions of today's Poland and the Czech Republic (the sole exception is Gdansk)—[which] makes one suspect that it was the pre-1945 *Reich*, and not the present understanding of a 'Europe of regions,' that still provides, at least subconsciously, the boundaries for the book." Böker acknowledges, "[a] definition of what constitutes German Gothic architecture is not at all clear as it might appear."[24]

3

Historiography

4 (Previous page) Adam Kraft's sacrament house (1493–96) in St. Lorenz, Nuremberg

Until recently, the German Late Gothic has received short shrift from architectural histories. This is of course especially true of anglophone histories, as much research conducted in German remains untranslated, let alone in Slavic languages including Czech. There are many reasons for this neglect, including the practical impossibility of conducting a comprehensive survey of churches and archives before the reunification of Germany and collapse of the USSR; the sheer complexity of the patchwork of semi-autonomous territories which made up the Holy Roman Empire and German-speaking world, which discourages study much as the Byzantine empire or the wars of Alexander's successors do; the dearth and obscurity of primary sources; and as the preceding description of the difficulties in naming the style will have shown, the fact that the historiography of the Gothic in Central Europe is tangled in a nettle of nationalisms.

A more general reason must be the disrepute heaped upon the whole of the Gothic during, immediately after, and periodically since the Gothic era to this day, when our attitudes to ornament still echo those of Adolf Loos. Historians have recently abandoned Jacob Burckhardt's characterisation of the whole mediaeval period as a series of "Dark Ages," but his seminal work of 1860, *The Civilisation of the Renaissance in Italy* (*Die Kultur der Renaissance in Italien*) established still-productive historiographical categories which continue to cast a long alpine shadow over the Gothic.[25] And what can be said of the Gothic generally applies doubly to the *Spätgotik*, labouring as it does under the label of being a "late" period; which is to say the baroque afterlife of something greater; overwrought, excessive, and loose of principle. Even that deeply insightful and prolific scholar of the Gothic François Bucher has referred to the Late Gothic as a "defensive phase … directed against the planar purity of Renaissance architecture"[26] and the chapel vaults of Ingolstadt as symbolic of "the last stand of a dying style."[27]

The title of Ethan Matt Kavaler's *Renaissance Gothic*[28] (2012) is a "provocative oxymoron"[29] which brings attention to the coexistence in time and place of Renaissance (what might then have been referred to as antique, or *Welsch* in German) and Late Gothic (modern) architecture. The corrective is necessary because Burckhardt's prevailing narrative of the Renaissance as a revolution of paradigms tends to preclude consideration of the innovation on tradition which was occurring at the same time. Many artists and architects who are identified with the Late Gothic (such as Benedikt Ried and Erhard Heydenreich) or the Renaissance (such as Albrecht Dürer and Jacob Haylmann) worked "concurrently in both manners,"[30] as attested to for example by the Ludvík Wing by Ried (recognised as the first example of Renaissance architecture in Bohemia, built between 1503–1520 adjacent to Vladislav Hall, built between 1493–1503) and Dürer's sketchbooks and *Four Books on Measurement* (*Underweysung der Mesung*), in which he illustrated and cited as an exemplar of design a Late Gothic vault as well as treating Ptolemy, Vitruvius, and the ideas of his Renaissance contemporaries.[31] St.-Annen-Kirche in particular is widely regarded as stradling the Late Gothic and Renaissance.

Kurt Kaser, writing in the years preceding the First World War on the status of the individual in mediaeval society, even argued that "the picture that Jacob Bernhardt

5 (Left) "Reconstruction of Troy, Jean Colombe, *Recueil des Histoires des Troie* (Min. 632). Kupferstichkabinett, Staatlichen Museen, Berlin." In: Alain Erlande-Brandenburg, *The Cathedral Builders of the Middle Ages*, trans. Rosemary Stonehewer (London: Thames and Hudson, 1995), 88. "By the end of the 15th century the era of great cathedral-building was finished, but artists were fascinated by the grandeur of Gothic building sites."

drew of the civilization of the Renaissance in Italy may be traced step by step in Germany."[32] Kavaler has detected tendencies in Late Gothic architecture which lend some credit to this argument:

> *The effects of this [Late] Gothic were also far more dependent on the role of the observer. Ornament was frequently used to fashion visual puzzles that offered satisfaction to viewers able to resolve them. Claude Lévi-Strauss has claimed that the true invention of the Renaissance was not the modern artwork but rather the modern viewer. Art of all media was increasingly predicated on the role of the beholder with a distinct perspective outside the work. Intentional ambiguity becomes ever more pervasive as the viewer is required to sort out visual clues much as in solving a riddle. Jürgen Julier has detected a kind of visual joke or irony in the very late Gothic ornament of the Upper Rhine, of changing lines of orientation and shifting patterns. Robert Bork and Linda Neagley have discussed scenographic effects in the Late Gothic architecture of Metz and Rouen, again dependent on the viewpoint of the observer. One might very generally point to the spread of a perceptual model in fifteenth-century painting, the optical effects initiated by van Eyck and his contemporaries. All of these phenomena are related to the increasingly greater burden placed on the observer, on the consequently greater valuation of the individual, and the concomitant role of the subjective.*[33]

Putting aside the question of who might have been excluded from that group of viewers capable of resolving the mason's visual puzzles, Kavaler's observation suggests a hypothesis: that the Renaissance was not wholly responsible for the humanistic individualism attributed to it, and that humanistic individualism had recourse to an architectural idiom besides the classical adopted by Renaissance architects.

Nevertheless, it remains the case that Renaissance principles were never reconciled with the Gothic, and that the Renaissance from its beginning was a reclamation of classical principles against the modern. Though the Gothic style survives to this day, merely being in competition with another world-view deeply undermined its authority—and that of the Gothic cathedral in particular—as the "material reality in which the totality of meaning was embodied." Ross Anderson has observed in this period a "fundamental change in the nature of making, from a pre-theoretical understanding in the Middle Ages in which guilds and ateliers are embedded *in* culture, to a Renaissance shift of understanding to the liberal arts and the attendant emergence of theory and the self-conscious making *of* culture."[34] This represented a disruption of what Anderson terms the "deep metabolism of the medieval town", or the "genuine continuity between articulated and embodied levels of medieval culture."[35] Certainly after the Enlightenment, it was "impossible to reconstitute Christianity as a central collective order, with the result that all meaning was sought in culture."[36]

The "pre-theoretical" nature of Gothic building praxis is one of the reasons the masons gradually lost their cultural authority—and clients—to Renaissance architects who had recourse to explicit, rationally defensible theory and

6 (Right) Jan van Eyck, *Saint Barbara*, 1437. Wikimedia Commons

modes of architectural representation easily understood by laypeople. On this trend, Lon R Shelby writes:

> *Some of [the Late Gothic masons' craft lore] began to disappear in the sixteenth century because of a fundamental shift in the role of the mason's craft in the art of building. A new style of architecture was spreading across Europe from Italy, and there was coming into being a new type of architect to promote and develop this style. He often came from a social class higher than that of the building craftsmen, and he need not have served an apprenticeship in one of those crafts. As the social and professional status of the architect rose, the masons' craft as a whole gradually dropped into the role of serving merely as builders for the architect. These changes were accompanied by a shift in the educational goals and methods that prepared men for the art of building.*[37]

By Late Gothic times, a stereotype was already established of white-gloved mason-architects who no longer dressed stone and may have been habitually absent from site, supervising projects elsewhere.[38] But the "new type of architect" Shelby refers to had softer hands still, and bypassed the hierarchy and pedagogy of the lodges (*Bauhütten*) by consulting the growing body of architectural theoretical literature directly.

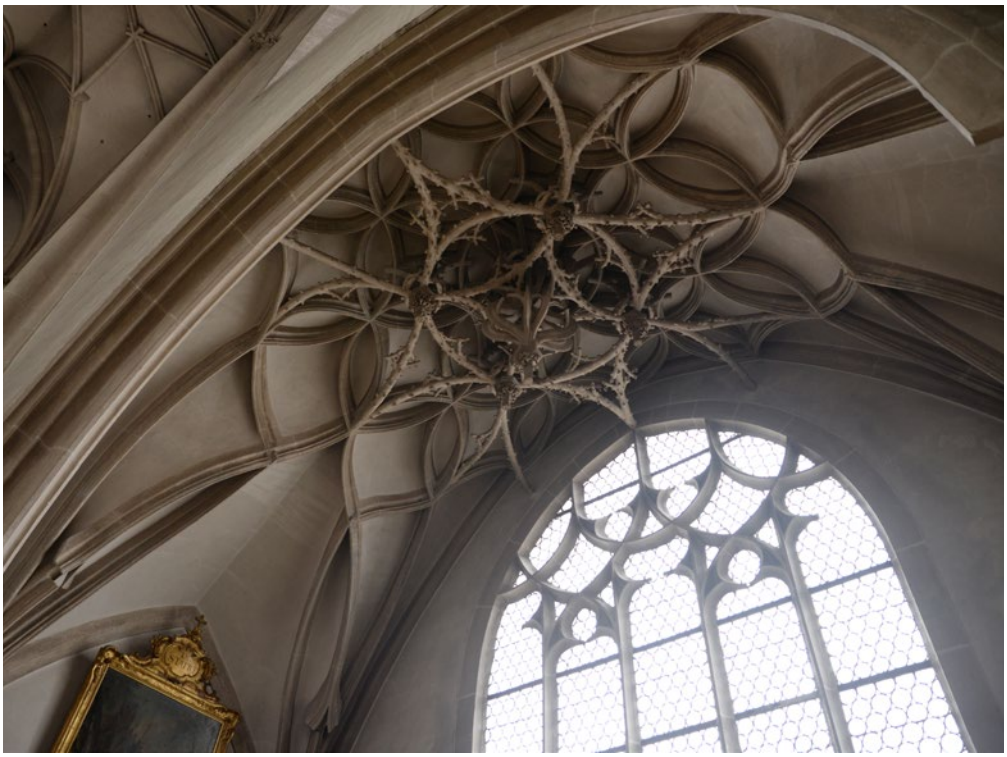
The masons remained unable or disinclined to defend their work in the same terms, which is another reason their design and building praxis remains as murky as it does today. The obfuscation of 18th century Freemasonry[39] and over-speculation by modern historians on a small number of primary sources have muddied the picture further. On this point, Robert Bork writes that:

> *Geometric 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 justified conclusions from the flights of interpretive fancy.*

Bork cites Walter Thomae, Paul Frankl, and Konrad Hecht as important critics of this body of research, and suggests that Hecht, "whose writings have exercised a chilling influence on the field [of geometric analysis of the Gothic] in the four subsequent decades [since the 1970s]", may have been "eager to challenge the nationalist legacy of geometrically-minded scholars like Otto Kletzl, who had enjoyed a favoured position in the Third Reich."[40] Their criticism reinforces the importance of turning to primary sources and detailed modern surveys of extant churches.

Sources

The limited body of primary textual sources related to (Late) German Gothic building praxis include: masonic craft ordinances generally dating from 1475 to 1525, and particularly the Regensburg Ordinance of 1459; the booklets of Mathes Roriczer, a mid-15th century *Dombaumeister* of Regensburg belonging to an important dynasty of masons, on the design of pinnacles (1486), gablets, and geometry (both between 1486–90); a booklet by Hanns



7 (Left) and **8** (Next page) A chapel vault in the Liebfrauenmünster, Ingolstadt, Erhard Heydenreich, c. 1510–1520

Schmuttermayer, who was most likely a goldsmith, also on pinnacle design (c. the 1480s);[41] the *Wiener Meisterbuch* (*Viennese Masterbook*) of the later 15th century; a book by an unknown author dating from c. 1500 titled *Von des Chores Maß und Gerechtigkeit* (*On the Measure and Correctitude of the Choir*); Lorenz Lechler's *Unterweisungen* (*Instructions*) of 1516; the *Baumeisterbücher*, folios of drawings from the 15th and 16th centuries which often contain idealised plans and sections of chapels for the purposes of training masons, an example of which is the *Stromersches Baumeisterbuch*[42] by Wolf Jacob Stromer (1561–1614), a *Ratsbaumeister* of Nuremberg, cited on pages 18–19; the *Codex Miniatus 3* (c. 1560–70), also known as the *Dresden Sketchbook of Vault Projection* and the "only contemporary document exclusively devoted to describing the construction of Late Gothic ribbed vaults;"[43] and a collection of 428 Gothic architectural drawings at the Akademie der bildenden Künste in Vienna, once the collection of the Vienna *Bauhütte*. Bucher, writing in 1968, described the Viennese collection and other Gothic drawings as having been neglected by historians, and the projection of vault plans into the third dimension as being one of the "most important and highly complex lodge theories."[44] Very likely, these drawings still warrant further hermeneutical and geometric analysis.

4

The Secret of the Masons

The art of translating two dimensional plans into three dimensional form was once believed to have been a guarded masonic secret. The chief source cited in support of this claim is the Regensburg Ordinance of 1459, which established a masonic brotherhood (*Bruderschaft*) pledged to uphold the articles of the ordinance. One oft-cited article in the ordinance reads:

> *If someone wants to undertake stonework with measure* (Maß) *or an extrapolation device* (Auszug)*, which he does not know how to take out of the base plan* (Grund)*, and he has not served a workman nor enjoyed lodge promotion, then he should not in any way undertake the task. However, if [that] one determines to undertake such, then no journeyman should stand by him or support his appointment.*[45]

Rather than reserving the technique as a secret, this article establishes a standard of certification and implicitly recognises that a journeyman would have known the technique, which he would have had to in order to judge whether a designer under which he worked knew it also.[46] This is confirmed more explicitly in another article:

> *Item, no workman, master, under master, or journeyman should instruct anyone on how to take the extrapolation device from the base plan—anyone that is to say, who is not of our handicraft.*[47]

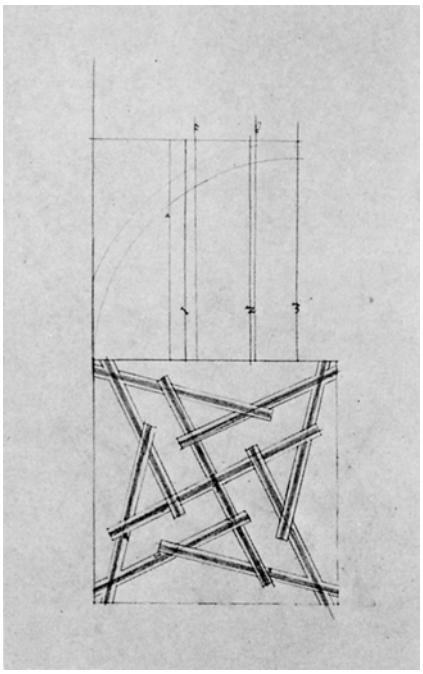
Shelby writes that it is "highly significant that the distinction was not between those who were members of the *Bruderschaft* and those who were not,"[48] and argues elsewhere that the masons, "until at least the very late Middle Ages," lacked the "institutional machinery for preserving technical craft secrets."[49]

The thorough integration of other crafts (such as carpentry and goldsmithing) in cathedral building necessitated by the fractal scalelessness of Late Gothic architecture also suggests that craftsmen besides the masons would have had to understand the skill of projection and other geometric procedures underpinning the collective work, which helps put to rest questions about how Hanns Schmuttermayer (likely a goldsmith) was able to describe the techniques in his booklet. In fact, as has been noted earlier, some of the most spectacular achievements of the Late Gothic besides vaults are instances of microarchitecture, such as the Adam Kraft's sacrament house in St. Lorenz, Nuremberg (1493– 96, pictured on page 6).

The Prinzipalbogen

In a recent paper documenting the spread of German Late Gothic design and construction techniques to Spain, Rafael Martín Talaverano et al introduce the *Prinzipalbogen*, or principal arc technique, thusly:

> *The construction of the form of German ribbed vaults is based on three different procedures. … The first and second ones rely on a previously determined regular surface on which the vault plan is projected, giving the position of the keystones and defining the form of the vault, which is independent of the plan.*
>
> *In the third method* (Prinzipalbogen)*, the control of the height of each point of the plan is done by means of a semicircular arch, which is not necessarily a rib*



9 "Dresden Sketchbook, fol. 10 verso." In: François Bucher, "Medieval Architectural Design Methods, 800–1560," *Gesta* 11, no. 2 (1972): 37.

> *of the vault. There is a relation between the rib plan and the form of the vault, but the same vault plan can result in different vault forms, depending on the* Prinzipalbogen *chosen, and on a certain number of decisions that the masons must make.*[50]

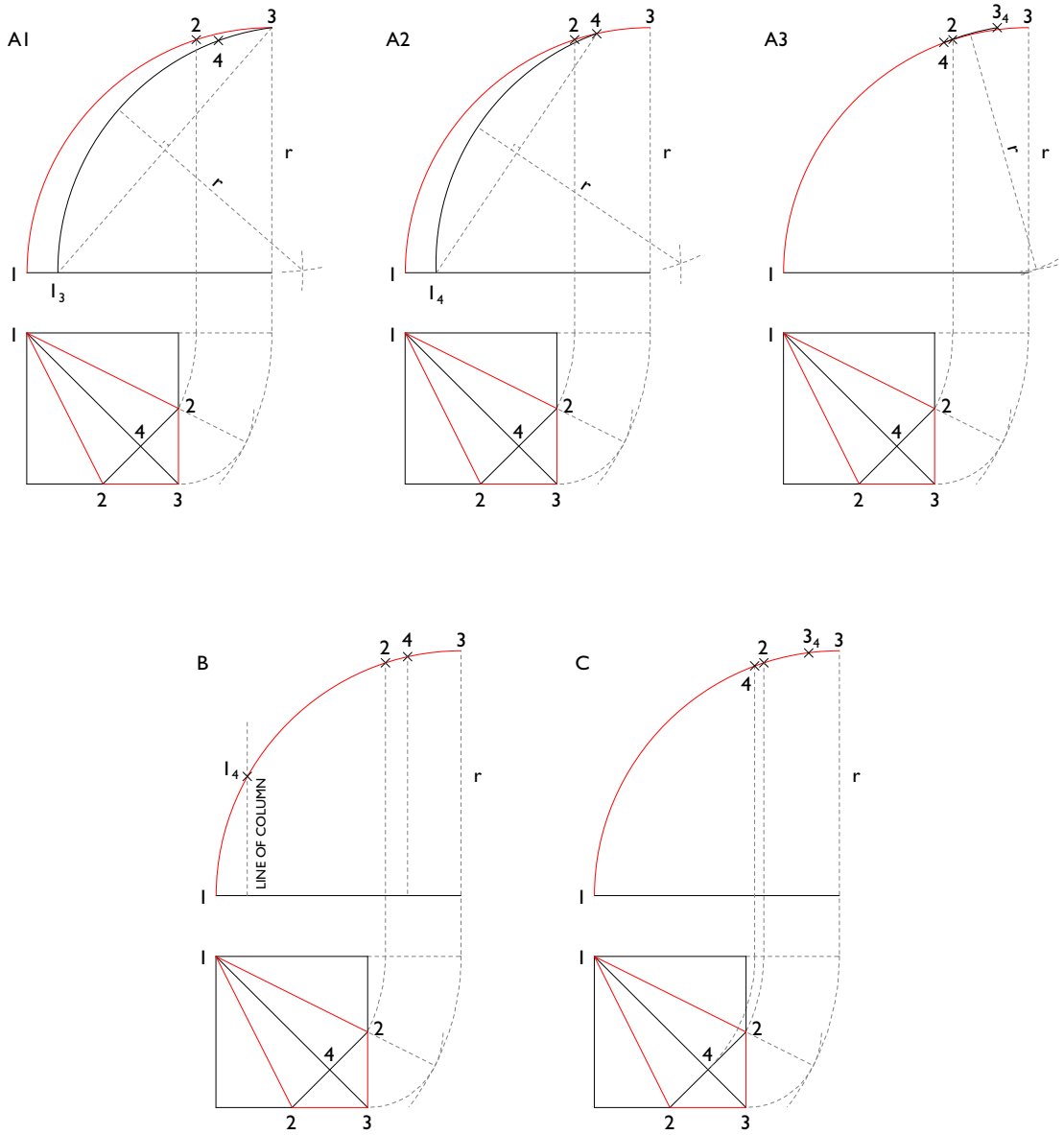
This relationship was described by Bucher in 1972:

> *The Dresden Sketchbook of vault projection of ca. 1544–67 explains the procedure which has been sufficient tested in models to have proven foolproof and fundamentally simple. The system works, though no one has yet been able to explain the theory behind it. Fol. 10 verso* [Figure 9] *shows a net-vault in plan with numbered rib intersections .... The steps for planning and construction are the following: The design is based on the rotation of the square. The letter a is seen on one rib, and on another rib, still in the lower left region the roman numeral I. Following the same rib we arrive at arabic 2, and turning sharply left at 3. This is the highest point in the vault. The distances between these points represent the longest possible route to the apex without backtracking. They are transferred to the top line of the square and provided with upward vertical lines. Added together they determine the center for a quarter circle. Transferred to the tracing floor the drawing gives us a) the plan, b) the one and only curvature for all the ribs, and c) their actual lengths. The configuration of the joints is an added problem which was treated at length by Lechler.*[51] *... Precision in the form of the webbing rarely became an issue. It simply had to be convex until the late brick webbings were introduced, some of which—as in Haarlem—were less than one inch and a half thick.*[52]

It is likely still the case that "no one has yet been able to explain the theory behind it."

The survey conducted for this report is intended to identify, where possible using somewhat coarse data, which of these techniques was used where, and how masons negotiated the design problems which followed, particularly in the application of the *Prinzipalbogen*.

To summarise, the *Prinzipalbogen* calls first for a regular circular arc to be defined, whose radius might be equal to the length in plan of the longest rib path from a springing point to the highest point in the vault without backtracking (this is perhaps the strict definition of the technique), or some other value which might be based on another rib path. The main principle of the *Prinzipalbogen* is that however it is defined, this regular circular arc is used to determine the height of keystones in the vault, so that the three dimensional form of the vault is derived using information in the plan, rather than the plan being projected onto a predetermined ideal vault surface. The ribs between these keystones also take the shape of a regular circular arc with the same radius. This greatly simplifies construction, as all the voussoirs (intermediate stones) will have the same shape. It is likely that even if the heights of keystones in a vault were derived using projection, the ribs would be given a consistent radius for this reason. A likely benefit of defining the principal arc using the longest rib path is that unsightly bulges in ribs resulting from a relatively small arc radius are avoided.

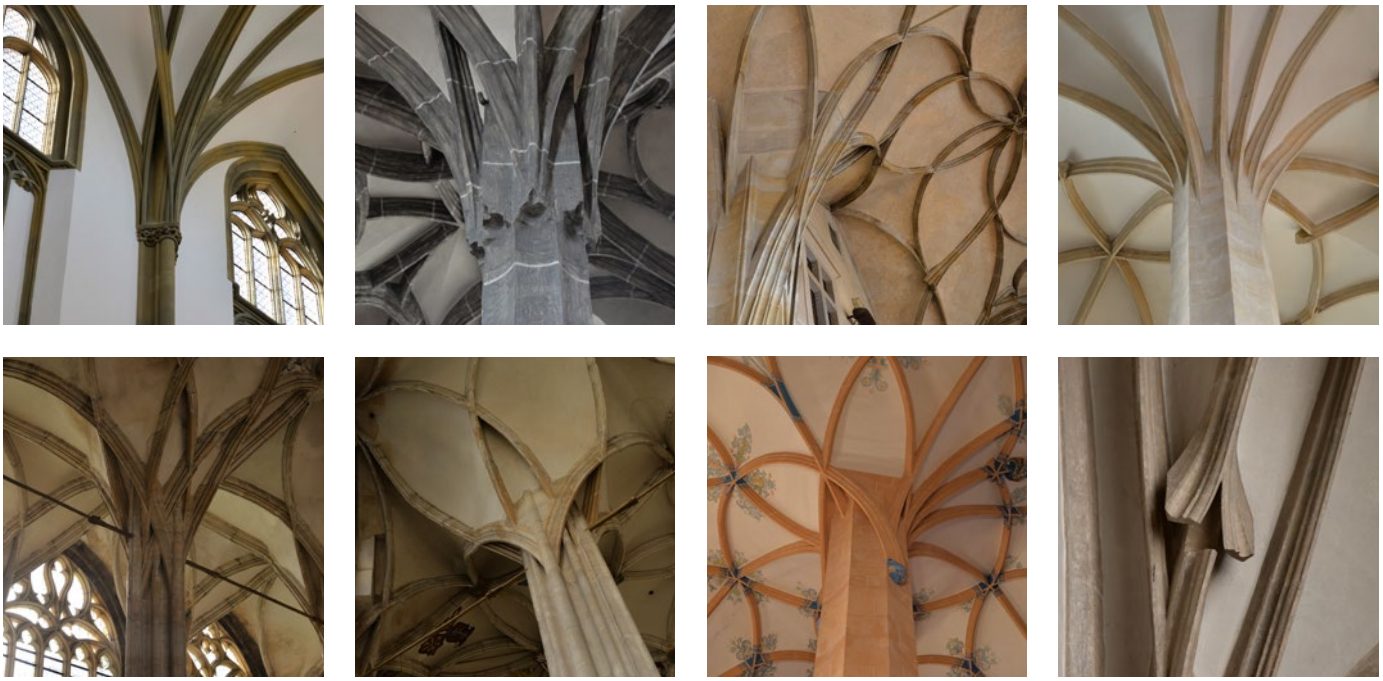


10 Five possible methods of resolving the misalignments in keystones and springing points caused by the *Prinzipalbogen*. In all cases, the curvature of all ribs is assumed to be based on a regular circular arc with a radius equal to that of the principal arc. The radius of the principal arc is defined by the longest rib path from a springing point to the vault apex without backtracking (1-2-3). Elevations (above) are derived from the plan (below). In elevation, A_B should be read as 'point A, where its height is derived from that of point B.'

The diagrams are based on those in: Palacios Gonzalo, José Carlos, and Rafael Martín Talaverano, "Technological Development in Spanish Gothic Vaults Design," International Journal of Architectural Heritage 7, no. 2 (January 2013): 192.

Where the length of one rib path from a springing point to the highest point in the vault is different to another, a misalignment at rib intersections or at the springing point results.

Figure 10 illustrates five ways of negotiating this design problem. In this case, the radius of the principal arc is defined by the longest rib path to the top of the vault (1-2-3). Methods A1 to A3 involve finding the form of ribs along paths other than that which defined the radius of the principal arc by moving the centre of the arc defining their curvature. In A1, an arc with the principal arc radius which passes through points 1 and 3 defines the form of the ribs along path 1-4-3, after which point 4 is located along it. In A2, the same ribs are derived from the highest keystone (3) downwards, where an arc with the principal arc's radius is thrown down from point 3 to point 4,



and the remaining rib 4-1 is resolved by moving the arc's centre. A3 does the opposite, moving up from a common springing point.

Methods B and C involve throwing an arc with the principal arc's radius down from the apex (B) or up from the springing point (C) along every rib path, and resolving misalignments in ways other than moving the centres of their arcs. Springing points which fall short in plan caused by method B pose little difficulty, as ribs can simply terminate in a column at different heights. Method C will result in discrepancies in height between ribs at their intersection in plan, which can be resolved by simply allowing these ribs to intersect only partially, and perhaps joining the lower rib to the vault surface using a 'diaphragm' of plastered stone.

It is important to note that the ribs of Late Gothic vaults often did not spring exactly from a common point (such as from point 1 in Figure in 9). The bulk of a column might conceal a wide spread of 'theoretical' springing points where the arcs of each rib, if extended, would be exactly vertical. The ribs in the floral vaults of Vladislav Hall and the choir of St. Barbara's Church by Benedikt Ried, and those of St.-Annen-Kirche (Figure 11), conspicuously do not meet, and the way they flaunt and meet their supports at a tangent is instrumental to their expression.

Very likely, many Late Gothic vaults designed using the *Prinzipalbogen* employ a combination of solutions. In others, multiple arc radii can be observed in the ribs. A reminder is salutary; that the best of the masons did not blindly follow the rules but used them to unlock new possibilities, standing on the shoulders of tradition as it were. Anderson writes:

> *Regarding the plan configuration of the vault out of which the three-dimensional development is* ausgezogen *(drawn), it is notable that there is not a single instruction for the correct configuration of vault-rib plans in any of the* Werkmeisterbücher*. In fact, an almost infinite variety of choice is implied by the few comments that do exist on this subject — for example, in Folio 54r. of Lechler's* Instructions*, where it is written that "no rib-sequence is like another."*[53]

> *The claim is not necessarily absolutely true — it may one day be shown that two vaults were in fact built to identical plans, but rather it is practically true. That is, as far as the medieval mason was concerned the primary arc technique* [Prinzipalbogen] *enabled the infinite variation that was necessary to realise the ambition of a unique mediation between humans and their God in the concrete situation of every vault, erected above the secure foundations of the typically configured ground plan of the chapel."*[54]

11 (Above) Various springing conditions of Late Gothic vaults. Left to right, top row: the Kloster Sankt Ulrich und Afra Augsburg, Pfarrkirche Weistrach, the Vladislav Hall, and Chrám svatého Mikuláše v Lounech (St. Nicholas Church in Louny). Bottom row: St. Barbara's Church, Kutná Hora (2 images); St.-Annen-Kirche in Annaberg-Buchholz; and the Liebfrauenmünster in Ingolstadt.

5

Scope of Research

Because of the relative dearth of anglophone sources on this subject and my ignorance of German and Czech, I have leaned on interviews, partial translations, and the advice of my supervisor Dr. Anderson for an understanding of key German sources. Nevertheless, all errors of fact or interpretation are my own.

Some of the most thorough and insightful research on the subject of Late Gothic vault construction is being conducted by Dr. David Wendland at the Technische Universität Dresden, and by Drs. José Carlos Palacios Gonzalo and Rafael Martín Talaverano of the Universidad Politécnica de Madrid. Dr. Wendland and his researchers have built, at a scale of 1:1, a ceiling of prismatic vaults found in Albrechtsburg Castle using materials, tools, and techniques faithful to Late Gothic practice. By doing this they confirmed for example that once the folds in the vault were defined by timber centring (formwork), the vault surfaces in-between could easily and most likely were built freehand; and that construction problems posed by the need to cut many bricks were in fact no problem at all, as the soft bricks of the period were easily carved into shape by hand-held tools. An installation designed by Dr. Wendland and his researchers which represents the building site of a Late Gothic prismatic vault will soon be opened to the public at the castle. This installation is discussed on pages 23–26. Dr. Palacios Gonzalo is also engaged in experimental archaeology, and videos of his students trepidatiously removing the centring from under 1:5 plaster vaults can be viewed online.[55] All three scholars have recently published conference proceedings on the design of Late Gothic vaults.[56]

It is my hope that the measured drawings, VR panoramas, and other photographs of the buildings surveyed[57] will by themselves represent a non-trivial contribution of materials for research into the Late German Gothic; but as a line of original research, there are only two ways in which this project can hope to have value beside the work of German, Czech and other academics working in this field.

The first is the breadth of analysis which will be possible—at the expense of a degree of accuracy and detail—in a field in which papers typically focus on a single church. The hypotheses tested by the aforementioned experimental vaults were based on detailed surveys of Late Gothic vaults in Germany and Spain (where German construction techniques have been observed). Drs. Palacios Gonzalo and Martín Talaverano have used hand-held laser distance measurers in their surveys, but also full survey stations to fix points in plan and against reference points. Dr. Wendland uses full survey stations exclusively.

In my visits to churches, typically of several hours and never with exclusive access, points directly below rib intersections were located by eye, as the use of a level on uneven stone floors without assistance would have multiplied the time taken to take measurements and increased the risk of the laser[58] missing the bottom surface of a keystone in the moment the measurement was taken. All conclusions drawn from comparisons with these measurements are treated as tentative, and only indicative of where further scrutiny ought be applied. Furthermore, as only the heights of keystones were measured, there are questions on which this data will not speak at all, such as those pertaining to the curvature of ribs.

12 Screen capture of a draft virtual reality panorama of the Vladislav Hall

The second virtue of the project will be in its suggestion of the experimental potential of parametric modelling in architectural historical research. Some of the models discussed in this report are parametric in that they incorporate the logic of the *Prinzipalbogen* rather than represent only their formal outcome based on one set of input criteria (such as a given vault plan and nominated principal arc radius). While the advantages this offers in the particular comparisons made in this report are limited, their true value will be apparent in further study of the interaction of two or more input variables or design decisions which yield an exponentially large range of possible forms.

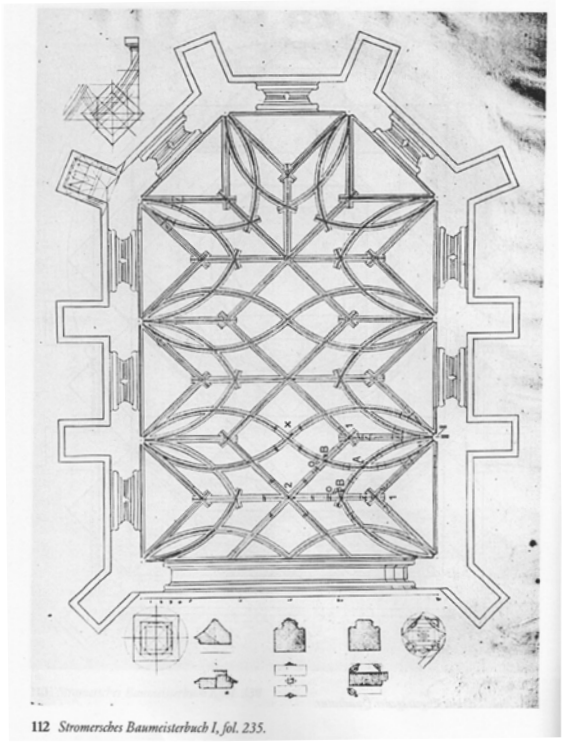
6

Preliminary Models

I have used digital models to develop an understanding of the opportunities and problems posed by the *Prinzipalbogen*, and to attempt to identify the application of the technique in the vaults of St.-Georgs-Kirche in Dinkelsbühl and the Vladislav Hall. No straightforward application of the *Prinzipalbogen* has been detected, but the models will be useful in focusing further enquiry.

Figure **15** shows a parametrically generated model resulting from the application of the traditional definition of the *Prinzipalbogen* to a plan found in the *Stromersches Baumeisterbuch* I, fol. 235 (Figure **13**). The plan is of an idealised chapel drawn for the purposes of education. The model follows an ealier digital modelling analysis by Anderson,[59] but incorporates the logic of the *Prinzipalbogen* using the graphical algorithm editor *Grasshopper*. Figure **16** is a view of the same model showing some of the construction geometry generated by the parametric definition. Figure **14** is a screen capture of the definition itself, in which variables and geometric operations are expressed as 'batteries' and connected in the manner of a flowchart.

13 (Next page) Stromersches Baumeisterbuch I, fol. 235. Stromersche Kulturgutstiftung Grünsberg / Germanisches Nationalmuseum, Nuremberg. In: Anderson, Ross. "Figures of Mediation: Late Gothic Chapel Vaults Between Primordial Stone and Medieval Theology," *Proceedings of the Society of Architectural Historians, Australia and New Zealand: 31 Translation*, ed. Christoph Schnoor (2014): 416.



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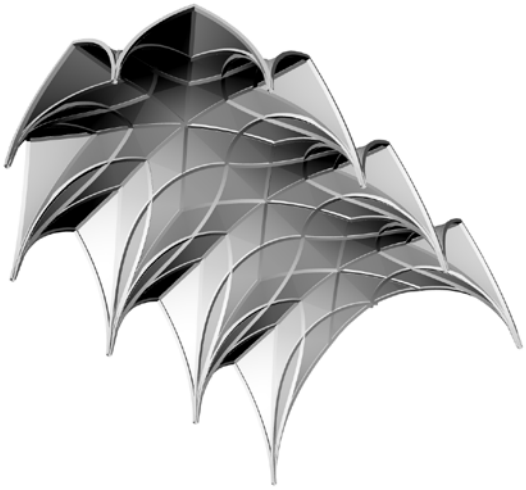

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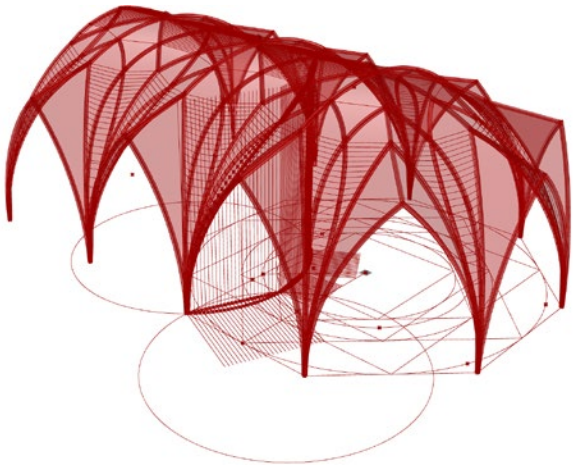

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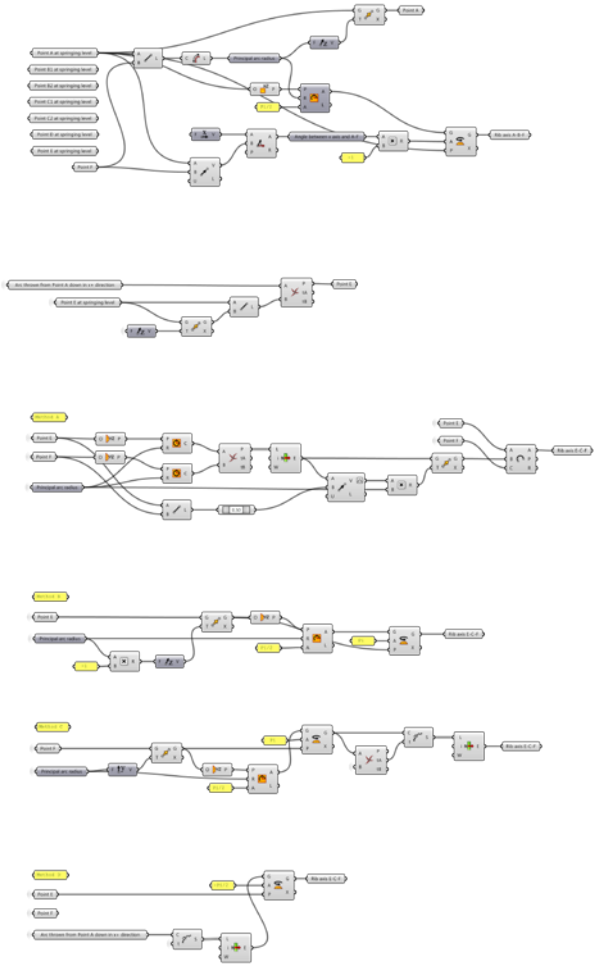

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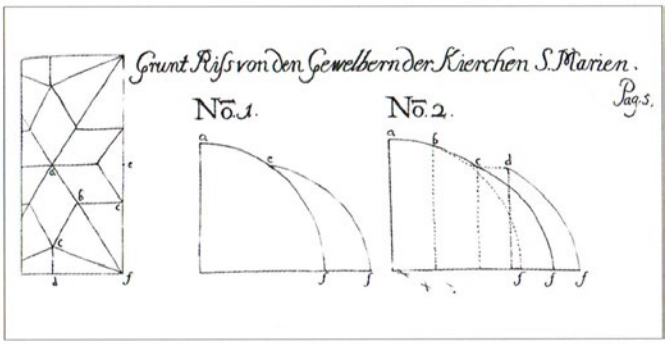
Figure **20** consists of line drawings of parametrically generated models based on the application of the *Prinzipalbogen* methods A, B, and C discussed above, to the vault plan and elevation in Figure **19**, found in Bartel Ranisch's documentation of vaults in Danzig. Their purpose is to illustrate, in an exaggerated way, the formal implications of each method. Figure **18** is a screen capture of the parametric definition of each model.

Figure **17** is a view of a partly simplified parametrically generated model of a vault in the Vladislav Hall. The *Prinzipalbogen* was applied to the plan as far as possible (the curve of the ribs in plan poses no theoretical problem, but locating springing points in these vaults is especially difficult), and the resulting discrepancies between the measured spot levels and the model based on various principle arc radii will be scrutinised.

Figure **21** illustrates the use of Grasshopper to begin an analysis of the vaults of St.-Georgs-Kirche. Spot levels of keystones taken on site were plotted in elevation along the axis of the church, and dotted arcs drawn which describe the profile of hypothetical regular surfaces onto which the keystones might have been projected. This study demonstrates the limitations of the relatively coarse data set gathered in the survey. The spot levels do not lie exactly on the arcs, but may be within the margin of error of construction, and more likely, of measurement.



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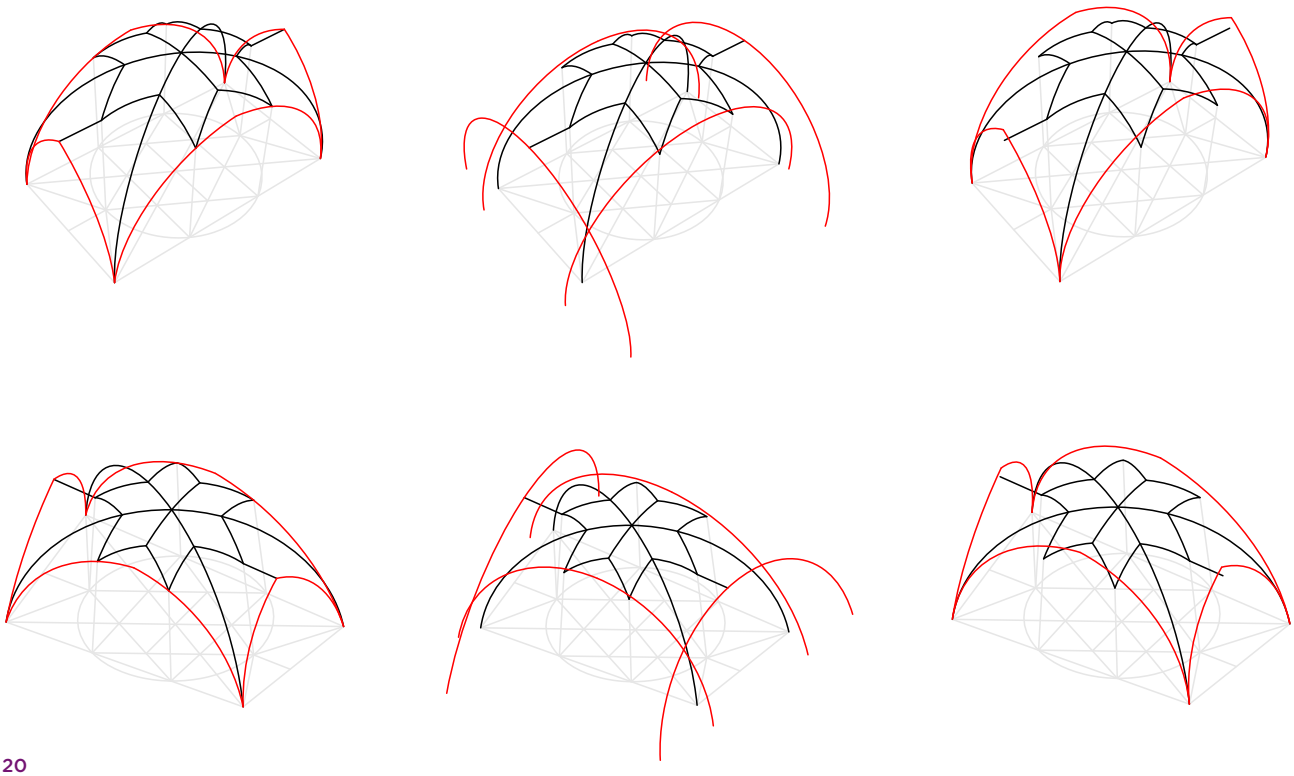

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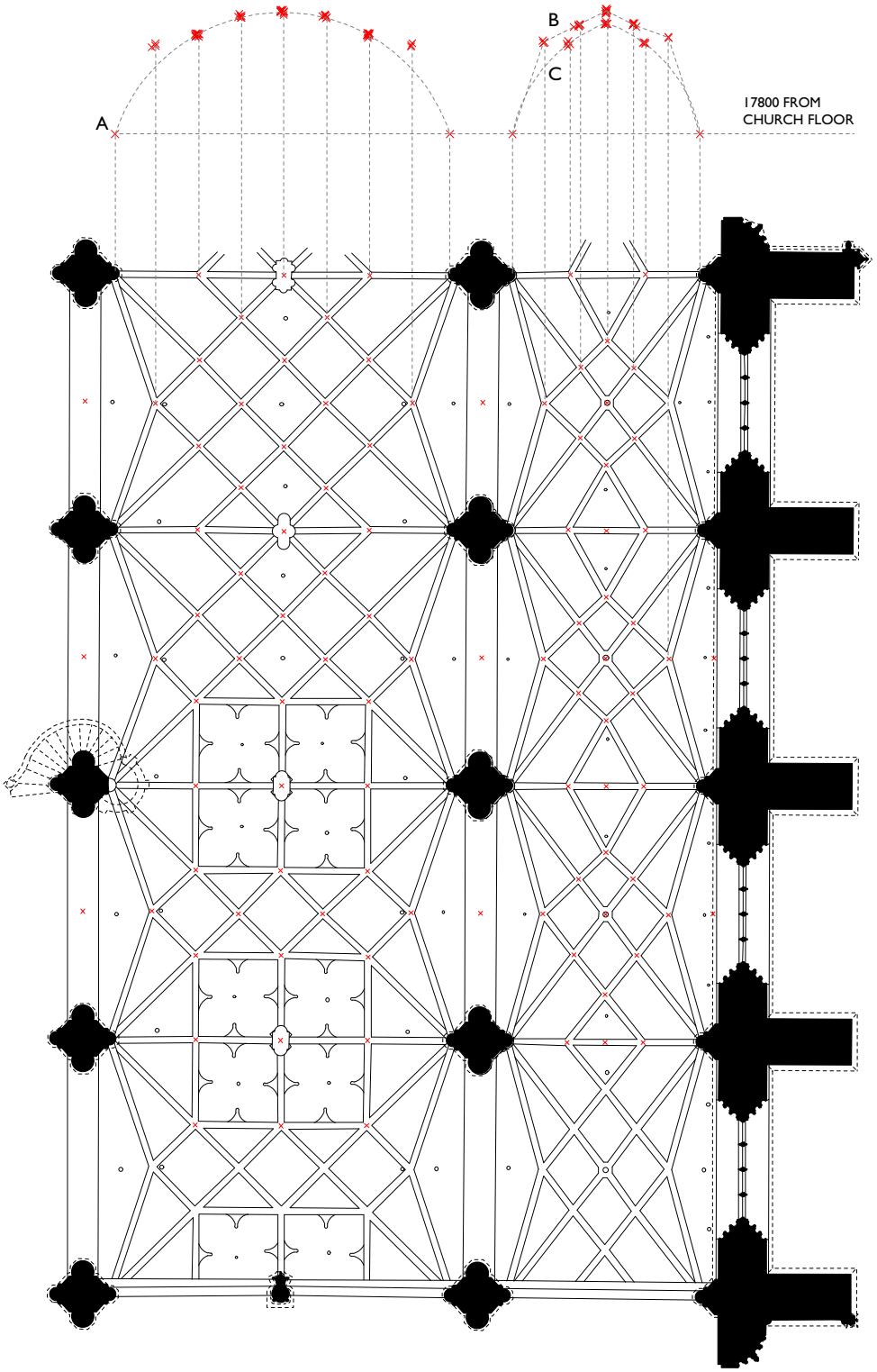
19 (Top) Bartel Ranisch, *Beschreibung Aller Kirchen-Gebäude Der Stadt Danzig* (Danzig: Johann-Zacharias, 1695). In: Wendland, David. "Wie Haben Die Spätgotischen Architekten Die Kurven Bogenrippen Geometrisch Konstruiert?" In *Das Schlingrippengewölbe Der Schlosskapelle Dresden*, Sächsisches Staatsministerium der Finanzen. (Altenburg: Klaus Jürgen Kamprad, 2013), 35.

20 (Bottom) The exagerrated formal implications of the application of the *Prinzipalbogen* methods A, B, and C (from left to right) discussed above. The rib being examined is highlighted red.



21 Plan of selected nave and aisle vaults of St.-Georgs-Kirche, Dinkelsbühl, at 1:175. The plan was traced over a survey shared by Mr.-Ing. Josef Ruhland, architect for St.-Georgs-Kirche, produced by Ingenieurbüro Christofori & Partner.

7

Notes from Albrechtsburg

I had the great pleasure of meeting Dr. Wendland at Albrechtsburg, where he and his researchers had constructed an installation depicting their best guess as to how the construction site of a Late Gothic prismatic vault elsewhere in the palace would have appeared (Figures **22** to **27**). The centring in the installation, arranged in the most informative way possible, had already been used to build a full-scale replica of a vaulted ceiling. The completed vault stands in a disused factory near Dresden. If it must be disposed of, Dr. Wendland hopes to destroy it in such a way that something can be learned about its structural properties.

These exercises in experimental archaeology have uncovered many construction problems and solutions which likely would not have occurred to historians studying drawings, documents, and extant vaults exclusively, especially given the extreme rarity of sources directly related to Late Gothic construction praxis. The subject of the installation is a prismatic vault, but its principles are applicable to ribbed vaults.

24

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The floor of the Albrechtsburg installation should be imagined to have been built at the level of the springing points of the vault under construction. The timber platform would have allowed masons to work safely, transport and store materials, and set up formworks while keeping the space below clear. Many Late Gothic churches were roofed, consecrated, and in service before they were vaulted over the course of years, which lends weight to the hypothesis that vaults were constructed in this way.

Less obviously, the platform likely also provided a tracing floor for setting out the vaults using the same drawing procedures used to derive the form on paper. Once a plan was traced, keystones were located in space by erecting timbers of the correct dimension directly on the traced plan. Building the working platform at the height of the springing points minimises the length of these timbers and as a result, the likelihood of their standing crooked.

Late Gothic design being as scaleless and informed by procedurally derived interrelationships as it was, it is likely that tracings were constantly referred to during construction. Masons may even have worked using no standard unit of measure at all, but rather a project-specific module. In order for the tracings to be precise, durable, and legible, Dr. Wendland hypothesises that the plan was first incised by a nail-like tool (of which documentation exists) guided by a straightedge (lines) or string (arcs), and highlighted using, for example, charcoal or ochre (Figure **24**). Masons are known to have highlighted guidelines in stone in this manner.

22 (Previous page, top) Overall view of the installation. The floor of the installation should be imagined to be at the springing level of the vaults.

23 (Previous page, bottom) Detail, showing in particular what was likely the ad-hoc use of timbers to fix the poles locating keystones firmly in place.

26

27

Once the keystones were located in space (perhaps using a nail as an exact marker, as in Figure **25**), the formworks would be filled in with curved profiles to receive the voussoirs of the ribs (or in the case of prismatic vaults, the bricks forming the folds in the vault). If the vault were designed according to the *Prinzipalbogen*, the pieces of the curved profiles could be shaped to the same radius en masse, and simply cut to the correct length (sweep of arc) when incorporated into the formwork (Figure **26**). Planed lumber was readily available in Late Gothic times, even from water-powered sawmills on barges which could be towed along rivers. In Dr. Wendland's experience, cutting these with a hand-axe, which was likely the tool of choice at the time, posed little difficulty. Furthermore, this formwork system would have been easily recyclable, carried from project to project until finally being used for firewood.

Actually building the vault confirmed another hypothesis: that once the ribs or folds of the vault were defined, effectively establishing a network of arches, the masonry vault surface between the ribs could effectively be constructed freehand. Early during construction, it seemed as though it might be possible to construct the whole vault in this way, using the formwork only as a guide—until the masonry was noted to have settled snugly against the formwork overnight (Figure **27**).

8

Site Visits

These cursory notes should not be considered art historical summaries of these sometimes deeply affecting buildings, but as guides to their relevance to the present research.

Contents

28 Map of site visits. Cities visited are in black.

8.1

Willibrordi-Dom
Wesel

Built in two stages, 1424–c. 1480, 1501–c. 1540
Destroyed in 1945 and reconstructed

Willibrordi-Dom was almost completely destroyed in the Allied crossing of the Rhine in 1945. During reconstruction, much of the 19th century interventions were undone (with the exception of the chancel perambulatory) to restore the basilica to its Late Gothic state. The cathedral is notable in featuring two double-layer vaults, especially rare in northern Germany.

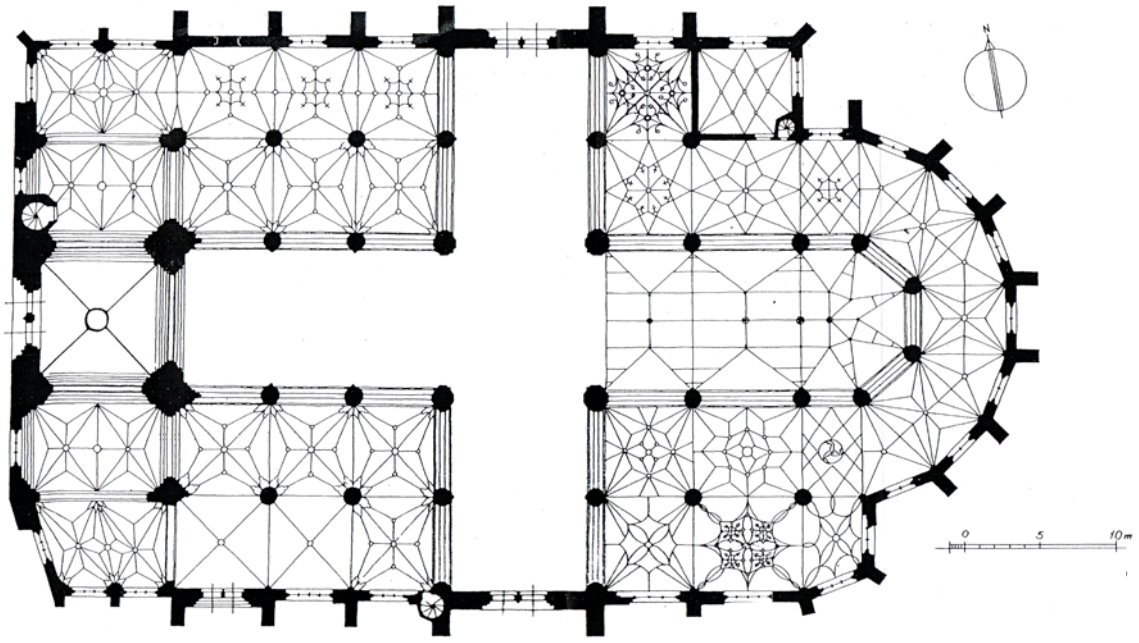
I had the pleasure of interviewing (through an interpreter) Dr. Wolfgang Dürer, who followed his father in carrying out the restoration of the cathedral. Because detailed documentation of the church did not exist or survive the war, vaults were reconstructed using, for example, wedding photographs in which they made an incidental appearance.

Survey scope: Keystone levels, VR panoramas

29 (Previous page) Detail of the double-layer (flying rib) vault of the Alyschläger Chapel

30 (Next page, top) Vault plan of Willibrordi-Dom by the office of Dr. Dürer, 1:500

31 (Next page, bottom) The double-layer vault of the Heresbach Chapel and unique surrounding ambulatory vaults



Gewölbefiguration

8.2

Dom zu Meißen
Meißen

Present hall church built between 1260–1410

A primarily High Gothic early hall church adjacent to the Albrechtsburg above Meißen. Of particular interest to this report are the vaults of the eccentrically planned sacristy (1504), the prismatic vaults of the cloisters, and the Funerary Chapel (1425) established by Frederick the Belligerent.

The adjacent Albrechtsburg by Arnold of Westphalia, which was ungoing conservation works during my trip but which I nevertheless had the opportunity to visit—though not properly photograph—is of even greater interest to scholars of the Late Gothic. Its grand scale and complexity necessitated the establishment of a *Bauhütte*, usually only found on the building sites of cathedrals. Dr. Wendland has reconstructed, at a scale of 1:1, using materials, tools, and methods faithful to Late Gothic practice, a ceiling of similar prismatic vaults found in Albrechtsburg. Its construction is documented in recent conference proceedings.[60] See Section 7 (pages 23–26) for a description of an installation soon to open in Albrechtsburg and designed by Dr. Wendland and his researchers, depicting the building site of a Late Gothic prismatic vault.

Scope of survey: Keystone levels, VR panoramas

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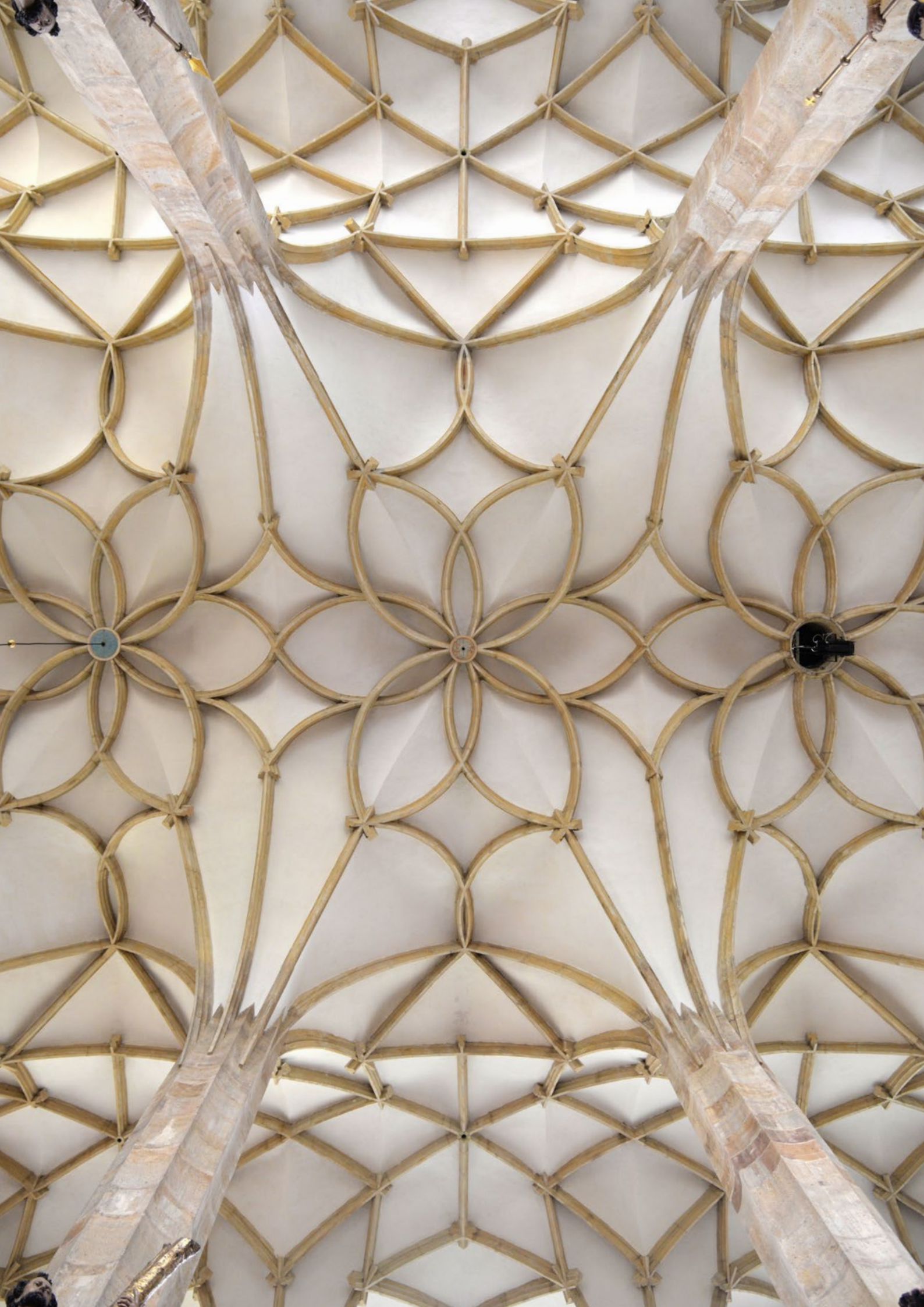
32 Vaults of the Funerary Chapel (1425) commissioned by Frederick the Belligerent

33 Vaults of the sacristy, whose irregular plan presented masons with a substantial challenge in vaulting

34 and **35** Eccentric prismatic vaults

36 View of the prismatic vaults of the cloisters



8.3

Kostel Nanebevzetí Panny Marie
Most

Church of the Assumption of the Virgin Mary

Jacob Haylmann
Begun in 1517, vaulted after 1532

Jacob Haylmann (Jacob von Schweinfurt) worked under Benedikt Ried on the Vladislav Hall and at Kutná Hora; and later vaulted St.-Annen-Kirche. Most's floral vaults, the elegantly resolved springing points, and fluted cross-sections of its columns clearly relate to those most prominent examples of the Late Gothic. Just as in those churches, the vaulted ceiling, suggestive of arrested movement, appears to grow organically from the columns from which it is not separated by capitals or expressed impost/springer stones.

Incredibly, the entire church (less its tower) was moved intact in 1975 after the communist Czechoslovakian government razed historic Most in order to make way for the modernist city centre which stands in its place today. Once a path to the church's present location almost a kilometre away was cleared, every element of the church was reinforced and the whole structure moved on rails by a convoy of trucks.

Scope of survey: Keystone levels, VR panoramas.
See drawings and measurements on pages 92–93.

38 (p34) and **39** (Previous page) Nave and aisle vaults

40 (Next page, top) and **41** (Next page, bottom) Unique aisle vaults incorporating flying ribs

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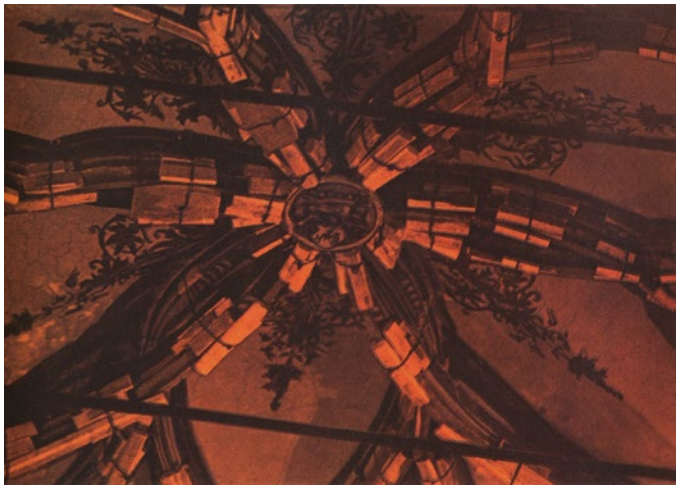

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42 (Above) Roof cavity of the church during conservation works to the tower

43 (Right, top) The church in its original location in the centre of historic Most

44 (Right, centre) Columns of the church reinforced for transport

45 (Right, bottom) A floral vault reinforced for transport

43, **44**, and **45** In: Heide Mannlová-Raková, *Kulturní památka Most: Děkanský kostel a jeho stavitelé* (Prague: Propagacni tvorba, 1988), 65 (Fig. 43), 109 (Fig. 44), 111 (Fig. 45).

8.4

St. Vitus Cathedral
Prague Castle

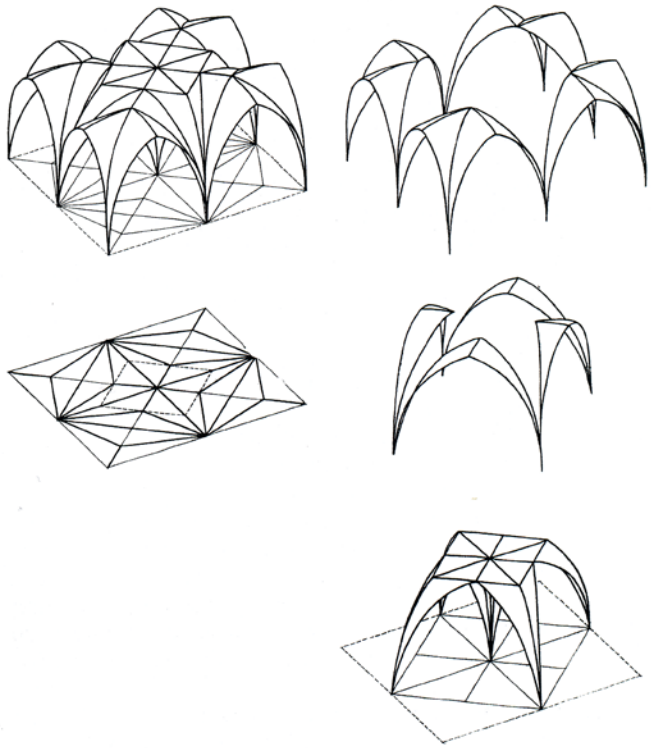
Founded in 1344, begun by Matthias of Arras Peter Parler takes charge in 1353, finishing work underway (mostly) to Matthias' design before continuing according to his own

A High Gothic cathedral into which Late Gothic features were introduced by Peter Parler. These include the choir vaults and the sumptuous St. Wenceslas Chapel (1344–1364). Spectacular flying ribs appear to support the Mosaic of the Last Judgement (1372) of the Golden Gate (Figure 49), built by Peter Parler's successors. The cathedral also bears a modern stained-glass window of by Alphonse Mucha (Figure 52).

Introducing St. Vitus, Frankl writes:

> *The importance of Bohemia in the Late Gothic style in Germany is due to the personality of the Emperor Charles IV (1316–78), the son of King John of Bohemia. ...*
>
> *Though not everyone will have the patience to work out and visualize [the] geometrical pattern [in the vaults] and to understand the geometrical principles involved, anyone can understand that Peter Parler made two innovations which he developed logically from the nature of the rib-vault: he turned the whole vault through 45 degrees, and he added to the existing types of ribs the new (English) type of the flying rib.*[61]

Scope of survey: Keystone levels, VR panoramas.
See drawings and measurements on pages 94–95.



48 (Above) Vault schema illustrated in: Benešovská, Klára. "Das Frühwerk Peter Parlers am Prager Vietsdom," *Umění. Časopis Ústavu dějin umění Akademie věd České republiky* 47, no. 5 (1999): 355.

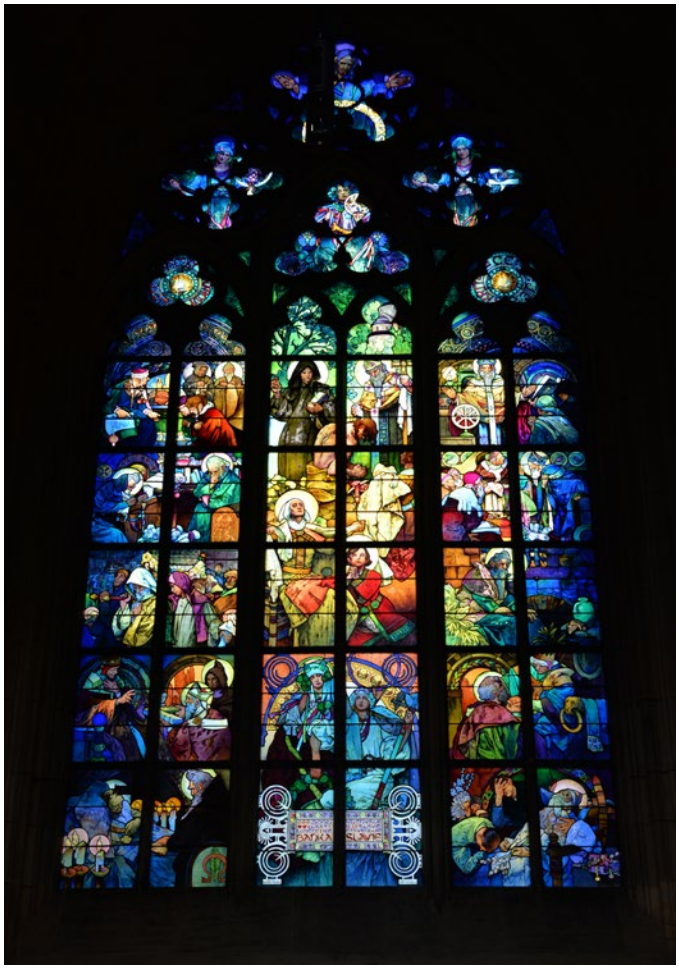
46 (p39) South facade of St. Vitus Cathedral

47 (Previous page) Crossing and transept

49

51

50



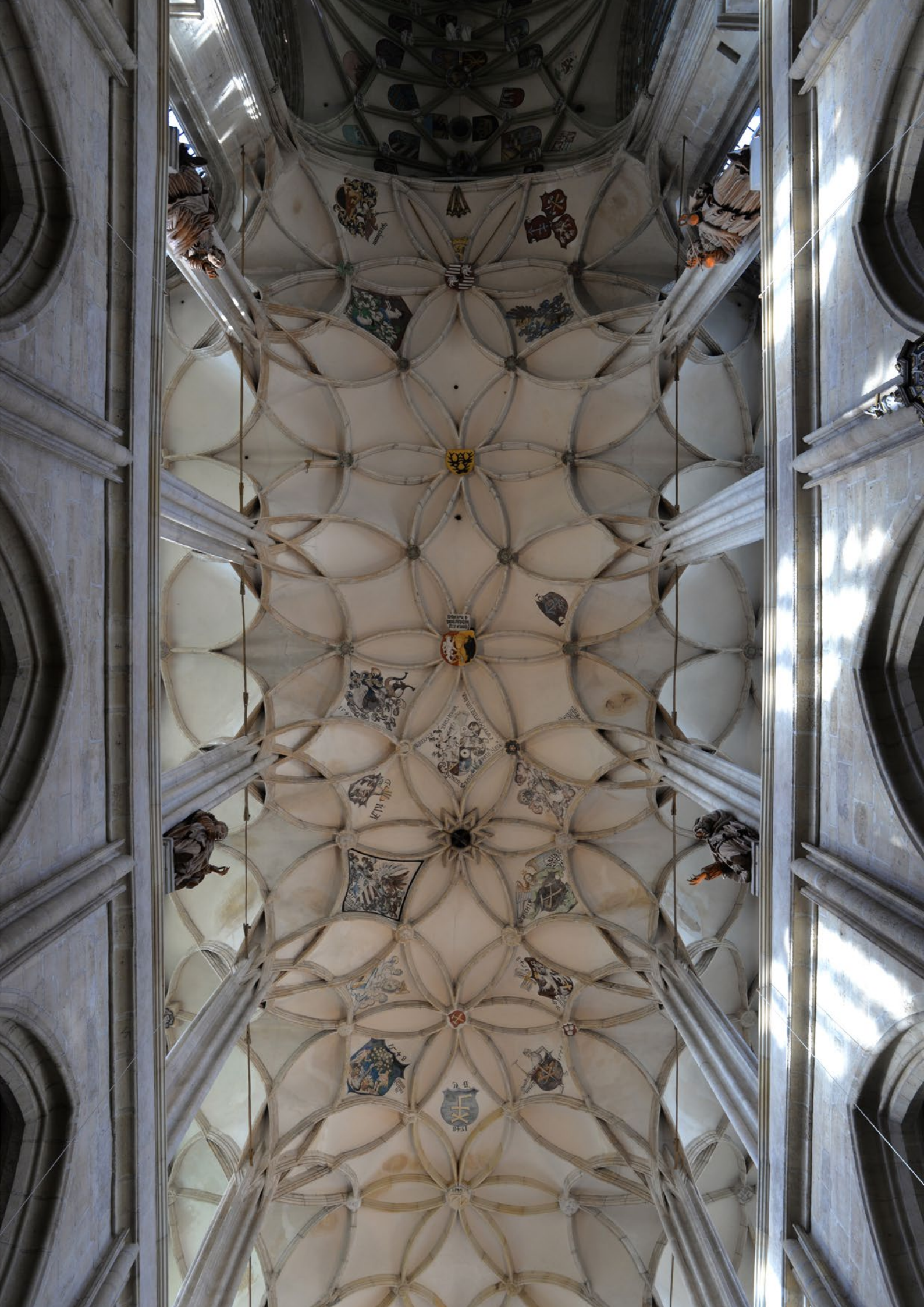
52

49 (Top left) The Golden Gate

50 (Bottom left) Flying buttresses to the South facade

51 (Top right) Extrados (top surface) of nave or choir vaults

52 (Bottom right) Stained glass window by Alphonse Mucha



8.5

St. Barbara's Church
Kutná Hora

Begun in 1388 most likely by Johann Parler
Interrupted by the Hussite Wars of 1419–1434
Nave and choir vaults designed by Benedikt Ried
Nave vault designed c. 1512, completed 1548
Church completed in 1905

This Parler church vaulted over a century later by Benedikt Ried is one of the most important monuments of the Late Gothic in Central Europe, and is recognised as a UNESCO world heritage site.

When Ried designed the nave vaults in c. 1512, he introduced the floral petal design he had executed earlier in the Vladislav Hall (1493–1503). While the enclosing, three-dimensional effect of the vaults of Vladislav Hall is unique, the design might be said to have been developed further in the articulation of the springers in St. Barbara's, where ribs from all angles meet their columns at a tangent. The full effects of this arrangement are not readily appreciated in the Vladislav Hall, where the vaults spring from pilasters or buttresses in the walls.

Work on the vaults designed by Ried continued posthumously. The workmanship, which is not up to the standard of the Vladislav Hall (Figure 55), may suggest the importance of the supervision on site of the master mason.

Scope of survey: VR panoramas

53 (Previous page) Nave vaults

54 (Next page, top) View of St. Barbara's Church as approached from Kutná Hora

55 (Next page, bottom) Detail of the springing condition of the ribs of the nave vaults

8.6

The Vladislav Hall
Prague Castle

Benedikt Ried, 1493–1503

The Vladislav Hall, originally destined to be a jousting hall, was the only secular building included in the survey (and the inspiration for the proposal of this project). The springers of the ribs being very low, the vaults play an unusually three-dimensional role in enclosing space. It is among the finest achievements of the Late Gothic masons, and Ried's most famous work. Kavaler writes:

> *As Werner Müller has observed, the defining elements of the active surface in the Vladislav Hall are difficult to isolate. Is it the masonry and shell of the vault that determines this unusual plastic form, or is it the complex lattice of looping and intersecting ribs that fixes the dimensions of the hall? The ribs here are so thin and razor-sharp that they hardly suggest a supportive function; they seem barely able to restrain the walls from further impinging on the interior. And yet the same peculiar convergence of masonry and webbing appears strangely amorphous and inarticulate without the linear pattern that imparts to them a calculable order and design.*[62]

As Kavaler suggests, basic principles determining the form of the petal shapes in plan are easy enough to understand. The double-curve of the ribs too, have been described by Wendland[63] as having the form of circular arc in elevation wrapped along the perimeter of a circular arc in plan, which was the method used to produce the parametric model on page 20. Though digital modelling studies conducted in Czech[64] will need to be translated to confirm this, it is likely still the case that no-one has been able to describe the geometric principles at play in the vaults in any more detail.

The Old Royal Palace contains many other vaults by Ried, including those of the Riders' Stair (c. 1500, Figure 60) which are at least as inventive as those in the Hall, and of the Bohemian Cancellery (c. 1505, Figure 59). The Bohemian Chancellery was the site of the Second Defenestration of Prague (the ejection from a third storey window or windows of two Catholic regents and their secretary by aggrieved Bohemian Protestants; a fall they survived, it is said, by falling into a dung-filled moat) in 1618, the match which lit the Thirty Years' War.

Kavaler remarks on Ried's historical influence:

> *Ried, probably coming from southern Germany, became the most important designer of Gothic palaces and churches in northern Bohemia — and one of the most impressive artists of the entire period. The interior to the famous Vladislav Hall in the Hradchin at Prague established new principles of vault design for leading architects in Austria, Bavaria, and even Prussia. Yet Ried also composed in an Italianate manner. The windows on the exterior of the Vladislav Hall, dated 1493, are surprisingly in an antique style — although a rather reductive one.*[65]

Scope of survey: Keystone levels, VR panoramas.
See drawings and measurements on pages 96–97.

56 (p46) Wide angle photograph of the Vladislav Hall from its West end

57 (Above) Detail of the columns and springing/impost condition of the vault ribs

58 (Next page, top) Vaults of the Hall of the Diet

59 (Next page, bottom) Vaults of the Bohemian Chancellery (c. 1505)

60 (p50) Vaults of the Riders' Stair (c. 1500). Its design is discussed by Bucher in relation to an apparent concept design sketch in: François Bucher, "Design in Gothic Architecture: A Preliminary Assessment," *Journal of the Society of Architectural Historians* 27, no. 1 (1968): 56–57,

8.7

Marienkirche
Pirna

Peter Ulrich (Peter von Pirna)
Built between 1504–1546

The Marienkirche is one of the largest and most sophisticated of the Saxon hall churches. The nave is closed with fine net vaults flanked the star vaults of the aisles. In the choir, superfluous flying ribs emerge from the walls which can only be virtuoso architectural humour.

Jan Białostocki gave the Marienkirche pride of place beside St.-Annen-Kirche, describing them as "the last brilliant illumination of the German Gothic" and lamenting that "with them the Gothic forces were extinguished."[66]

Frankl describes the church thusly:

> *In the parish church at Pirna, built between 1504 and 1546, the architect formed an aisled hall with piers with eight concave sides, and a close net-vault creates a continuous stream of movement from west to east, while each bay in the aisles is centred by the form of the star-vault, thus producing a series of lateral currents crossing the main, longitudinal one. The nave and aisles form a visual unity in which the arches of the arcade seem to have become ribs; the liernes in the nave and those in the aisles meet on these arches, and emphasize the continuity of the crossings streams of movement. The choir has double-curved ribs. Throughout the church, the section of the ribs forms two shallow hollows on each side, and the concave forms of the piers and of the ribs are stylistically analogous with the mouchettes in the tracery and with the double-curved ribs of the choir vault. In addition to these features, there are flying ribs rising from the corners of the choir and running into the meshes of the vault, and these ribs are formed like tree-trunks from which all the branches have been cut off except one, which winds spirally up the stem. In this church one can truly say that all the stops are out.*[67]

Scope of survey: Keystone levels, VR panoramas

61 (Previous page) Nave vaults

62 (Next page, top) Wide angle photograph of the interior

63 (Next page, bottom) Decorative ribs in a choir vault

8.8

Chrám svatého Mikuláše v Lounech

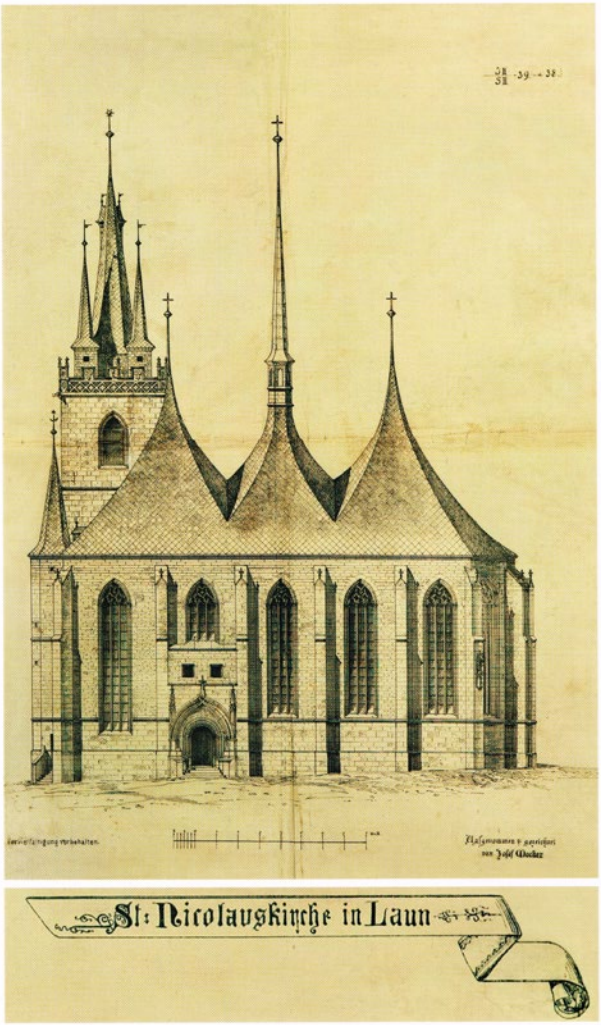
St. Nicholas Church in Louny

Benedikt Ried, completed 1538

One of Benedikt Ried's final works and completed posthumously. The floral vaults of Vladislav Hall and Kutná Hora are abandoned in favour of a simpler design incorporating truncated ribs and a prominently expressed crease in the vault surface. The fluted columns and springers are once again remeniscient of the roughly contemporary St.-Annen-Kirche.

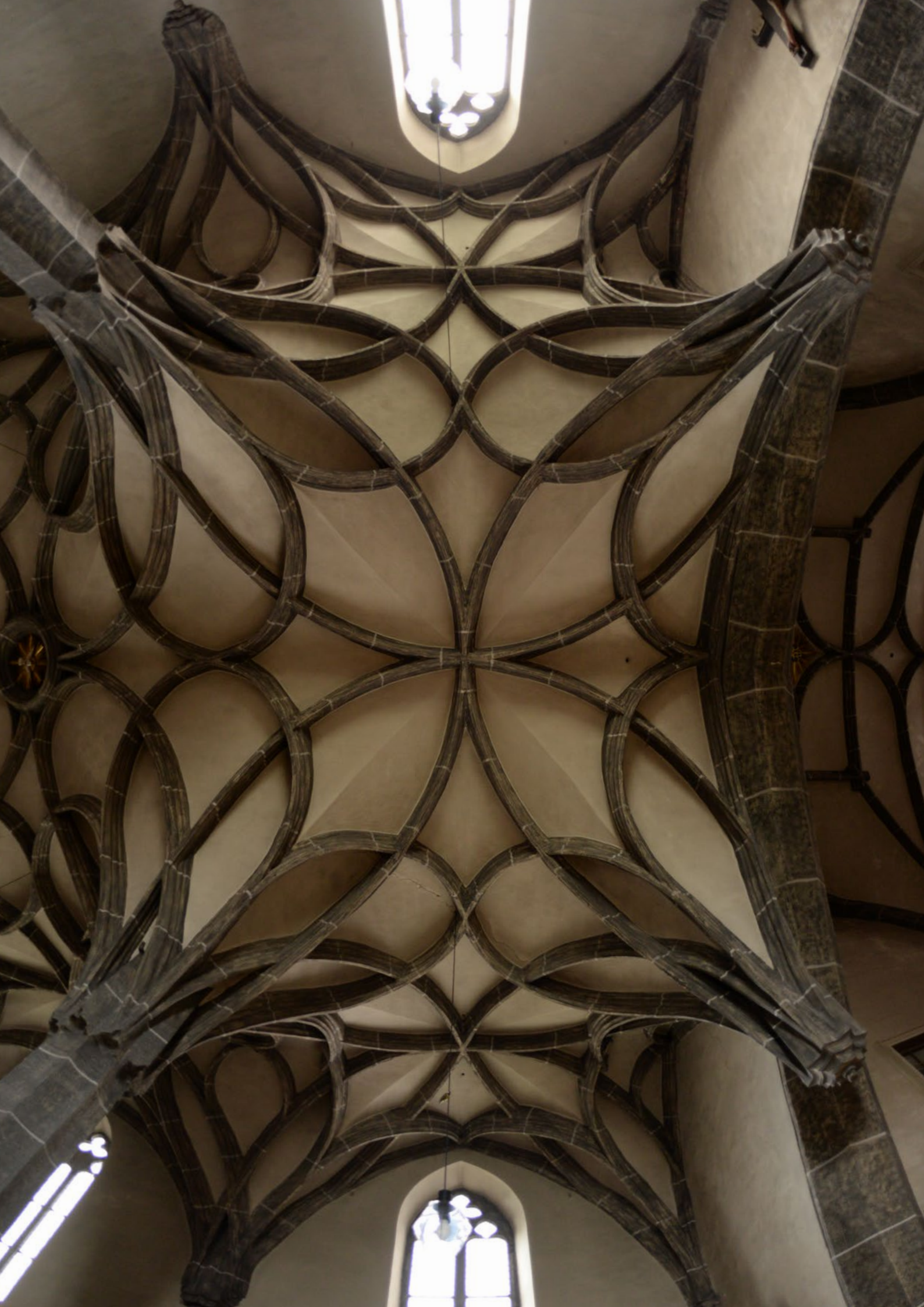
The visitor's attention is stolen from the vaults by an immense tripartite timber altarpiece carved by Jerome Kohl and his student František Preiss in 1701–1706.

Scope of survey: Keystone levels, VR panoramas



64 (Previous page) Nave vaults

65 (Right) Postcard bearing an elevation of the church



8.9

Pfarrkirche Weistrach

c. 1515–20
Extended in the 19th century by Karl Lussmann

The vaults of the parish church of Weistrach spring from low piers and dominate the interior. The vault design bears the mark of Benedikt Ried's influence, and of the Vladislav Hall in particular. Though the vaults of these two buildings share geometric design principles, the effect of their application could not be more different. The ambiguous, womb-like vaults of the Vladislav Hall are interlaced with sinuously thin ribs of warm stone; whereas the thick dark ribs in Weistrach, already in a much smaller church, appear ominously heavy and terminate in unusual bulbous capitals. Nevertheless, the looping vaults and their dense intersections impart to the church a mad, frenetic energy, particularly in the pendant cones flanking the apse.

Scope of survey: Keystone levels, VR panoramas

67

68

66 (Previous page) Nave vaults. Note in particular the pendant cones terminating in hanging keystones.

67 (Right, top) View of the extrados (top surface) of the vaults. The acoustic qualities of the roof cavity are such that concerts have been performed there rather than in the body of the church itself.

68 (Right, bottom) Examples of the tuft stone used in the walls

69 (Next page, top) Hanging keystone of a pendant cone

70 (Next page, bottom) Interior view, facing the apse

8.10

Heilig-Kreuz-Münster
Schwäbisch Gmünd

Begun in 1320
Choir (1351) and perhaps nave by Heinrich Parler

The parish church of Schwäbisch Gmünd is the oldest hall church in Swabia. The church, and particularly its choir (1351) by Heinrich Parler, are widely associated with the advent of the German Late Gothic. It established the Parler dynasty, that family of masons who would later be known as the Junkers of Prague. Particularly intricate stellar net vaults stand over the choir (vaulted in 1491–1504) and ambulatory.

Frankl writes:

> *The west front at Schwäbisch Gmünd has no towers, since the Romanesque towers which flanked the west end of the choir were then still standing. The composition is very simple. The decisive factor is a relaxation of strict regularity. The central oculus is slightly smaller than the two flanking ones, and the gable over the porch pushes the string course above it slightly higher in the central bay than in those on either side. The portal seems to stand loosely in its bay. Accoding to Schmitt, the work of construction progressed from west to east, and the façade cannot therefore have been built later than 1320. Because of this relaxation of the principles of regularity in the façade, the nave at Gmünd can be called the first Late Gothic building in Germany.*[68]

Scope of survey: Keystone levels, VR panoramas.
See drawings and measurements on pages 98–100.

71 (p59) Choir and ambulatory vaults

72 (Previous page) Nave and aisle vaults

8.11

St.-Georgs-Kirche
Dinkelsbühl

Nicklaus Eseler, 1448–1499

A *Staffelhalle* church which, like the entire moated *Altstadt* around it, survived both World Wars unscathed.

I borrow a description of the church once again from Frankl:

> *In the church of St George at Dinkelsbühl, Eseler built a hall-church that was a stylistic unity, like Amberg. However, he articulated the piers by adding finely differentiated shafts so that, looking westwards, they close into a series of dark vertical lines with light grey intervals. The choir is built to the typical Parler plan, with a central pier in the periphery of the ambulatory. Amberg and Nördlingen seem rather bare compared with Dinkelsbühl. The decision to do without chapels and galleries is almost like a step back to the period of the Wiesenkirche at Soest. At Nürnberg and Schwäbisch Gmünd it was the chapels and galleries which created a horizontal counterbalance to the verticals: at Dinkelsbühl the very wide-meshed net-vault is sufficient to achieve this effect. Eseler lived to see the church completed in 1492, when he was an old man.*[69]

Scope of survey: Keystone levels, VR panoramas.
See drawings and measurements on pages 101–103.

73 (p62) The squat yet aspirational profile of St.-Georgs-Kirche is emblematic of the *Hallenkirche* type.

74 (Previous page) Nave and aisle vaults

8.12

Lorenzkirche
Nuremberg

Choir by Konrad Heinzelmann from 1439
Continued by Konrad Roriczer who largely completed the choir by 1477 and introduced his own vault design
Choir vault by Jakob Grimm, 1464–77

One of the largest churches in Germany, the Lorenzkirche is a Late Gothic brick cathedral with a tall nave (37m) closed with star vaults. The spatial effect of it being a hall church is mitigated by the seemingly close columns which occlude most of the aisles from view. The cathedral was heavily damaged in the Second World War and since reconstructed.

Frankl describes details of the church which are "intended to make the whole more difficult to comprehend."[70] This is certainly the final effect. The choir vaults are particularly striking and historically important, cited by Kavaler alongside Dinkelsbühl as "prime examples of this growing visual emphasis on the figured Gothic vault of the later fifteenth century."[71]

The Lorenzkirche is famously the home of Adam Kraft's sacrament house of 1493–96, pictured on page 6.

Scope of survey: Keystone levels, VR panoramas

76 (Above) Entrance portal of Lorenzkirche

77 (Previous page) Choir and ambulatory vaults

8.13

Frauenkirche
Munich

Jörg Ganghofer, 1468–1488

The relatively very short span of time in which this church was built helps account for the unusual regularity of its star vaults. The close spacing of the piers and proportions of the church are such that from the entrance foyer, no aisle windows are visible. According to legend, the Devil financed the construction of the church on the condition that it contain no windows, and ran out of the church furious or frightened when he noticed the trick. Frankl takes this legend to be a sign that "people of the time were well aware of how surprising and exciting are the views that unfold as one proceeds along the nave, and the discovery of the ambulatory when one has already followed the line of the choir vault to the last chapel is equally surprising."[72]

The Frauenkirche was also heavily damaged during the Second World War and since reconstructed.

Scope of survey: Keystone levels, VR panoramas

77 (Previous page) Nave and aisle vaults

8.14

Kloster St. Ulrich und Afra Augsburg

Aisleless basilican church by Valentin Kindlin after a fire burned down the Romanesque church in 1474 Continued by Burkhard Engelberg, Baumeister from 1477 and responsible for adding the aisles (completed 1489) and Simpertus Arch (1492)

Of particular interest in this church are the vaults of the south aisle (ca. 1493), which are asymmetrical along the axis of the aisle, and the sumptuous Simpertus arch (1492), in which all ribs are double-curved. Both of these striking features were introduced by Burkhard Engelberg who took over the construction of an otherwise old-fashioned church.[73]

Scope of survey: Keystone levels, VR panoramas
See drawings and measurements on pages 104–105.

78 (p69) The asymmetrical south aisle vaults

79 (Previous page) The Simpertus Arch

80 (Next page, top left) Elaborate keystone

81 (Next page, top right) Springing point/pilaster detail, under the Simpertus Arch

82 (Next page, bottom) Vault under the Simpertus Arch

83 (p73, top) Detail of the North portal

84 (p73) North portal


ORSUM

8.15

Liebfrauenmünster
Ingolstadt

Begun in 1425
Chapels (c. 1512–1520) by Erhard Heydenreich, Baumeister between 1509–1524

A *Staffelhall* church (like Dinkelsbühl), certainly most famous for the bizarre, varied, and profuse vaults of its six chapels by Erhard Heydenreich; the most iconic of which is a double-layered vault in which the flying ribs of the lower vault take the shape of branches (Figures 7 and 8 on pages 10–11).

Bucher describes these vaults as symbolising "the last stand of a dying style." "They are still based on a disciplined geometric grid which explodes into fireworks of incredible technical and design sophistry. The Renaissance was to reject these games with a vengeance, very much as the Bauhaus was to obliterate Art Nouveau."[74]

Scope of survey: Keystone levels (of only the much simpler nave and aisle vaults), VR panoramas

86 (Above) Preparations for *Hubertusmesse*, held in honour of Saint Hubertus, the patron saint of hunters

85 (Previous page), **87** (Next page, top), and **88** (Next page, bottom) The vaults of various chapels of the Liebfrauenmünster. See also Figures 7 and 8 on pp10–11.

8.16

Ulmer Münster

Begun in 1377 by Heinrich Parler II
Significant design changes by Ulrich Ensinger (Baumeister from 1392) and others
Completed in the late 19th century after a long interruption (1543–1844)

The Ulmer Münster can boast of being the tallest church in the world (161.53m to the steeple, 41.6m in the central nave), but also incorporates many stylistic features, including the "diagonal corner piers, the penetrations of the plinths, the slight concavities of the gables in the blind tracery, the ogee arches, the continuous frieze of tracery over the figures in the three front arches, the free rhythm of the alternately wide and narrower openings" as well as its general fineness of detail[75] which make it a prime example of the mature German Late Gothic.

The church was begun in 1377 by the Parlers (Heinrich Parler II, Michael Parler II, Heinrich Parler III) but only completed in the late 19th century. It was substantially altered by masons who succeeded the Parlers, including Ulrich Ensinger (from 1392). The nave is flanked by two star-vaulted aisles, and the choir is closed by a wide net vault.

Scope of survey: Keystone levels, VR panoramas

89 (Previous page) Ulmer Münster

90 (Next page, top) and **91** (Next page, bottom) Aisle vaults

8.17

St.-Annen-Kirche
Annaberg-Buchholz

1499–1522
Vaulted between 1517–1525 by Jacob Haylmann, Baumeister from 1515

St.-Annen's rich floral looping vaults and its three-aisled hall church design are widely regarded as epitomising the German Late Gothic. Upon visiting it, one is struck by the contrast between its austere, almost martial exterior and the warm, exactingly constructed interior of pale warm stone and vaults which evoke—though the image is burdened by its associations with Romantic nationalism—the canopy of a forest, as well as, more abstractly, arrested movement. Their complexity does not overwhelm, but always rewards closer scrutinty. Frankl writes:

> *These vaults make great demands on a comprehension of geometrical forms, but not on aesthetic feeling. All the complicated curves and intersections serve to produce an impression of rich and undulating movement. … [The] prominent feeling is one of harmony and of ease in grasping the whole, though at Annaberg these qualities are combined with a degree of continuity among all the spatial parts which far surpasses that achieved at Soest.*[76]

Jacob Haylmann (Jacob von Schweinfurt) worked under Benedikt Ried on the Vladislav Hall and at Kutná Hora.

Scope of survey: Keystone levels, VR panoramas.
See drawings and measurements on pages 106–108.

94 (Above) Interior view, facing East

92 (p92) The austere, almost martial exterior of St.-Annen-Kirche

93 (Previous page) Nave and aisle vaults

9

Conclusion

Almost from the outset, the Gothic evinced a scaleless, fractal character which was the product of a design and building praxis grounded in the belief in an orderly Christian universe governed by universal laws whose proper domain was geometry rather than arithmetic or philosophy. While its exact definition as a style is fraught with complexity and the contestation of nationalisms, the mature German Late Gothic was arguably the fullest expression of these design precepts.

Central to the practice of German Late Gothic masons was the technique of deriving the three-dimensional form of vaults (and other architectural and sculptural elements) from a two-dimensional plan—knowledge once believed to be a guarded masonic secret. In the case of vaults, this technique could take the form of projection, or else a genial technique now known as the *Prinzipalbogen* was employed which allowed masons to derive the form of a vault using only information in the plan. It is the aim of this research, initiated by the survey of vaults documented in this report, to identify its application in extant Late Gothic vaults, and to better understand the efficiencies, opportunities, and problems posed by the technique.

Ultimately, a clearer picture of Late Gothic design and building praxis—which recent scholarship suggests was eminently more practical than previously believed—may emerge and speak to fundamental problems in design such as the proper role, if such a thing exists, of the module in light of the "difficulty of being both certain and free."[77]

A sourcebook on the Late Gothic; the photographs, interactive panoramas, and measurements collected over the course of this survey; and results of ongoing model-making studies will be published to: http://spaetgotik.org

10

Endnotes

1 Ross Anderson, "From the Bauhütte to the Bauhaus: The Progressive Immanentisation of an Architectural Paradigm" (PhD diss., University of Cambridge, 2012), 9.

2 See: Paul Frankl, *Gothic Architecture*, ed. Nikolaus Pevsner, trans. Dieter Pevsner (Harmondsworth, Middlesex: Penguin, 1962), ch. 4.2 "The Mature Late Gothic Style in Germany."

3 François Bucher, "Medieval Architectural Design Methods, 800–1560," *Gesta* 11, no. 2 (1972): 49.

4 Bucher, "Mediaeval Architectural Design Methods," 49.

5 François Bucher, "Design in Gothic Architecture: A Preliminary Assessment," *Journal of the Society of Architectural Historians* 27, no. 1 (1968): 52.

In a footnote to this statement, Bucher adds: "The solutions used for theoretically and mathematically 'impossible' problems, such as the construction of the heptagon through a complex subdivision of the diameter of a circle in which it was to be inscribed, as well as the frequent use of a rotating polygon especially in Italy, will have to be discussed in a future article."

6 François Bucher, "Micro-Architecture as the 'Idea' of Gothic Theory and Style," *Gesta* 15, no. 1/2 (1976): 71.

7 The use of this term is borrowed from Dr. Wendland's European Research Council project, *REGothicVaultDesign* (*Reverse Engineering Gothic Vault Design*).

8 Ross Anderson, "Figures of Mediation: Late Gothic Chapel Vaults Between Primordial Stone and Medieval Theology," *Proceedings of the Society of Architectural Historians, Australia and New Zealand: 31 Translation*, ed. Christoph Schnoor (2014): 420.

9 Frankl, *Gothic Architecture*, 155.

10 Frankl, *Gothic Architecture*, 154.

11 See: Kalina, Pavel. *Benedikt Ried a počátky zaalpské renesance*. Prague: Academia, 2009.

12 Ranisch, Bartel. *Beschreibung Aller Kirchen-Gebäude Der Stadt Danzig.* Danzig: Johann-Zacharias, 1695.

13 Bucher, "Medieval Architectural Design Methods," 41.

14 Bucher, "Design in Gothic Architecture," 51.

15 Bucher, "Medieval Architectural Design Methods," 38.

16 Bucher, "Medieval Architectural Design Methods," 37.

17 Bucher, "Design in Gothic Architecture," 51.

18 Bucher, "Design in Gothic Architecture," 58.

Bucher cites: "P. Booz, *Der Baumeister der Gotik*. The clearest analysis of the sequential process involved in

the determination of sizes of architectural members is found in Lorenz Lacher's *Unterweisung* of 1516. Booz uses Lacher … and the Vienna sketchbook … to explain the geometric and measuring techniques used to determine shapes and then to reuse the same profile for smaller pieces. This is a practice still applied in present-day lodges."

Full citation:

Booz, Paul. *Der Baumeister der Gotik (Kunstwissenschaftliche Studien 27).* Munich: Deutscher Kunstverlag, 1956.

19 Bucher, "Design in Gothic Architecture," 49.

20 Bucher, "Design in Gothic Architecture," 51.

21 Bucher, "Design in Gothic Architecture," 71.

22 Paul Crossley, review of *German Gothic Church Architecture* by Norbert Nußbaum, trans. Scott Kleager, *Journal of the Society of Architectural Historians* 60, no. 1 (2001): 94.

23 A Google Books Ngram Viewer graph, which plots the frequency with which "*Sondergotik*" appears in German books in Google's database against time, shows that its use peaked in 1940, declined sharply, then gradually with occasional upticks to today.

24 Hans Böker, review of *German Gothic Church Architecture* by Norbert Nußbaum, trans. Scott Kleager, *Speculum* 77, no. 3 (2002): 957.

25 Ethan Matt Kavaler, *Renaissance Gothic: Architecture and the Arts in Northern Europe 1470–1540* (New Haven and London: Yale University Press, 2012), 1–2.

An outline of the book is discernable in an earlier informative paper by Kavaler:

Kavaler, Ethan Matt. "Nature and the Chapel Vaults at Ingolstadt: Structuralist and Other Perspectives." *The Art Bulletin* 87, no. 2 (2005):230–48.

26 Bucher, "Medieval Architectural Design Methods," 44.

27 Bucher, "Medieval Architectural Design Methods," 48.

28 Kavaler, *Renaissance Gothic*.

29 Kavaler, *Renaissance Gothic*, 22.

30 Kavaler, *Renaissance Gothic*, 17.

31 Kavaler, *Renaissance Gothic*, 51.

For more on Dürer's orientation towards the Gothic and the Renaissance, see: Paul Frankl, *The Gothic: Literary Sources and Interpretations through Eight Centuries* (Princeton, NJ: Princeton University Press, 1960), 315–24.

32 Quoted on: Kavaler, *Renaissance Gothic*, 2.

Kavaler cites: "Krauss and Kaser 1912, 526; Ferguson 2006, 278 and more generally 253–89. See also Schwemmer 1995."

Full citations:

Kraus, Victor, and Kurt Kaser. *Deutsche Geschichte am Ausgang des Mittelalters, 1438–1519*. Vol. 2. Stuttgart: Cotta, 1912.

Ferguson, Wallace K. *The Renaissance in Historical Thought: Five Centuries of Interpretation*. Toronto: University of Toronto Press, 2006. Originally published in 1948.

Schwemmer, Oswald. "Ernst Cassirer und die Neorenaissance." In *Renaissance der Renaissance: ein bürgerlicher kunststil im 19. Jahrhundert*. Vol. 3, 1–12. Munich: Deutscher Kunstverlag, 1995.

33 Kavaler, *Renaissance Gothic*, 5.

34 Anderson, *From the Bauhütte to the Bauhaus*, 9.

35 Anderson, *From the Bauhütte to the Bauhaus*, summary.

36 Anderson, *From the Bauhütte to the Bauhaus*, summary.

37 Lon R. Shelby, *Gothic Design Techniques: The Fifteenth-Century Design Booklets of Mathes Roriczer and Hanns Schmuttermayer* (Carbondale and Edwardsville, IL: Southern Illinois University Press, 1977), 3.

Shelby cites:

James S Ackerman, "Architectural Practice in the Italian Renaissance," *Journal of the Society of Architectural Historians* 13 (1954): 3–4.

38 Alain Erlande-Brandenburg, *The Cathedral Builders of the Middle Ages*, trans. Rosemary Stonehewer (London: Thames and Hudson, 1995), 68.

39 See: Anderson, "The transformation from operative to speculative masonry," in *From the Bauhütte to the Bauhaus*.

40 Robert Bork, "Gothic Vaulting and the Dynamics of Plan Design," in *Traces of Making: Entwurfsprinzipien von spätgotischen Gewölben / Shape, Design, and Construction of Late Gothic Vaults*, ed. Katja Schröck and David Wendland (Petersburg: Imho, 2014), 59.

Bork cites:

Labuda, Adam. "Das Kunstgeschichtliche Institut an der Reichsuniversität Posen und die 'nationalsozialistische Aufbauarbeit' im Gau

Wartheland 1939–1945." In *Kunstgeschichte an den Universitäten im Nationalsozialismus*, edited by Held von Jutta and Martin Papenbrock, 143–60. Göttingen: V & R Knipsers.

41 For a discussion on dating the treatises of Roriczer and Schmuttermayer, see: Shelby, *Gothic Design Techniques*, 1–39.

42 Anderson, *From the Bauhütte to the Bauhaus*, 12.

43 Rafael Martín Talaverano, Carmen Pérez de los Ríos, and Rosa Senent Domínguez, "Late German Gothic Methods of Vault Design and Their Relationships with Spanish Ribbed Vaults," in *Nuts & Bolts of Construction History: Culture, Technology and Society*, ed. Robert Carvais, André Guillerme, Valérie Nègre, and Joël Sakarovitch (Paris: Picard, 2012), 83.

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44 Bucher, Design in Gothic Architecture, 50.

45 Shelby, Gothic Design Techniques, 47.

46 Shelby, Gothic Design Techniques, 48.

47 Shelby, Gothic Design Techniques, 48.

48 Shelby, Gothic Design Techniques, 48.

49 Shelby, Gothic Design Techniques, 46.

50 Martín Talaverano, Pérez de los Ríos, and Senent Domínguez, "Late German Gothic Methods of Vault Design," 85.

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51 Bucher cites:

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52 Bucher, *Medieval Architectural Design Methods*, 47.

53 Anderson, "Figures of Mediation," 420.

54 Anderson, "Figures of Mediation," 420, footnote 19.

55 For example: "Descimbrado de una bóveda de crucería gótica de Josep Rives," https://www.youtube.com/watch?v=WfBRt- VNs8Dc.

56 Schröck, Katja, and David Wendland, ed. *Traces of Making: Entwurfsprinzipien von spätgotischen Gewölben / Shape, Design, and Construction of Late Gothic Vaults*. Petersberg: Imhof, 2014.

57 To be published to: http://spaetgotik.org.

58 The laser distance measurer used was a Bosch DLE70 Professional, with a "typical measurement accuracy" of ±1.5mm.

59 Anderson, *From the Bauhütte to the Bauhaus,* Figure 23.

Anderson, "Figures of Mediation."

60 Schröck, Katja, and David Wendland, ed. *Traces of Making: Entwurfsprinzipien von spätgotischen Gewölben / Shape, Design, and Construction of Late Gothic Vaults*. Petersberg: Imhof, 2014.

61 Frankl, *Gothic Architecture*, 161-162.

62 Kavaler, *Renaissance Gothic*, 31–32.

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63 David Wendland, "Wie Haben Die Spätgotischen Architekten Die Kurven Bogenrippen Geometrisch Konstruiert?" in *Das Schlingrippengewölbe Der Schlosskapelle Dresden*, Sächsisches Staatsministerium der Finanzen (Altenburg: Klaus Jürgen Kamprad, 2013), 34–38.

64 See: Kalina, Pavel. *Benedikt Ried a počátky zaalpské renesance.* Prague: Academia, 2009.

65 Kavaler, *Renaissance Gothic*, 18–19.

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67 Frankl, *Gothic Architecture*, 203–4.

68 Frankl, *Gothic Architecture*, 155–56.

69 Frankl, *Gothic Architecture*, 186–87.

70 Frankl, *Gothic Architecture*, 185.

71 Kavaler, *Renaissance Gothic*, 136.

72 Frankl, *Gothic Architecture*, 188.

73 Frankl, *Gothic Architecture*, 194.

74 Bucher, *Medieval Architectural Design Methods*, 48.

75 Frankl, *Gothic Architecture*, 180.

76 Frankl, *Gothic Architecture*, 209.

77 Anderson, "Figures of Mediation," 420.

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12

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Appendix A

Vault Spot Level Measurements

The following are plans of selected churches on which the heights of keystones measured on site are indicated. Before making use of this data, please note the caveats in Section 5 (Scope of Research) on pages 16–17.

Contents

Appendix A.1

Kostel Nanebevzetí Panny Marie, Most

Source of plans: Heide Mannlová-Raková, *Kulturní památka Most: Děkanský kostel a jeho stavitelé* (Prague: Propagacni tvorba, 1988), 25.

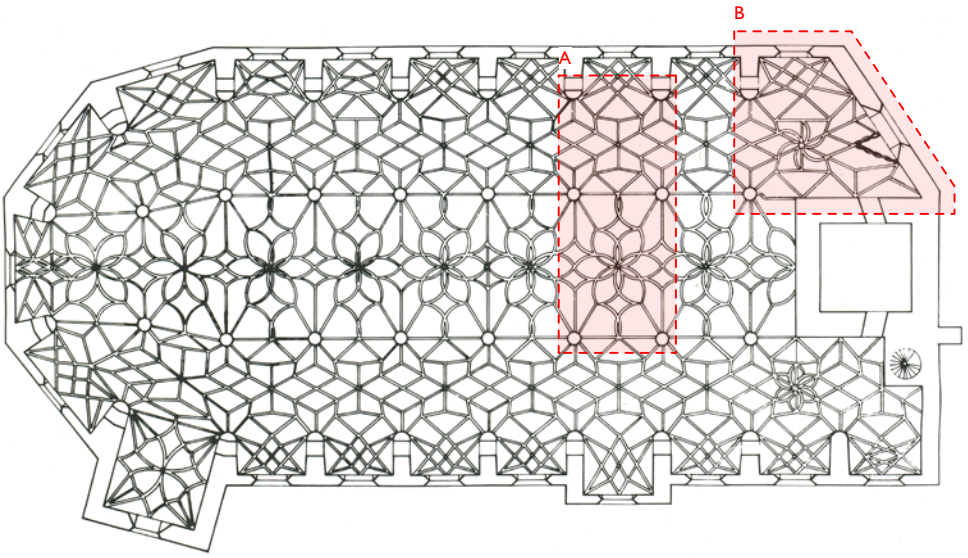
All measurements for this church are relative to the floor level of the gallery.

Vault bay group A (Nave and Aisle)

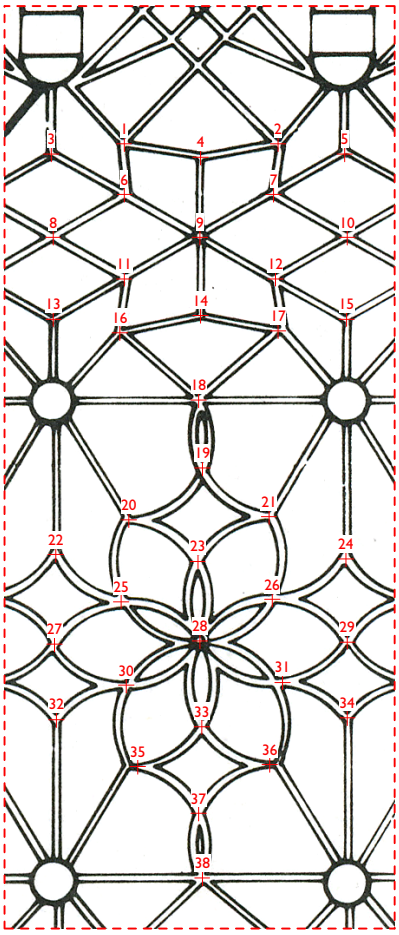
1 . . . 15583
2 . . . 15620
3 . . . 15460
4 . . . 16447
5 . . . 15483
6 . . . 16495
7 . . . 16432
8 . . . 16566
9 . . . 16713
10 . . 16698
11. . . 16522
12 . . 16473
13 . . 15453
14 . . 16529
15 . . 15511
16 . . 15618
17 . . 15573
18 . . 16377
19 . . 16261
20 . . 15269
21 . . 15235
22 . . 15442
23 . . 16050
24 . . 16074
25 . . 16082
26 . . 16070
27 . . 16082
28 . . 16289
29 . . 16036
30 . . 16114
31 . . 16047
32 . . 15459
33 . . 16016
34 . . 15407
35 . . 15278
36 . . 15236
37 . . 16262
38 . . 16441

Vault bay B (Gallery)

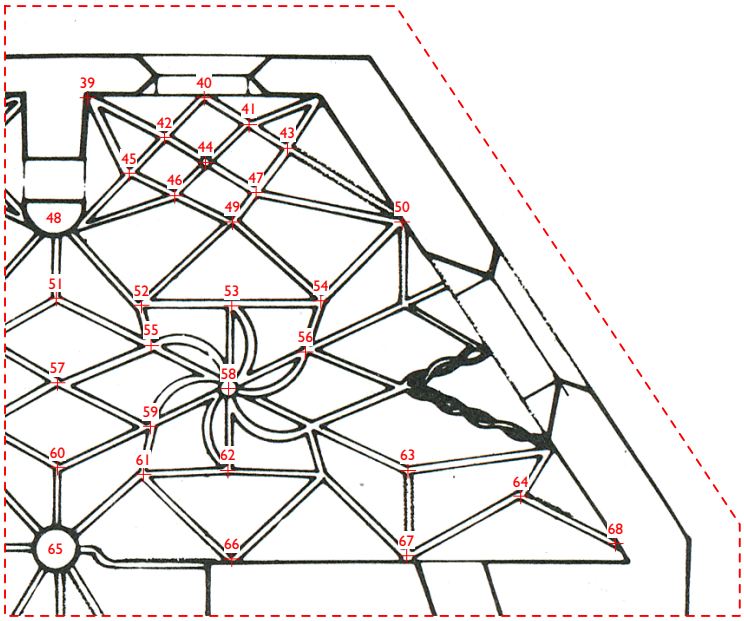
39 . . ≈9555 (springing point)
40 . . ≈10746 (springing point)
41 . . 10630
42 . . 10581
43 . . 10432
44 . . 10871
45 . . 10389
46 . . 10585
47 . . 10562
48 . . ≈7048 (springing point)
49 . . 10656
50 . . ≈7419 (springing point)
51 . . 9718
52 . . 9919
53 . . 10775
54 . . 9926
55 . . 10802
56 . . 10796
57 . . 10977
58 . . 9351 (lower/flying rib intersection)
≈10926 (higher rib intersection)
59 . . 10784



KOSTEL NANEBEVZETÍ PANNY MARIE, MOST
(CHURCH OF THE ASSUMPTION OF THE VIRGIN MARY)
PLAN, APPROXIMATELY 1:500 (NO SCALE PROVIDED WITH ORIGINAL)



VAULT BAY GROUP A
NAVE AND AISLE
PLAN, APPROXIMATELY 1:150



VAULT BAY B
GALLERY
PLAN, APPROXIMATELY 1:150

60 . . 9747
61 . . 9878
62 . . 10730
63 . . 9876
64 . . 9947
65 . . ≈7163 (springing point)

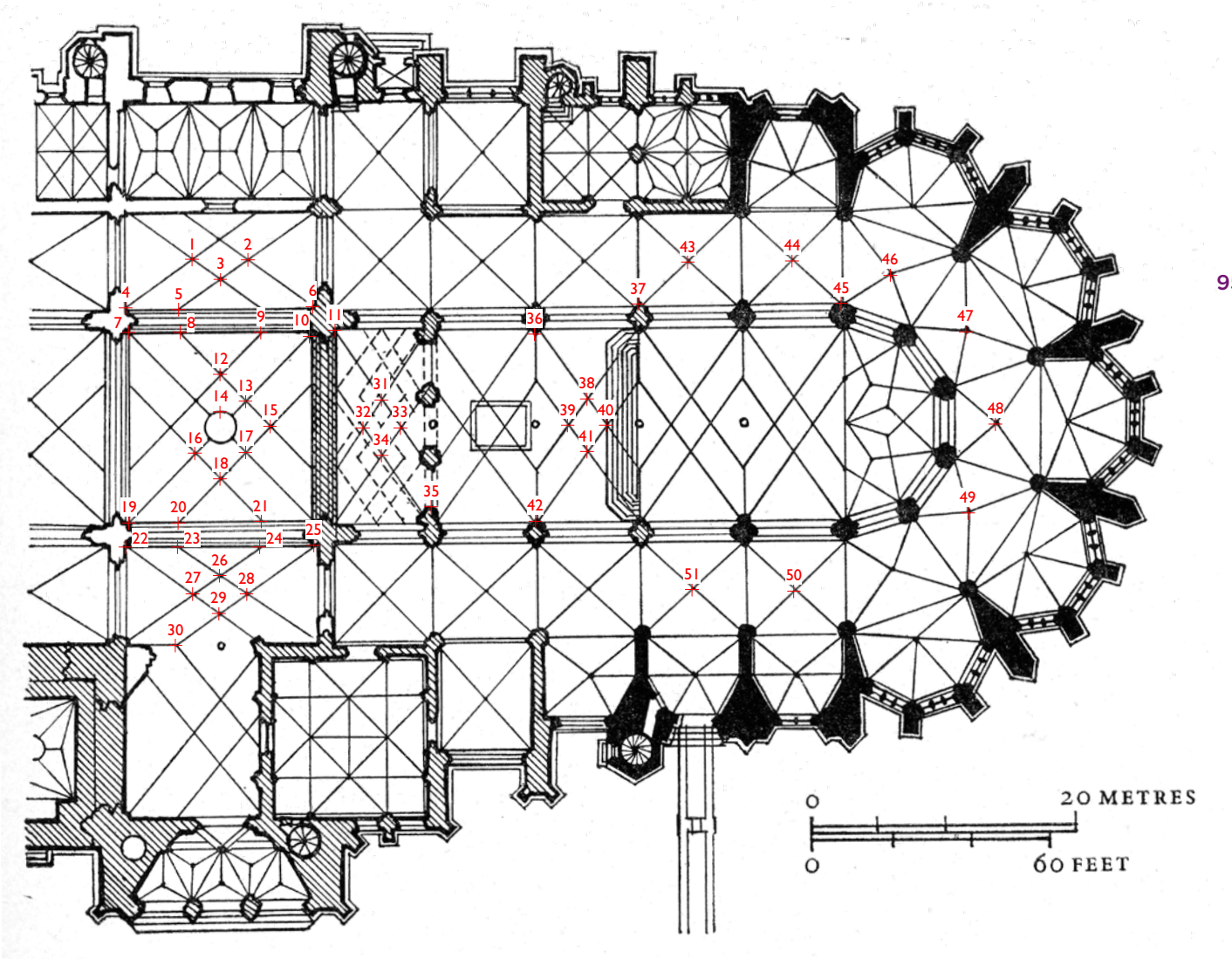
66 . . ≈10782 (springing point)
67 . . ≈6904 (springing point)
68 . . ≈7256 (springing point)

Appendix A.2

St. Vitus Cathedral, Prague Castle

Source of plans: Paul Frankl, *Gothic Architecture*, ed. Nikolaus Pevsner, trans. Dieter Pevsner (Harmondsworth, Middlesex:Penguin, 1962), 161.

1 . . . 32854
2 . . . 32918
3 . . . 33217
4 . . . ≈24972 (springing point)
5 . . . 31899
6 . . . ≈24698 (springing point)
7 . . . ≈24593 (springing point)
8 . . . 32108
9 . . . 32118
10 . . 33353
11. . . 33544
12 . . 33933
13 . . ≈33402
14 . . 33556
15 . . 33541
16 . . 32490
17 . . 33370
18 . . ≈25071 (springing point)
19 . . 32037
20 . . 32086
21 . . ≈25083 (springing point)
22 . . 32007
23 . . 31859
24 . . ≈25041 (springing point)
25 . . 33164
26 . . 32825
27 . . 32811
28 . . 33180
29 . . 31910
30 . . ≈24920 (springing point)
31 . . 32655
32 . . 33232
33 . . 33219
34 . . 32660
35 . . ≈24965 (springing point)
36 . . ≈24847 (springing point)
37 . . ≈9543 (springing point)
38 . . 32588
39 . . ≈33081
40 . . 33177
41 . . 32742
42 . . ≈24574 (springing point)
43 . . 14422
44 . . 14407
45 . . ≈9480 (springing point)
46 . . 14249
47 . . ≈14204
48 . . 14493
49 . . 14611
50 . . 14666
51 . . 14672



TRANSEPT, CHOIR AND AMBULATORY OF ST. VITUS CATHEDRAL
PLAN 1:500

Appendix A.3

The Vladislav Hall, Prague Castle

Source of plans: Pavel Kalina, *Benedikt Ried a počátky zaalpské renesance* (Prague: Academia, 2009), 109.

Points 3, 7, 13, 16, 21, 24, 30, and 34 indicate the bottom of the ends of free-flying rib extensions. Unless otherwise noted, where two ribs at different elevations partially intersect, the measurement given is the elevation of the bottom face of the bottom rib.

Vault bay A

1 . . . ≈12759
2 . . . 10114
3 . . . 10282
5 . . . 10717
6 . . . 10730
7 . . . 10427
9 . . . ≈11146
11 . . . 12509
12 . . 10020
13 . . 11913
14 . . 12308
15 . . 12348
16 . . 11970
18 . . 13156
20 . . 12366
21 . . 11963
22 . . 12306
23 . . 12247
24 . . 11892
26 . . 12589
27 . . 10039
28 . . ≈11175
29 . . 10134
30 . . 10365
31 . . 10745
32 . . 11041
34 . . 10251
35 . . 10081
36 . . ≈12668

Vault bay B

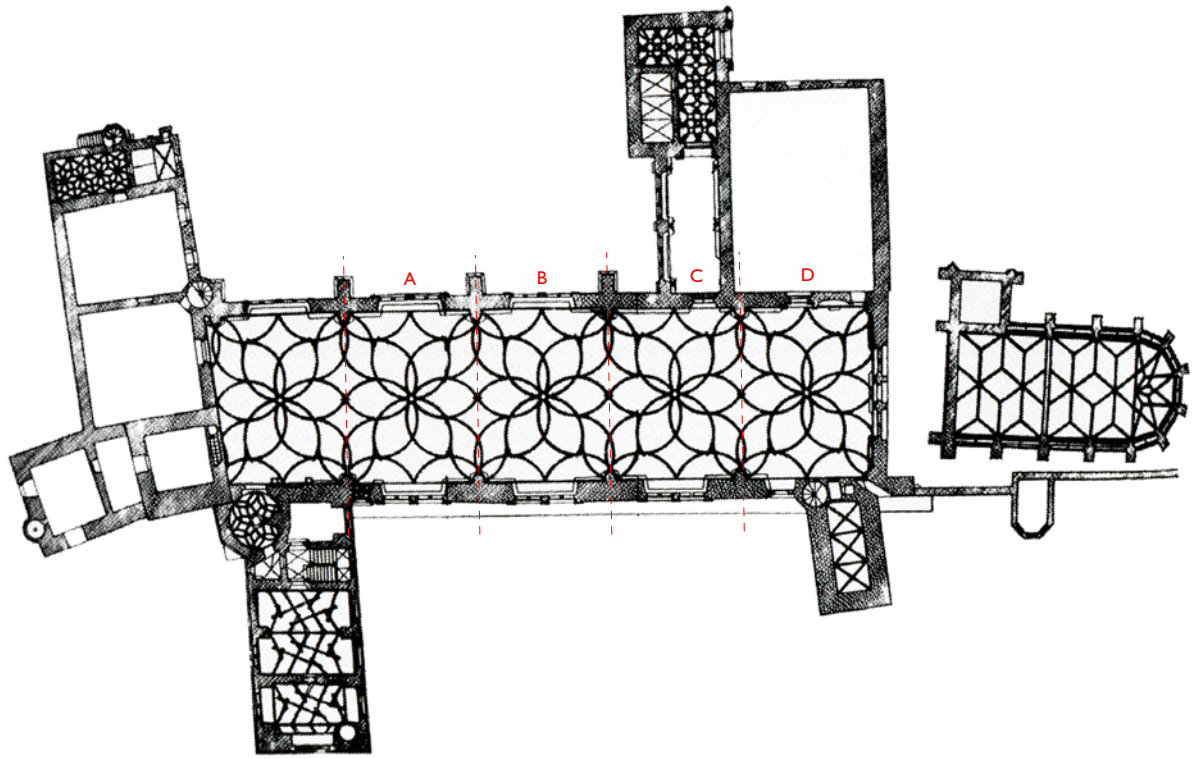
1 . . . ≈12676
2 . . . 10066
3 . . . 10258
5 . . . 11071
6 . . . 10576
7 . . . 10206
8 . . . 10002
10 . . 10020
11 . . . 12442
12 . . 10023
13 . . 11904
14 . . 12238
15 . . 12269
16 . . 12021
17 . . 12366
18 . . 12986
20 . . 12102
21 . . 12041
22 . . 12338
23 . . 12300
24 . . 12059
25 . . 10039
26 . . 12552
27 . . 10016
29 . . 10120
30 . . 10342
31 . . 10737
32 . . 11174
34 . . 10283
35 . . 10052
36 . . 12702

Vault bay C

2 . . . 10016
3 . . . ≈10197
4 . . . 10625
5 . . . 11040
7 . . . 10151
8 . . . 10124
9 . . . 11128
10 . . 10023
11 . . . 12467
12 . . 10032
13 . . 12054
14 . . 12266
15 . . 12260
16 . . 11960
17 . . 12102
18 . . 13000
20 . . 12096
21 . . 11991
22 . . 12281
23 . . 12314
24 . . 12052
25 . . 10016
26 . . 12549
27 . . 10081
28 . . 11224
29 . . 10134
30 . . 10288
31 . . 10652
32 . . 11230
33 . . 10675
34 . . 10305
35 . . 10226
36 . . 12780

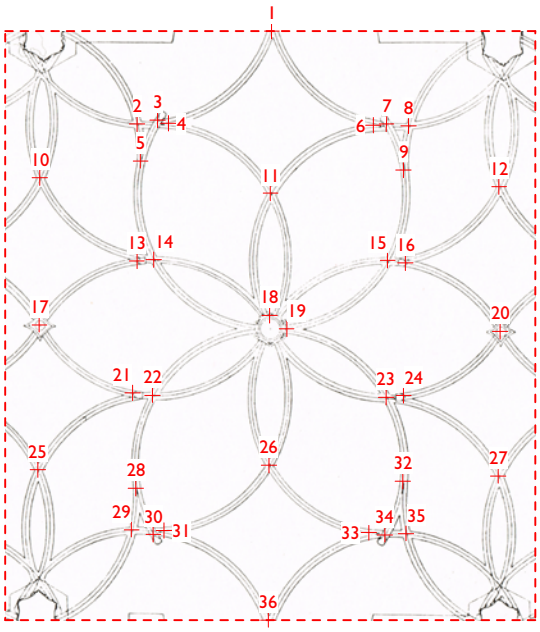
Vault bay D

2 . . . 10098
3 . . . 10313
4 . . . 10667
5 . . . 11123
6 . . . 10697
7 . . . 10357
8 . . . 10104
9 . . . 11152
10 . . 10032
11 . . . 10049
13 . . 12024
14 . . 12314
15 . . 12348
16 . . 12019
17 . . 12096
18 . . 13031
21 . . 12035
22 . . 12333
23 . . 12338
24 . . 12140



OLD ROYAL PALACE OF PRAGUE CASTLE, INCLUDING THE VLADISLAV HALL
PLAN, APPROXIMATELY 1:700 (NO SCALE PROVIDED WITH ORIGINAL)

25 . . 10081
26 . . 12580
27 . . 9536 (on wall)
28 . . 11103
29 . . 10167
30 . . 10369
31 . . 10690
32 . . 11199
33 . . 10815
34 . . 10519
35 . . 10174
36 . . 12783



TYPICAL VAULT BAY
PLAN, APPROXIMATELY 1:200
(NO SCALE PROVIDED WITH ORIGINAL)

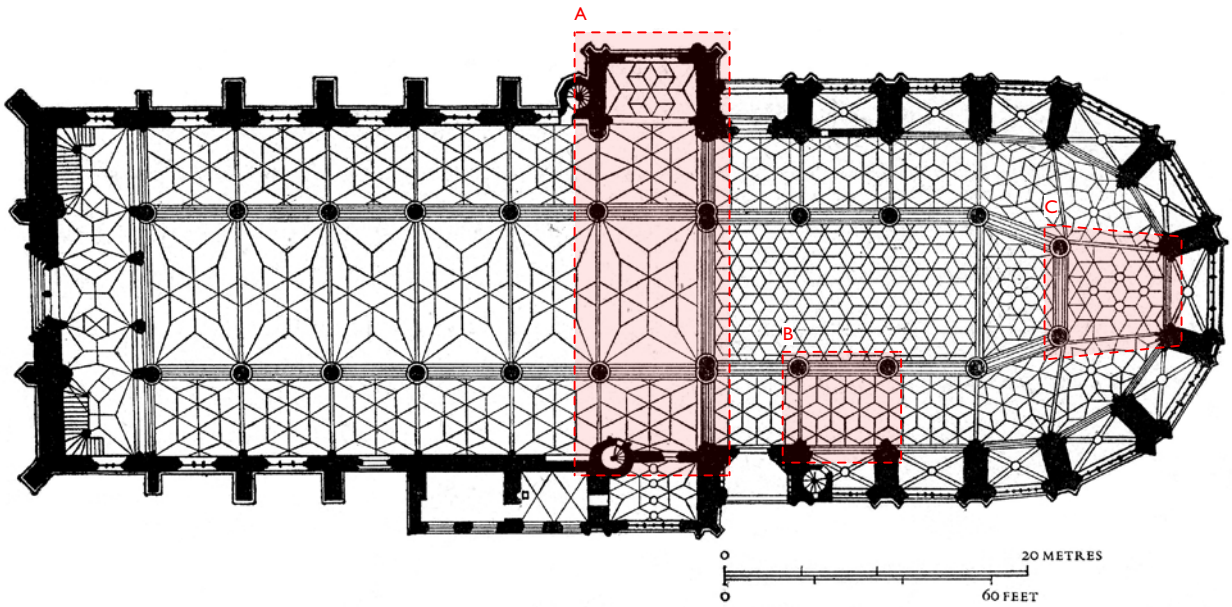
Appendix A.4

Heilig-Kreuz-Münster, Schwäbisch Gmünd

Source of plans: Paul Frankl, *Gothic Architecture*, ed. Nikolaus Pevsner, trans. Dieter Pevsner (Harmondsworth, Middlesex:Penguin, 1962), 155.

Vault bay group A (Crossing and Transept)
Points 1–13 include a step of 178.

1 . . . 6686 (upper ridge in impost)
2 . . . 10063
3 . . . 10493
4 . . . 9619
5 . . . 10242
6 . . . 9840
7 . . . 10297
8 . . . 10459 (coat of arms boss)
9 . . . 9630
10 . . 10256
11 . . . 6689 (upper ridge in impost)
12 . . 9981
13 . . 10451
14 . . 18428
15 . . 18445
16 . . 17501
17 . . 17515
18 . . 17245
19 . . 18673
20 . . 17253 (17080 + 173 step)
21 . . ≈17756 (arch apex)
22 . . 18170
23 . . 18146
24 . . 17235
25 . . 18674
26 . . ≈17282 (≈17109 + 173 step)
27 . . 17473
28 . . 17536
29 . . 18422
30 . . ≈18440
31 . . ≈12187 (bottom ridge in impost)
32 . . ≈17934 (arch apex)
33 . . ≈12208 (bottom ridge in impost)
34 . . 18614
35 . . 18406
36 . . 18367
37 . . 18966
38 . . 18598
39 . . 18631 (18295 + 166 + 170 steps)
40 . . 18888 (arch apex)
41 . . 18926
42 . . 18938
43 . . 18238 (arch apex, 17741 + 166 + 170 + 161 steps)
44 . . 18627
45 . . 18630 (18294 + 166 + 170 steps)
46 . . 18632
47 . . ≈18448
48 . . 18424
49 . . 18624
50 . . ≈12066 (bottom ridge in impost)
51 . . 18072 (arch apex)
52 . . ≈15310 (rib intersection)
53 . . 18458
54 . . 18440
55 . . 17550
56 . . 17548 (17011 + 177 + 179 + 181 steps)
57 . . 17310
58 . . 18695 (18518 + 177 step)
59 . . 17255 (16718 + 177 + 179 + 181 steps)
60 . . 17277 (arch apex)
61 . . 18204
62 . . 18154 (17617 + 177 + 179 + 181 steps)
63 . . 17277
64 . . 18700 (18163 + 177 + 179 + 181 steps)



HEILIG-KREUZ-MÜNSTER, SCHWÄBISCH GMÜND
PLAN 1:500

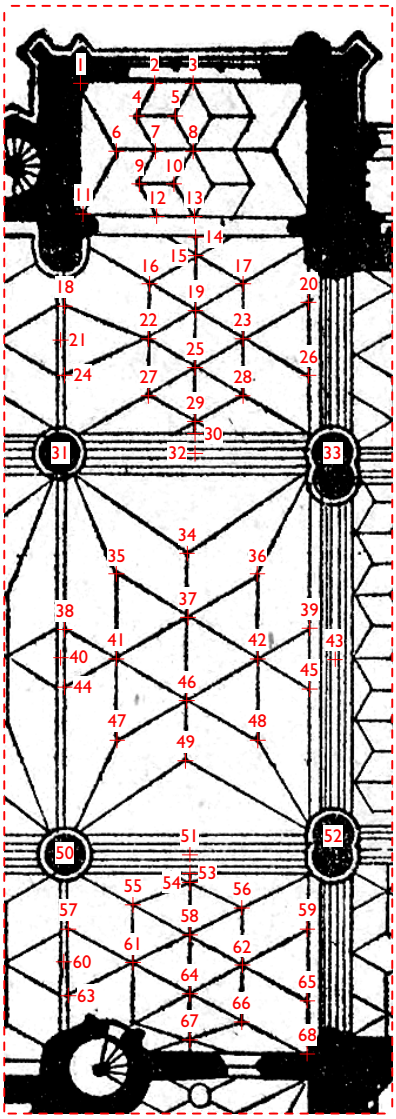
65 . . 17306 (16718 + 177 + 179 + 181 steps)
66 . . 17503 (17617 + 177 + 179 + 181 + 151 steps)
67 . . 18449 (17761 + 177 + 179 + 181 + 151 steps)
68 . . 11772 (bottom ridge in impost)
(11235 + 177 + 179 + 181 steps)

Vault bay B (Ambulatory)

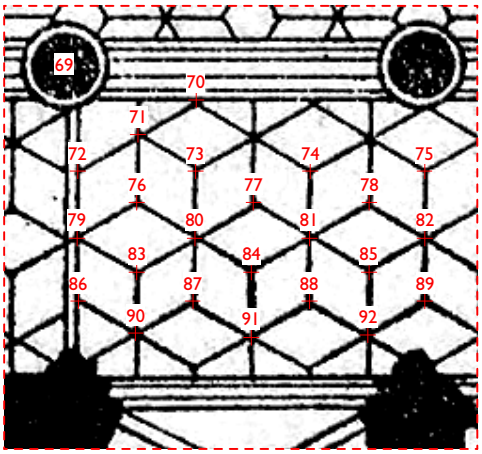
69 . . ≈14586 (green bottom ridge in impost)
70 . . 19147
71 . . 19249
72 . . 19310
73 . . 20060
74 . . 20060
75 . . 19192
76 . . 20186
77 . . 20206
78 . . 20135
79 . . 20046
80 . . 20399
81 . . 20239
82 . . ≈19959
83 . . 20198
84 . . 20221
85 . . 20132
86 . . 19248
87 . . 20037
88 . . 20009
89 . . ≈19028
90 . . ≈19206
91 . . 19508
92 . . ≈19202

Vault bay C (Ambulatory)

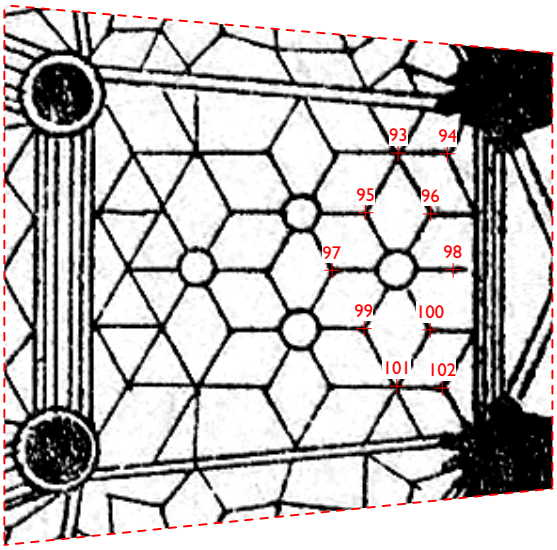
93 . . 19508
94 . . 18731
95 . . 20392
96 . . 19635
97 . . 20524
98 . . 19755 (rib intersection; ribs missing on plan)
99 . . 20437
100 . 19614
101 . . 19494
102. . ≈18727



VAULT BAY GROUP A
CROSSING AND TRANSEPT
PLAN 1:200



VAULT BAY B
AMBULATORY
PLAN 1:125



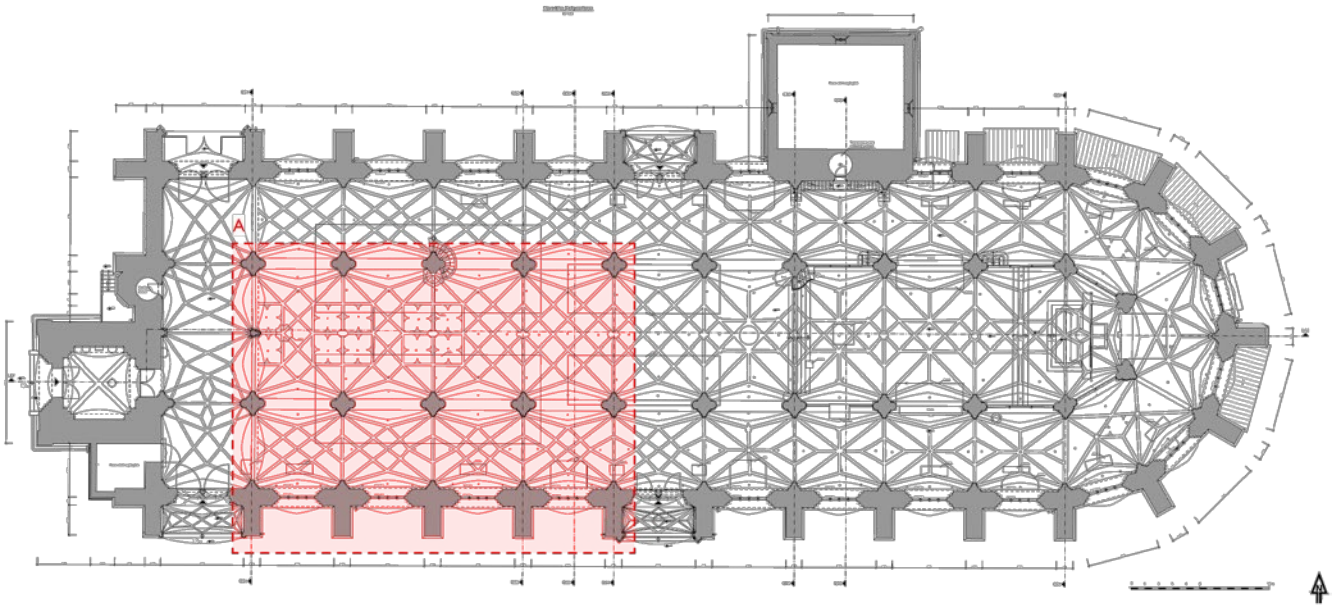
VAULT BAY C
AMBULATORY
PLAN 1:125

Appendix A.5

St.-Georgs-Kirche, Dinkelsbühl

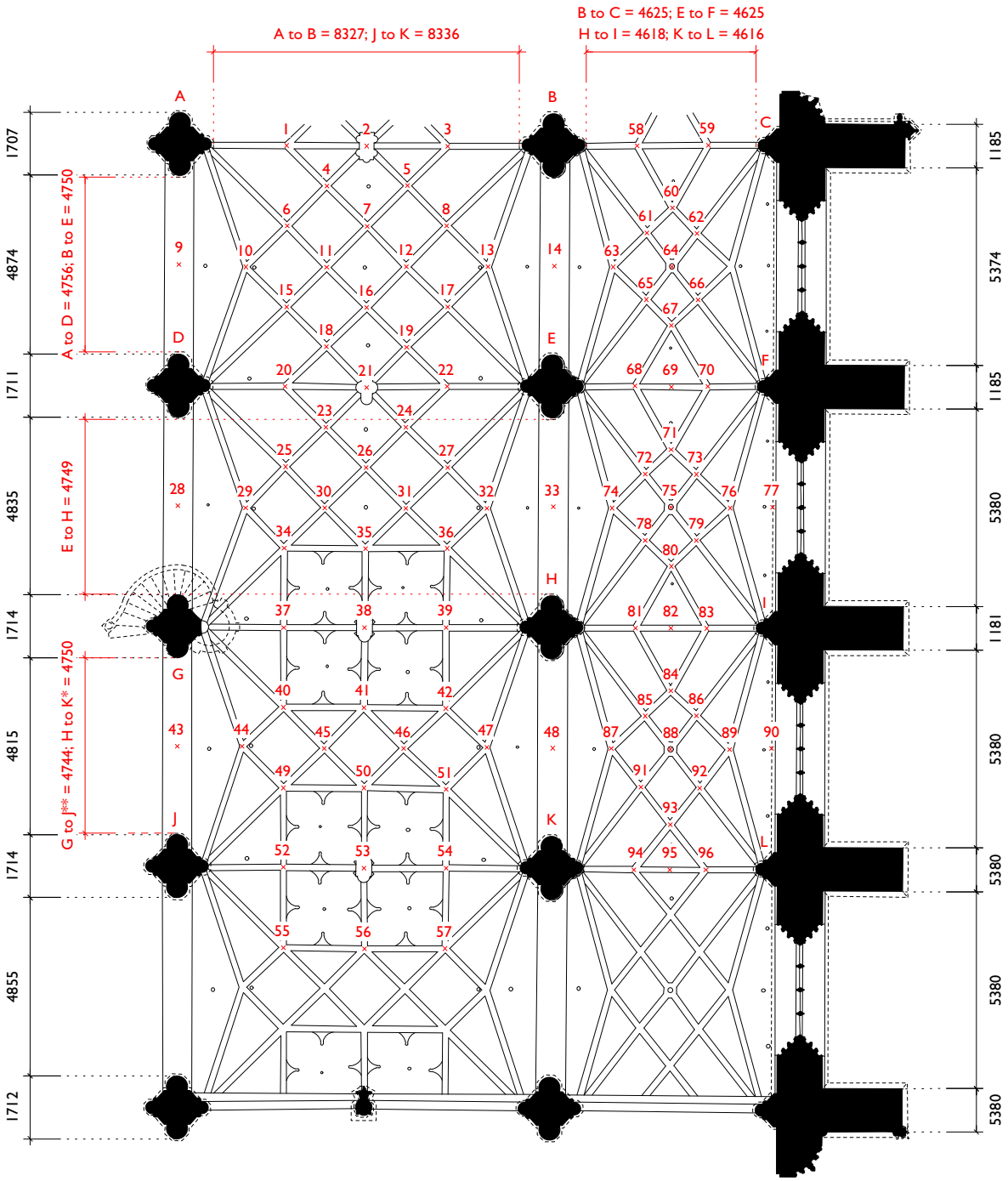
Source of plans: Shared for the purposes of this report by Mr.-Ing. Josef Ruhland, architect for St.-Georgs-Kirche; produced by Ingenieurbüro Christofori & Partner. The plan on p103 was traced over the survey. Not all plan dimensions noted on p103 were noted in the survey.

1 . . . 20297
2 . . . 20854 (20804 + 50mm coat of arms)
3 . . . 20333
4 . . . 20790
5 . . . 20800
6 . . . 20356
7 . . . 20947
8 . . . ≈20378
9a . . 19643 (arch apex)
9b . . 20396 (groin of vault)
10 . . 20121
11. . . 20836
12 . . 20844
13 . . 20132
14a. . 19712 (arch apex)
14b. . 20448 (groin of vault)
15 . . 20366
16 . . 20933
17 . . 20380
18 . . 20783
19 . . 20773
20 . . ≈20327
21 . . 20904 (20854 + 50mm coat of arms)
22 . . 20354
23 . . 20824
24 . . 20838
25 . . 20373
26 . . 20984
27 . . 20381
28a . 19648 (arch apex)
28b . 20425 (groin of vault)
29 . . 20066
30 . . 20875
31 . . 20868
32 . . 20081
33a . 19695 (arch apex)
33b . 20451 (groin of vault)
34 . . 20378
35 . . 20975
36 . . 20377
37 . . 20372
38 . . 20957 (20907 + 50mm coat of arms)
39 . . 20395
40 . . 20298
41 . . 20964
42 . . ≈20350
43a . 19668 (arch apex)
43b . 20395 (groin of vault)
44 . . 20025
45 . . 20807
46 . . 20822
47 . . 20042
48a . ≈19734 (arch apex)
48b . 20476 (groin of vault)
49 . . 20314
50 . . 20927
51 . . 20264
52 . . ≈20311
53 . . 20938 (20888 + 50mm coat of arms)
54 . . ≈20313
55 . . 20353
56 . . 20982
57 . . 20338
58 . . 20106
59 . . 20117
60 . . 20983



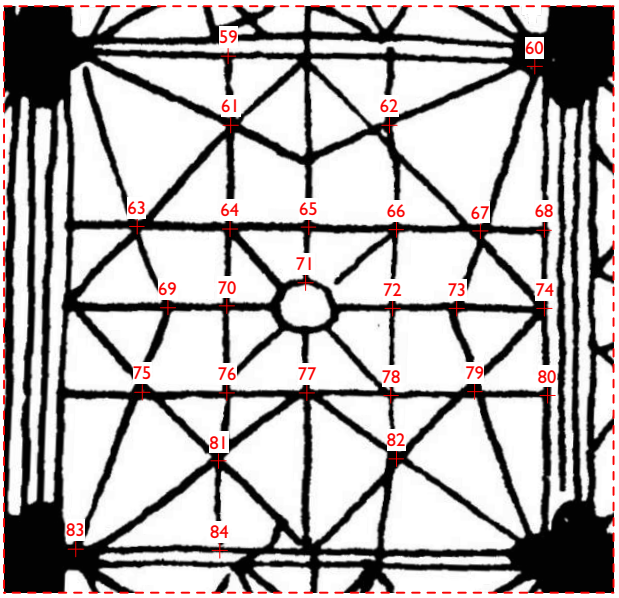
ST.-GEORGS-KIRCHE, DINKELSBÜHL
PLAN 1:500

61 . . 20604
62 . . 20631
63 . . 20154
64 . . 20967
65 . . 20620
66 . . 20639
67 . . 20933
68 . . ≈20045
69 . . 20627 (apex of arch formed by ribs)
70 . . 20144
71 . . 21021
72 . . ≈20576
73 . . 20612
74 . . 20140
75 . . 20889
76 . . 20274
77 . . ≈20444 (groin of vault)
78 . . 20566
79 . . 20590
80 . . 20900
81 . . 20178
82 . . 20681 (apex of arch formed by ribs)
83 . . 20150
84 . . 20999
85 . . 20603
86 . . 20643
87 . . 20193
88 . . 20954
89 . . 20284
90 . . ≈20453 (groin of vault)
91 . . 20548
92 . . 20550
93 . . 20627
94 . . 20105
95 . . 20612 (apex of arch formed by ribs)
96 . . 20130
97 . . 20627 (apex of arch formed by ribs)


A to B = 8327; J to K = 8336
B to C = 4625; E to F = 4625
H to I = 4618; K to L = 4616
A to D = 4756; B to E = 4750
E to H = 4749
G to J** = 4744; H to K* = 4750
1707
4874
1711
4835
1714
4815
1714
4855
1712
1185
5374
1185
5380
1181
5380
5380
5380
5380

Appendix A.6

The Basilika St. Ulrich und Afra Augsburg



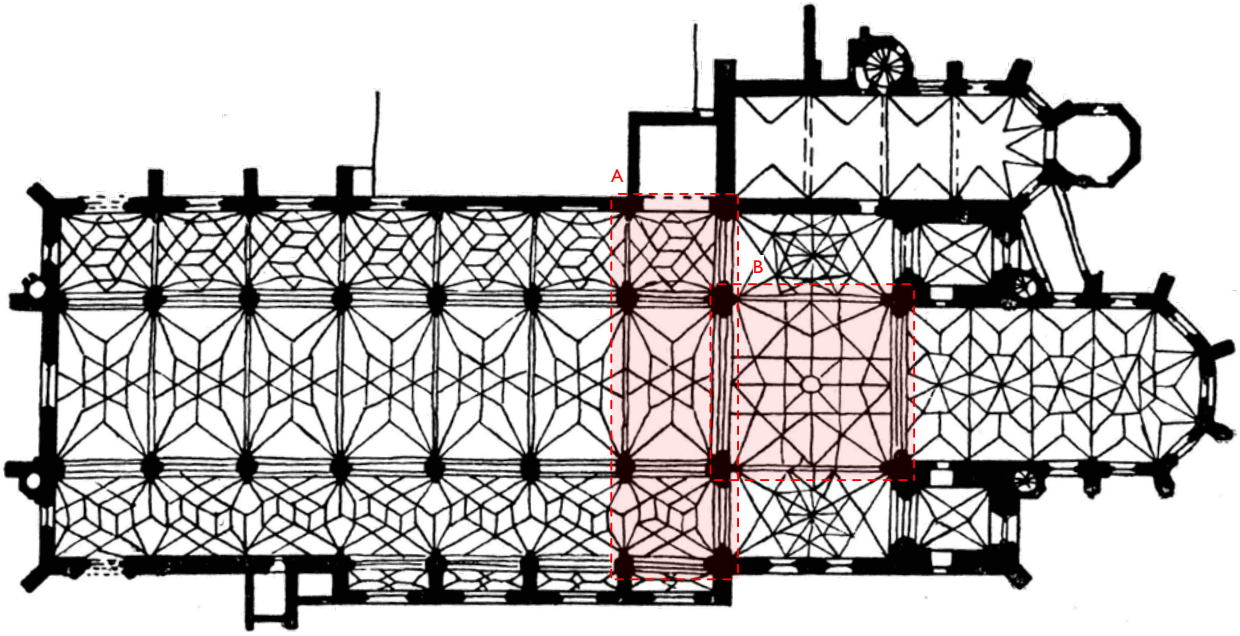
VAULT BAY B
CROSSING/CHOIR
PLAN, APPROXIMATELY 1:200
(NO SCALE PROVIDED WITH ORIGINAL)

Vault bay group A (Nave and aisles)

1 . . . 8124 (topmost ridge in impost stone)
2 . . . 12865
3 . . . 12872
4 . . . 11609
5 . . . 12868
6 . . . 13584 (coat of arms keystone)
7 . . . 12859
8 . . . 11544
9 . . . 12791 (groin of vault)
10 . . 12456
11. . . 13463
12 . . 13465
13 . . 12442
14 . . 12692 (groin of vault)
15 . . 11623
16 . . 12857
17 . . 13627
18 . . 12846
19 . . 11589
20 . . 12853
21 . . ≈12836
22 . . 12442
23 . . 7798 (bottom of impost stone)
24 . . 12071 (arch apex)
25 . . ≈21340 (bottom of impost stone)
26 . . 28557
27 . . ≈28608
28 . . 28586
29 . . ≈28643 (rib where it meets the boundary arch)
30 . . 29154
31 . . 28504 (rib where it meets the boundary arch)
32 . . 28813 (arch apex)
33 . . 29153
34 . . 29129
35 . . 28722
36 . . ≈28587 (rib where it meets the boundary arch)
37 . . 29159
38 . . 28506 (rib where it meets the boundary arch)
39 . . ≈28615
40 . . 28587
41 . . ≈28571
42 . . ≈21491 (bottom of impost stone)
43 . . 27933 (groin of vault)
44 . . 11747
45 . . 12696 (groin of vault)
46 . . 11738
47 . . ≈7789 (bottom of impost stone)
48 . . 12522
49 . . 12863
50 . . 13085
51 . . 13471
52 . . 13494
53 . . 12867
54 . . 13588
55 . . 13579 (coat of arms keystone)
56 . . 13108
57 . . 13494
58 . . 13086

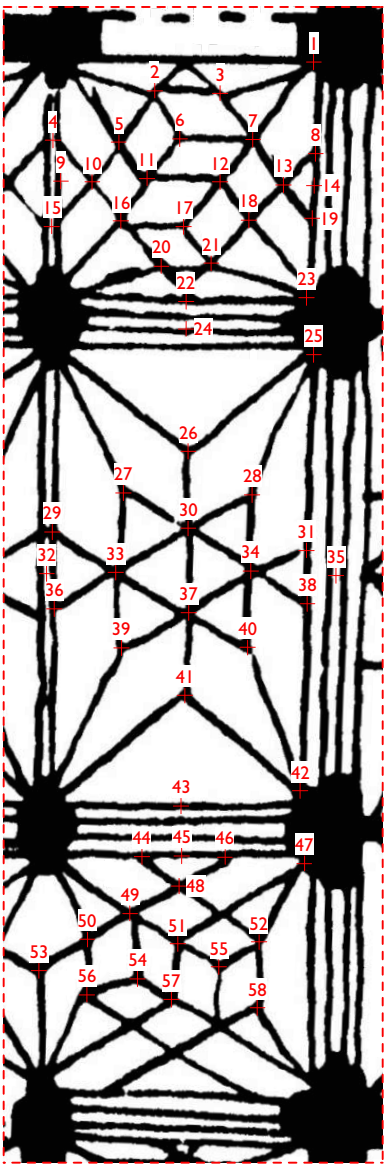
Vault B (Crossing/choir)

59 . . 27172 (rib where it meets the boundary arch)
60 . . ≈19754 (bottom of impost stone)
61 . . 27960
62 . . 27993
63 . . ≈27946



THE BASILICA ST. ULRICH UND AFRA AUGSBURG
PLAN, APPROXIMATELY 1:600 (NO SCALE PROVIDED WITH ORIGINAL)

64 . . 28835
65 . . 29432
66 . . 28875
67 . . 28026
68 . . 27583 (rib where it meets the boundary arch)
69 . . 29264
70 . . 29422
71 . . 29643
72 . . ≈29452
73 . . ≈29284
74 . . 28582 (rib where it meets the boundary arch)
75 . . 27992
76 . . 28791
77 . . 29323
78 . . 28810
79 . . 28036
80 . . 27607 (rib where it meets the boundary arch)
81 . . 27890
82 . . 27987
83 . . ≈19635 (bottom of impost stone)
84 . . 27111



VAULT BAY GROUP A
NAVE AND AISLES
PLAN, APPROXIMATELY 1:200
(NO SCALE PROVIDED WITH ORIGINAL)

Source of plans: Wikimedia Commons

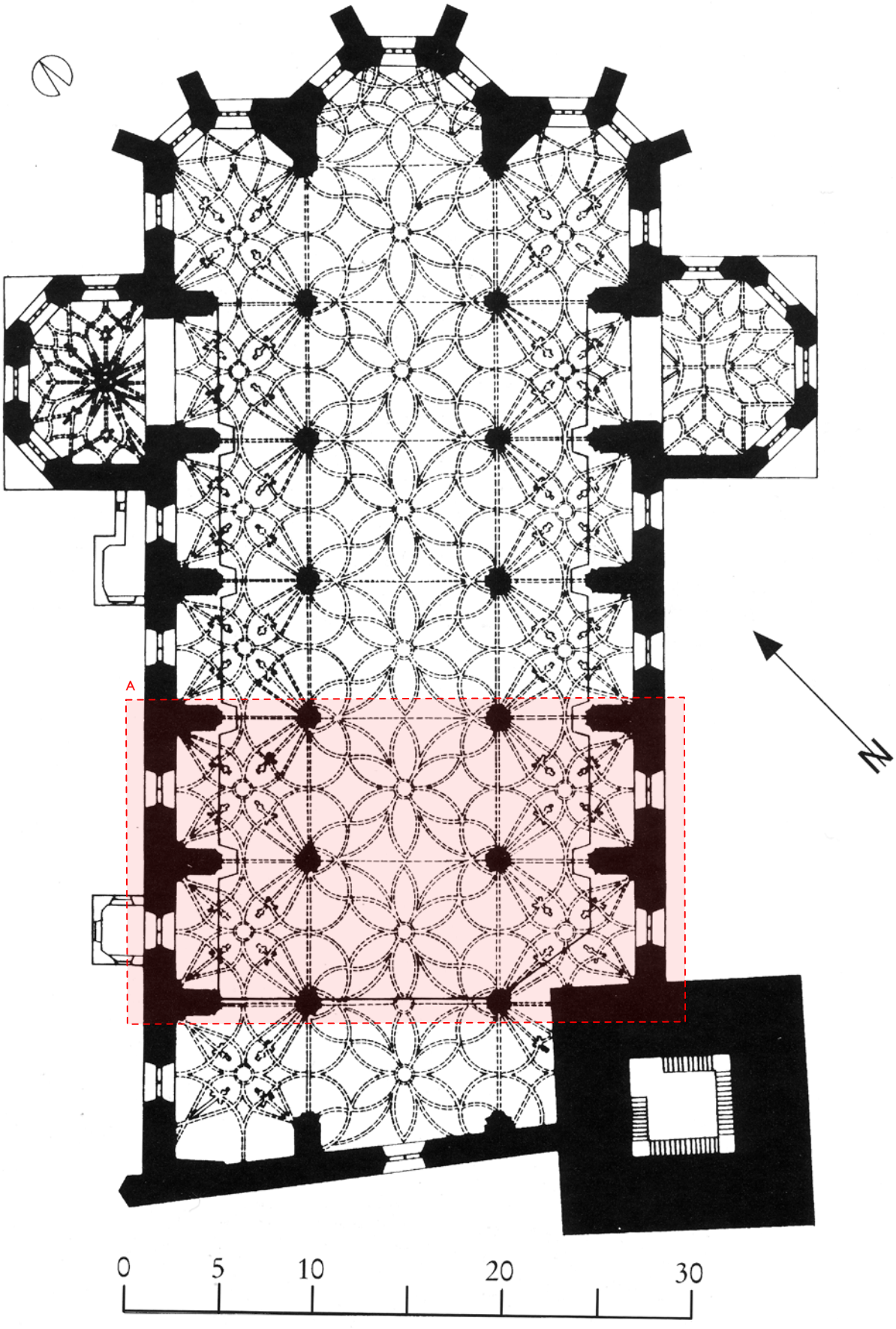
Appendix A.7

St.-Annen-Kirche, Annaberg-Buchholz

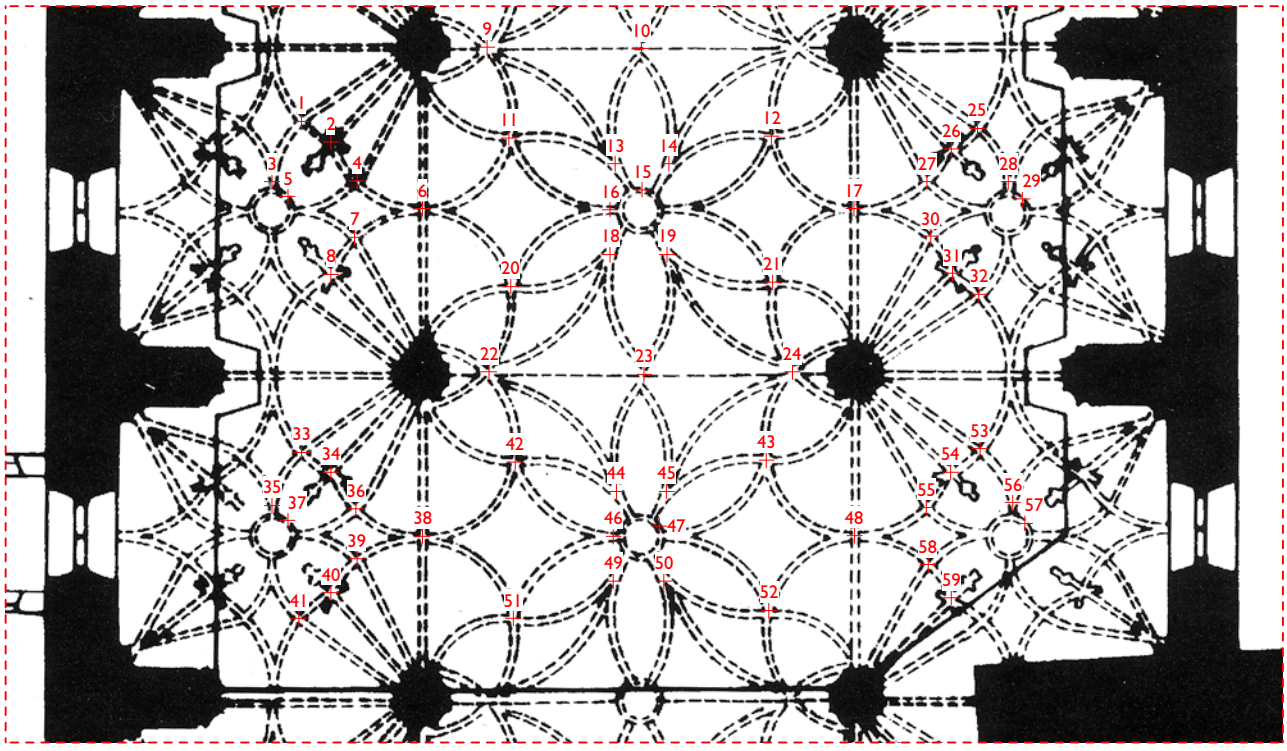
Source of plans: Heinrich Magirius, *St. Annen zu Annaberg* (Regensburg: Schnell & Steiner, 2013), inside of back cover.

Vault bay group A

1 . . . 20044
2 . . . 19683
3 . . . 20779
4 . . . ≈20006
5 . . . 20633
6 . . . ≈20102
7 . . . 20012
8 . . . ≈19705
9 . . . ≈18305
10 . . 19223
11 . . . ≈19337
12 . . 19327
13 . . ≈20354
14 . . 20359
15 . . 20623
16 . . ≈20635
17 . . 20679
18 . . 20350
19 . . 20355
20 . . 19216
21 . . ≈19222
22 . . ≈18265
23 . . 19197
24 . . ≈18286
25 . . ≈20024
26 . . 19714
27 . . 20027
28 . . 20774
29 . . 20590
30 . . 20051
31 . . ≈19700
32 . . 20017
33 . . 20010
34 . . 19671
35 . . 20768
36 . . 19888
37 . . 20570
38 . . 20577
39 . . 19983
40 . . 19661
41 . . ≈19973
42 . . 19317
43 . . 19300
44 . . 20342
45 . . 20343
46 . . ≈20641
47 . . ≈20659
48 . . 20654
49 . . ≈20598
50 . . ≈20365
51 . . 19303
52 . . ≈20344
53 . . 20017
54 . . 19709
55 . . 20001
56 . . 20766
57 . . 20519
58 . . ≈20013
59 . . 19682



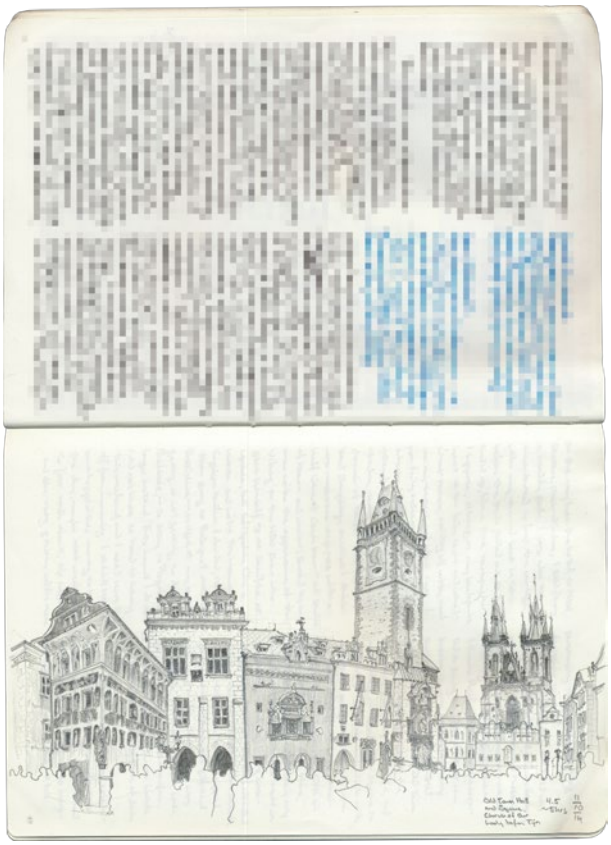
ST. ANNE'S CHURCH, ANNABERG-BUCHHOLZ
PLAN, 1:300



VAULT GROUP A
PLAN 1:175

Appendix B

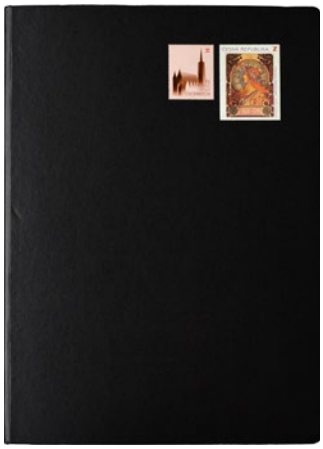
Travel Sketches and Photographs

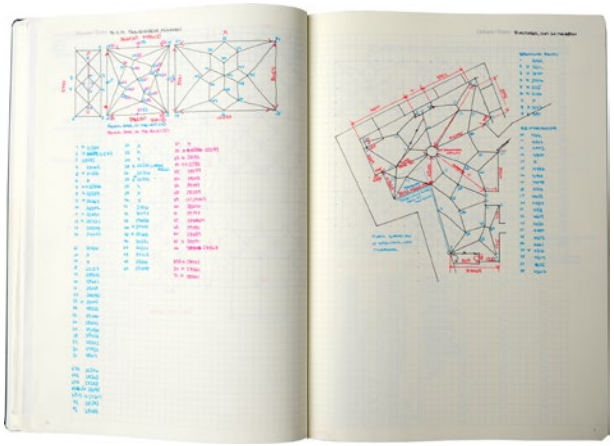


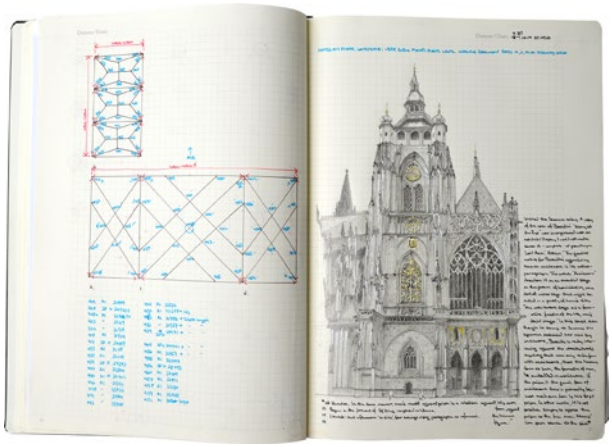
95 (Above, left) Pages of a waterlogged sketchbook. Inscriptions around the Jan Hus monument in the Old Town Square of Prague.

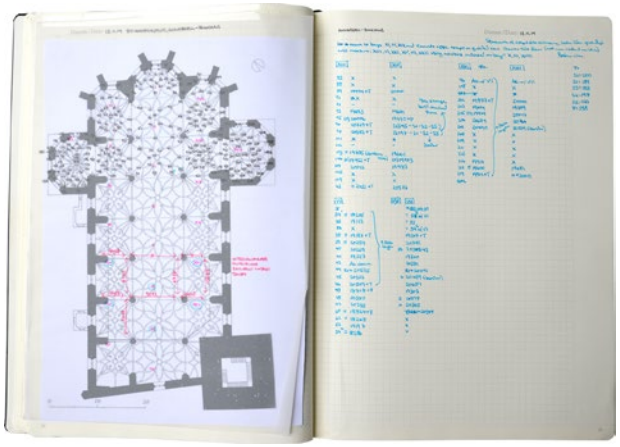
96 (Above, right) Sketch of the Old Town Hall and Church of Our Lady before Týn.

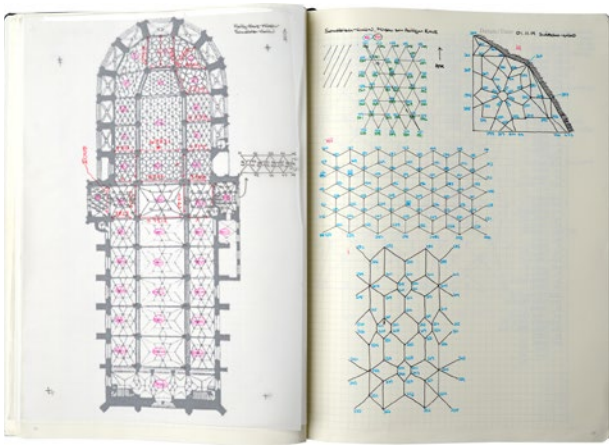
97 (Next page) Notebook of vault measurements. Left to right, first row: the Frauenkirche, Munich and the sacristy of the Dom zu Meißen. Second row: St. Vitus Cathedral; St-Annen-Kirche, Annaberg-Buchholz. Third row: the Heilig-Kreuz-Münster, Schwäbisch Gmünd; St.-Georgs-Kirche, Dinkelsbühl. Fourth row: the Liebfrauenmünster, Ingolstadt; Ulmer Münster.

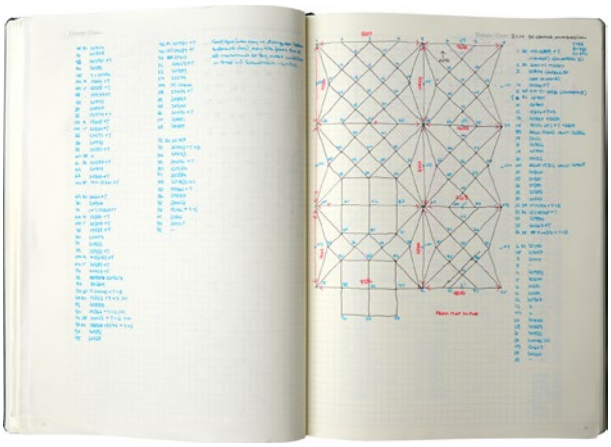


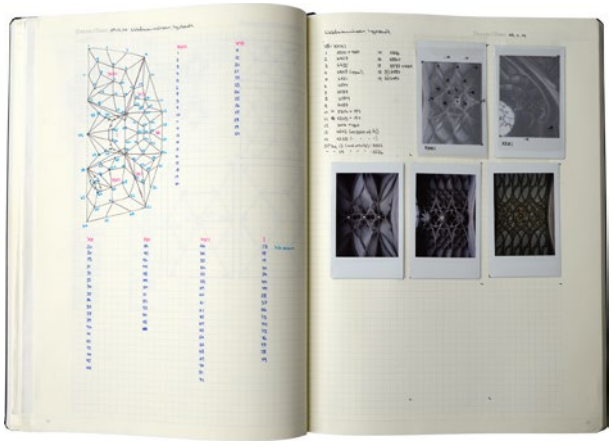


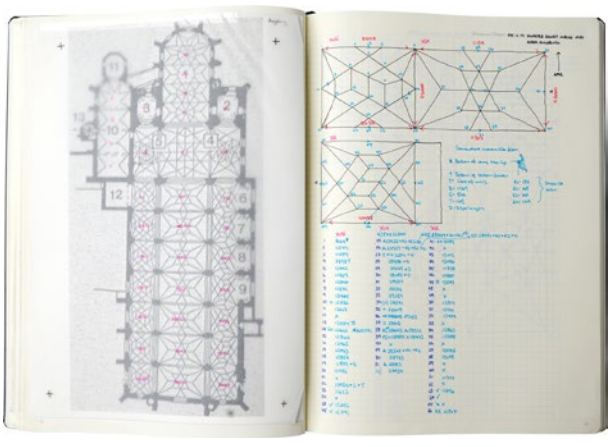










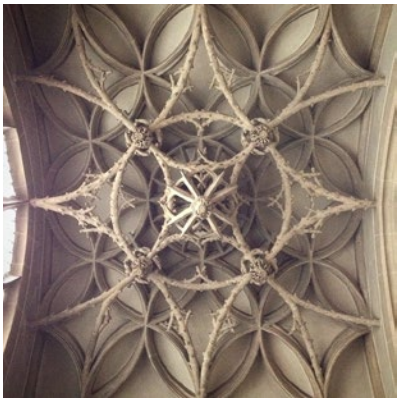




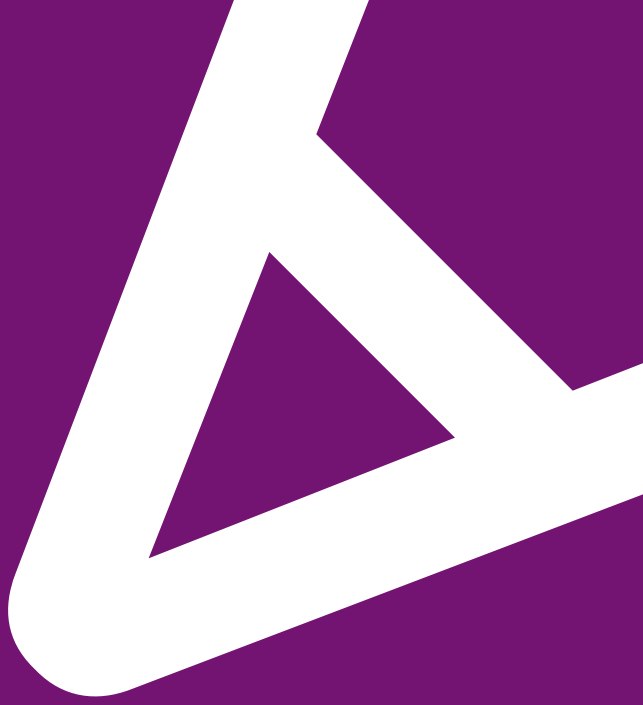






98 (Above) Selected Instagram photographs



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