DEFINING ROMANESQUE ARCHITECTURE AS EXEMPLIFIED BY DURHAM CATHEDRAL, ENGLAND

A Thesis

by

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ABSTRACT

Architects are often concerned with elements of structure and their relationship to the spaces they create. In this study I use case-control and observational study of two preexisting styles of architecture: Romanesque and Gothic. Combining analysis of the buildings with numerical coding of five particular architectural elements allowed the researcher to make conclusions about the identification of Durham Cathedral in Durham, England as a Romanesque church. Using S. Ambrogio in Milan, Italy, Speyer Cathedral in Speyer, Germany, St. Etienne in Caen, France, and St. Denis in Paris, France, I provide a set of case studies to compare and contrast the qualities of Romanesque and Early-Gothic architecture. When compared to an analysis of Durham Cathedral, these case studies provide evidence for the classification of Durham Cathedral as Romanesque but fail to completely support this classification. With an analysis of the buildings in question, architects have come to the general conclusion that these case studies, with the exception of St. Denis, exhibit mostly Romanesque traits. St. Denis, considered the first of the Gothic churches, is seen as a turning point for architectural development. This church represents the first examples in which High Romanesque became the Early Gothic through the development of new construction techniques and evolving ideals in architectural design. When comparing the system of vertical load-bearing members supporting the case studies it becomes evident that the Romanesque churches rely on heavy piers and large columns to support the weight of high vaults and ceilings. In contrast, St. Denis relies on thin walls and columns combined with large buttressing to

achieve similar support. Comparing the vaults of these case studies, evidence supports the conclusion that earlier vaults lacked proper construction to use ribs as structural load-bearing members. In applying quantitative values to five particular architectural elements, this study provides evidence to support the conclusion that Durham exhibits both the traits of Romanesque and Proto-Gothic architectural developments.

DEDICATION

This study is dedicated to those who understand the words of Winston Churchill: “Now this is not the end. It is not even the beginning of the end. But it is, perhaps, the end of the beginning.”

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This work was supervised by a thesis committee consisting of Dr. Nancy Klein, my chair, and Dr. Stephen Caffey of the Department of Architecture and Dr. Shelley Wachsmann of the Department of Anthropology.

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GLOSSARY

Definitions given in consultation with Curl & Wilson (2015), unless otherwise noted.

Ambulatory---Aisle linking the chancel-aisles behind the high altar in a large church: it can be canted, semicircular, or straight on plan, with chapels to the east and the sanctuary to the west..

Archivolt--- Collection of fasciae and other mouldings in a concentric ring forming a curved band around a classical arch terminating on a platband at the springing.

Articulation---Architectural composition in which elements and parts of a building are expressed logically, distinctly, and consistently, with clear joints.

Bay---Regular structural subdivision of a building, such as a church: in the latter case the building is divided along its long axis by bays defined by the buttresses, piers, and vaults, with windows inserted into the curtain-wall of each bay.

Buttress---Pier–like projection of brick, masonry, etc., built either in close connection with a wall needing extra stability, or standing isolated to counter the outward thrust of an arch, vault, or other elements.

Cathedral---Principal church of the see or diocese containing the *cathedra*.

Chancel---Liturgical eastern part of a church, used by those officiating in the services, and often defined by a cancellus or screen.

Chapel---Screened compartment in a large church, usually in aisles, to the east of the transepts, or to the east of the high altar, with its own altar, separately dedicated, and often of great magnificence.

Chevet---Apsidal liturgical east end of a large church, with the ambulatory around the semicircular end of the choir off which the chapels radiate.

Double Bay System---A structural support system in which regular subdivisions of the building are separated by alternating pairs of large and small structural members, with a single large bay of the interior being equivalent to two smaller bays of the aisle. (Author)

Gothic---Architectural style, properly called Pointed, evolved in Europe (starting with France) from the late 12th century until the 16th century, even lingering until the 17th and 18th century in some places (e.g. Oxford and certain provincial areas). As its correct name suggests, it is the architecture of the pointed arch, pointed rib-vaults, piers with clusters of shafts, deep buttresses (some of the flying type), window-tracery, pinnacles, spires, battlements, and a soaring verticality.

Intermediate---Existing in between two examples. (Author)

Major Bay---A large structural subdivision of a nave divided by large primary load bearing members. (Author)

Medieval---Period of European history from the end of the 8th century through the first half of the 16th century. (Author)

Minor Bay---Smaller structural subdivisions within a double bay system contained within major bays, minor bays are the subdivisions that define the aisles in churches or cathedrals when present in a double bay system. (Author)

Nave---Central clerestoreyed aisle of a basilican church, or the main body of the church between the western wall and the chancel, whether aisled or not, used by the laity.

Quadripartite---Divided by the system of construction used into four parts.

Radiating Chapels---Chapels arranged on the radii of the apsidal eastern end of a church or cathedral choir.

Rayonnant---Style of French Gothic architecture prevalent from 1227 to mid-14th century.

Rib---Molding on a flat or vaulted ceiling.

Romanesque---Architectural style of buildings erected (7th century– end of 12th century) in Romanized Western Europe having characteristics similar to those in Early-Christian, late-Roman, and Byzantine architecture, notably the semicircular-headed arch, the use of the basilican form for churches, and the survival of design-elements such as the Classical capital (though much coarsened and transformed).

Sexpartite---An architectural element divided by its constituent pieces into six parts. (Author)

Single Bay System---This is a system of structural support in which the bays of the nave directly correspond to the bays of the aisle in a church or cathedral. (Author)

Transept---Any large division of a building lying across its main axis at 90 degrees.

Transverse arch---divides a compartment of a vault from another, spanning from wall to wall or from wall to pier, forming a bay.

Vaulting---Arch the depth of which exceeds the span, i.e. an elongated arch covering a space, or a structure composed of various curved elements in various combinations, built of brick, concrete, masonry, etc., and sometimes of plaster and wood to suggest something heavier.

Voussoir---Cuneus, or block (normally of brick, masonry, or terracotta), shaped on two opposite long sides to converging planes in what is normally the shape of a wedge, forming part of the structure of an arch or vault, its sides coinciding with the radii of the arch.

Web---Cell, compartment, infill, or severy between ribs of a Gothic vault.

Westwork---Westwerk in German, i.e. massive, wide, tower-like west front of an early Romanesque or Carolingian church containing an entrance-vestibule with a chapel and other rooms over it opening to the upper part of the nave.

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CHAPTER I

INTRODUCTION

Architects are often concerned with elements of structure and their relationship to the spaces they create. When studying rib vaulting, architects focus on the development of the rib as a structural member. Furthermore, when studying vertical supports in Romanesque and Gothic churches, attention is given to the buttresses and piers. Although not exhaustive for all elements used in the differentiation between the Romanesque and Gothic styles, these two elements do provide architects with a point of comparison.

Purpose

In this thesis, I examine the history of Durham Cathedral (1093-1133) as well as four contemporary churches. In doing so I explore barrel, groin, and rib vaulting and their development over the course of Romanesque architecture, placing them alongside developments in large primary load bearing members (i.e. piers). This allows researchers to interrogate the conclusion that the rib vaulting method and large primary load bearing members define Durham Cathedral as a Romanesque monument.

Origins and Relationships for the Terms Romanesque and Gothic

The term Romanesque comes from a division in the backgrounds of ancient Roman citizens. Those who were from Rome originally were known as *Romanos,*

whereas those people who were not true Romans in their eyes were considered *Romanescos,* Roman-like. This distinction led to the idea that the Roman way was superior to the Roman-like way in Late Antiquity (Seidel 2006). This idea carried forward into the 19th century, when Englishman William Gunn was searching for a term to describe the architecture of the early medieval period that came after the Roman Imperial architecture, but before the Gothic architecture of the French. To define this period, Gunn used the term Romanesque; this implied to his readers that the Romanesque style was a Roman-like style. While used to describe a vast category of art and architecture, this was a pejorative term. This term implied that the Roman-like way medieval architects had chosen to emulate the previous styles of architecture were incomplete or flawed. The term would be further contested by the French, who saw their architecture on the Île-de-France as being far superior to this earlier Romanesque architecture. They used, instead, the term *Romane* to refer to this predecessor architecture as a stepping stone leading to the Gothic style of their later churches. Seen as a link between the styles, when used by scholars, Romanesque and *Romane* were used to imply that the architecture of Late Antiquity Rome and the Gothic churches of France were superior to Romanesque architecture. This was an interesting choice as Gothic, used pejoratively by Renaissance architects and artists, implied that the architecture was befitting the Goths, a barbarian tribe known for sacking and defiling Rome. The myth of the Goths, referenced by one author refers to the idea that the Goths sacked Rome and destroyed Roman architecture, replacing it with “anticlassical” architecture (Reeve, 2012, p.237). Likewise the architecture of the Goths (Germans) was tall like their forests

and the branches bent to form vaults; this “wild, untamed architecture of the forest that was employed for primitive dwellings by barbarian builders,” was in many ways reflective of the writings of many who studied Roman classical architecture and tried to emulate it as an ideal (Reeve, 2012, p. 237). This terminology was used by Renaissance artists and architects to demean Gothic architecture as being less prestigious than the architecture of Late Antiquity Rome in the same way as the term Romanesque. Similarly the term Gothic was used to show ideological and temporal distance from the previous period by renaissance artists and architects (Reeve, 2012). These terms both expressed a series of ideals, though they also represent a set of commonly accepted architectural values that will be expressed throughout this study. These ideals revolve around the evolution of technology in architecture, and the manner in which these large churches were constructed. The transition from the architecture of antiquity to the architecture of the Gothic was one of modernization and progressive change, contrary to the pejorative use of the term by later artists and architects (Reeve, 2012). This modernization, however, was tempered by the weight of tradition. As Reeve points out the history of classical architecture spans many centuries of writing, and includes such influential works to the Renaissance as Vitruvius. In contrast, the architecture of the Gothic period has fewer works of theory. This left Gothic architects faced with both an immense challenge in utilizing their new technological advancements, and an incredible mobility of design allowing the Gothic style of architecture to change at will to fit new scenarios (Reeve, 2012).

Socio-politically, Romanesque architecture manifested itself in the manner churches and castles were designed. For example, the builders of castles saw great value in the solid and stark nature of Romanesque architecture. Passages within walls allowed soldiers to move between fortifications without risk. In contrast, the builders of churches chose to focus on the individual elements of articulation within the Romanesque. The use of piers to replace columns, in the earliest examples of Romanesque architecture, allowed church leaders to alternate the division of bays between piers and columns. In doing so, they created a system of structural support prevalent throughout church architecture to the present day.

The Gothic period, known for a heavy focus on cathedrals, contrasts with the Romanesque period, known for a heavy focus on monasteries. The emphasis on monasteries, rather than cathedrals, likely reflects the monastic reforms in 10th century England and France. These reforms, furthermore, lead to the construction of cathedrals to meet the needs of larger towns, providing people with a desire to build more affluent houses of worship.

Fernie et al. (2015) argue architecture before 1150 “belongs to the heritage of the Roman Empire;” however, any attempts to define a starting point for the Romanesque period have rarely been successful. Due to differences in perception between architectural historians when the term Romanesque was coined, no single element of a church’s design was ever identified as the key element of Romanesque architecture. In fact, the articulation of these elements provides the evidence used by Fernie et al. to designate these buildings as Romanesque. Unfortunately, the ambiguous nature of

articulation creates almost as many problems as solutions. As a result, articulation in any one example might show great differences when compared to articulation in others.

The geography of the Romanesque style covers the breadth of Europe. Though development of Romanesque ideals shadowed the spatial development of the Roman Catholic Church, early examples of Romanesque architecture suggest that the Roman Empire rather than the church influenced the spread of these ideals. By the first half of the 12th century, Romanesque architecture had spread across much of Europe, eventually making it as far as Jerusalem (Fernie et al., 2015). Rather than a stylistic label, these churches shared a number of identifiable links explained by political power, increasing pilgrimage between holy sites, and the importance of the papacy (Fernie et al., 2015). The Holy Roman Empire, for example, spread Romanesque ideas into Scandinavia, whereas the Normans carried these ideas into England. By comparison to these overarching links, intense regionalism fueled different political desires to stand out among contemporaries. Regionalism allowed regions to add artistic elements to their architecture, while pilgrimages ensured stylistic elements travelled in spite of this regionalism.

Fernie et al. (2015) claim that Romanesque architecture's essence lies in its articulated clarity. As a part of this clarity, Fernie mentions two major developments: the substitution of the pier for the column in what would become the alternating system, and adoption of Carolingian building elements. These Carolingian elements were adopted due to an increased popularity in relics, changes in the church rules regarding altars, and greater complexity in the liturgy. Extra chapels and altars were built in subterranean

crypts that would extend beyond the eastern end of the church, while to the west large facades were built called westworks. These additional spaces, though independent structures in the Carolingian period, were incorporated into the Romanesque churches in a manner that made them a smaller part of a larger whole, while maintaining the spatial independence of shape and function. What had been a Carolingian outer crypt became a Romanesque ambulatory and set of radiating chapels, the simple geometry of the apse providing a crucial anchor for the design of the new spaces. It is this simple form begetting a more articulated extension that defines the Romanesque period.

To move from the columnar basilicas to the larger alternating arcades of later Romanesque churches, piers were needed to support the growing weight of large vaults and high ceilings. In alternating between large piers and smaller, but still structural columns, a double bay system would form in the nave of many Romanesque churches. This system would often extend into the choir and the transepts providing a more unified structure. In response to the newer expressions of faith, or the increased number of relics brought back from the holy land or found in reference to the saints of the Christian church, new church structures became more common. For example, chapels, small additions to churches fitting in ancillary spaces, were permitted on the basis that altars to the saints were more prevalent. In allowing these side altars and chapels, churches and cathedrals would take on new shapes, with the transepts and choirs extending along with the new spaces. New methods of enlarging these spaces also took hold, such as new methods of vaulting that allowed for a lighter, well lit room in which to display saintly relics. Larger ceilings denoted more holy spaces, and thus even the smallest chapel

aspired to have vaults. A more inclusive design would also incorporate ideas from the interior. Specifically, in spaces visible to the public when outside, the westwork developed as a monumental façade to decorate the entry to a holy space.

These developments were not a disjointed collection of modifications, though, as the whole of the building was changed, both in design and function, during the Romanesque period. The modifications to the façade, though major shapes on their own, provided a sense of unity within the building, at large. As an example, crypts were no longer hidden far below the floor of the church; instead, these holy spaces extended under the ambulatories or were entered from the choir in a manner treating them as an extension of a larger space rather than a separate construction. As mentioned previously, in some cases, the developments that led to the outer crypt's purpose were instead used in an ambulatory and set of radiating chapels, meaning that the outer crypt was no longer necessary as a worship space and could be used exclusively for burials.

Stone blocks carved in precise fashion replaced the rubble masonry of the previous eras in the construction of large buildings. New structural elements such as the rib were experimentally applied to the previous groin vaulting, first as decorations, then as structural members. Gothic structural developments, on the other hand, are consistently held in higher regard than those of the Romanesque by classical scholars. In addition, these Gothic developments were seen as superior to the previous periods of architectural development. This new architecture was seen as achieving "unparalleled size, lightness, and visual complexity," (Kidson, 2016). New structural developments were needed to achieve this complexity. Rib vaults, pointed arches, and flying buttresses

changed the architectural emphasis to one of verticality rather than building to a larger scale. The defining of Gothic precedent, by the examples found in northern France, can influence the way in which scholars interpret other works outside of the French realm. Examples of the Gothic style outside of this realm should be viewed as independent developments, with their own histories and influences that may or may not include that found in the French realm.

In contrast to the Romanesque style, the Gothic style's success would be reflected by its longevity (Kidson, 2016). While Gothic architecture would span the whole of Europe, the beginnings of the Gothic style were centered on France. This emphasis on French architecture , starting with St. Denis in Paris, laid the foundation for the whole of the Gothic style. Future architectural decisions, in this style, used structural technology developed as a result of Gothic ideals. Architectural historians once argued heavily for the contrasts between the architecture of Antiquity, the architecture of the Renaissance, and Gothic architecture. Modern scholars, on the other hand, suggest that a greater connection exists between Gothic ideals and those of Late Antiquity than Gothic period historians liked to admit. As the ideas and prevalent social structures of the 12th century would have formed the church, so too would it have formed church architecture. Further evidence for this greater connection exists when compared with the other arts and sciences of the time (Kidson, 2016). Kidson argues that the development of the Gothic style provided "emancipation" for medieval architects to build in any form desired by their patrons or architects. To better understand the terms Romanesque and

Gothic as they are used today, an examination of different case study churches provides necessary information.

Selection of Case Study Churches

In this thesis, I have selected five case study churches. The relevant construction period for these churches to this thesis spans the medieval period, from the 10th to the 13th centuries. These churches are all located in Europe and represent regions in Italy, Germany, France, and England. The primary case, Durham Cathedral, was selected for the developments allowed by its position in the Romanesque period. This position, spanning the intermediate years between the High Romanesque period and the beginning of the Gothic period, allowed for several developments in structural design that would carry forward into later Gothic churches. The second case, St. Denis, was selected as the first Gothic church in Europe (i.e. the choir and apse). This places the Gothic choir's construction a short time after Durham Cathedral's completion. St. Denis is a necessary selection as it demonstrates, in the words of one scholar, "proto-Gothic" traits (Crosby, 1948 p. 14). These traits lead many to believe that St. Denis should be accepted as the first of the Gothic churches, and in this study will be referred to as such. In addition, the use of St. Denis allows for a quick comparison of Gothic traits between those developing at Durham Cathedral and those fully developed at St. Denis. S. Ambrogio (ca. 9th century), Speyer Cathedral (ca. mid-11th century), and St. Etienne (ca. late 11th century), being definitively Romanesque, provide contemporary examples of Romanesque construction to Durham Cathedral. In the case of S. Ambrogio, Speyer Cathedral, and St.

Etienne, these churches were under construction at roughly the same time as Durham Cathedral for various reasons, and at various stages, giving an abundance of comparable elements that are distinctly Romanesque in nature. These churches also allow comparisons between the similarities of Romanesque elements, or the contrasting of Gothic elements.

History of the Five Churches and Major Renovations

Of the five churches being used as examples in this paper, the first to be founded was St. Denis in Paris, France. Probably founded in the 5th century, the first church to be definitively dated was the Carolingian Church of St. Denis, consecrated in the 8th century AD. Later construction of an Early Gothic choir and westwork would give rise to a new style of architecture. Finally a Rayonnant reconstruction (consecrated 13th century) of the area between Abbot Suger's *chevet* and westwork would create the building that stands today. Next, the Church of S. Ambrogio in Milan, Italy was founded, though the dates of its founding are contested. Fernie suggests the first Romanesque version of this church, and the first architectural phase preserved, was completed in the mid-10th century AD. S. Ambrogio saw its first renovation in the form of a dome built upon a lantern at the end of the 11th century. An additional tower would be added in the mid-12th century. In the early 11th century Emperor Konrad II founded the Cathedral at Speyer, Germany. This Cathedral was completed in the mid-11th century. At the end of the 11th century Speyer Cathedral would undergo its first renovation, with a further chapel added shortly thereafter. The most significant

remodeling of Speyer came in the 18th century when the nave was reconstructed in its Romanesque form following severe damage in the previous century. In the mid-11th century, William the Conqueror founded the Benedictine Abbey at St. Étienne, also called *Abbaye aux Hommes*, which would then build a church in Caen, France. This church would be completed in the last decade of the 11th century. St. Etienne would see its first renovation in the late 12th century when the Romanesque end of the church would be rebuilt into its current form. In the early 17th century there would be further restorations to the crossing, transept, and choir following the mid-16th century collapse of the crossing tower. At the same time as the completion of St. Étienne, the Cathedral at Durham, England would be founded and completed in the mid-12th century. Durham Cathedral had problems with the choir vaults threatening to collapse and in the early 13th century these vaults had to be replaced. At the same time, the masons at Durham began work on the second transept that would become the Chapel of the Nine Altars. In the late 15th century the cathedral's central tower was replaced following its destruction in a storm. An additional belfry would be added between a few decades later.

CHAPTER II

SCOPE OF RESEARCH

Description of the Study

Centered on three themes, (a) my discussion on the history of churches in the Romanesque and Gothic styles, (b) my comparison of vaulting and primary load bearing members in the Romanesque and Gothic periods, and (c) my placement of the vaulting and primary load bearing members at Durham Cathedral within the larger context of vaulting during these periods, this thesis provides researchers with data describing the relationship between Durham Cathedral and the comparative churches. Using Mixed Method techniques, a methodology in which researchers combine qualitative and quantitative research methods, researchers can extract information from comparative analyses between Romanesque and Gothic churches. In this study the combination of qualitative analysis of architectural features combined with the coding used in Chapter V can, in turn, be used to interrogate the definition of Durham Cathedral as Romanesque.

In comparing these churches it is important to begin with an analysis of the plan and elevation for each church, focusing on the interior. Any differences or similarities in the plan or elevation for the churches can be highlighted when viewed with a critical eye. In addition, reference for the years of construction is used to identify contemporary construction for comparison of similar techniques that may have developed simultaneously.

Significance of the Study

In my study, I focus on the transition from the Romanesque style of the 10th and 11th centuries to the Gothic style of the late 12th century. Durham Cathedral will be placed in the line of development between the two styles (i.e., Romanesque and Gothic). My study uses information related to the development of vaulting at Durham Cathedral and the four comparative churches. I discuss the evolution of vaulting in church architecture by comparing five examples (case studies) from the Romanesque and Gothic period. I, therefore highlight the evolution of church architecture over the 10th - 12th centuries.

Methods

In my study, I use a case study methodology to discuss, compare, and place Durham Cathedral within a sample of five churches built in the Romanesque or Gothic styles... "A case study involves research conducted on one or more cases bounded by parameters set by the researcher" (Creswell, 2007 p 73). To this end, I have identified five churches to serve as cases. I analyze three churches defined as Romanesque and one defined as Gothic in addition to Durham Cathedral as the exemplar. To address the three themes in my study, I (a) collect images and authoritative descriptions for the five case churches, (b) visually analyze the images each church, (c) summarize the evolution of vaulting based on the images and descriptions, and (d) compare the results to the characteristics exhibited at Durham Cathedral. Following this, I analyze aspects of

Durham Cathedral with the intention of explaining the church's place between the Romanesque and Gothic styles.

To collect images and descriptions, I conducted a review on Oxford Art Online's images related to the five case churches and search the personal church websites of the five case churches related to the interior elevations and internal structure. To collect descriptions I conducted a search in the JSTOR archives using key words individually and in combinations including: (a) Romanesque, (b) Gothic, (c) vaulting, (d), rib vaulting, and (e) Durham Cathedral. In addition to collecting descriptions I have searched the Texas A&M University Library Catalog using the same key words. In collecting these images and descriptions I can visually analyze the architecture present at the five case churches.

I begin by examining the plan and then the elevation for each of the case churches. In examining each plan, I move from west to east; in doing so I examine the least to the most sacred spaces within each of the churches. In examining each plan, I will make note of geometry, scale, and position for the spaces. In examining each elevation I move from the ground through the vertical supports to the vaulting and the roof; in doing so I trace the structural supports from the ground to the roof. In visually analyzing these images I trace lines for the evolution of vaulting.

To trace lines for the evolution of vaulting, I identified key words, phrases, and architectural trends, in doing so I built a timeline for the development of vaulting (i.e. barrel, groin, and rib). In building this timeline I create a context in which to place Durham Cathedral within the Romanesque and Gothic styles. Completing the visual

analysis of images and the timeline allows me to combine the results as they are exhibited at Durham Cathedral.

I use a method incorporating the visual analysis of images (i.e. plan and elevation) with descriptions (i.e. timeline of vaulting). Specifically in my use of a method, I use my analysis of the timeline of vaulting to inform the selection of specific architectural elements within the plan or elevation for the case churches. In using this method I alternate visual analysis of images with descriptions in order to place the vaulting at Durham Cathedral within the larger context of vaulting used in Romanesque and Gothic styles.

Limitations

My study contains limitations related to the visual analysis of images and the descriptions. For example, my analysis of the five case churches is based on the visual analysis of images and not on measurements taken *in situ*. In addition few descriptions have been written in the last decade, with a large number written at least 30 years ago. Also, my authoritative sources used in this study are written exclusively in English, as I am not fluent in other languages (i.e. French, German, Italian, Latin) associated with the field. Finally I reviewed descriptions relating to the placement of Durham Cathedral between the Romanesque and Gothic styles. Combined, these limitations influence my ability to place the vaulting at Durham Cathedral in the larger context of vaulting in the Romanesque and Gothic styles.

CHAPTER III

LITERATURE REVIEW

In this study, many of the sources consulted approached the question of Romanesque and Gothic influence from the historical point of view (Billings 1843; James, 1983; Hoey, 1996; Fernie, 2015; Kidson, 2016). One of the primary writers using this method, Billings, writes a firsthand account of the architecture of Durham Cathedral, with an in depth summary of church documents leading up to its construction. This view traced elements of construction such as the use of piers and different vaulting techniques through Europe, both spatially and chronologically. For many of the sources consulted on each case study, the work centered on a specific building or period of time (Billings, 1843; Anselmi et al., 2015; Baylé, 2015; Winterfeld, 2015; Gardner et al., 2016). For a smaller number of sources, the work focused on the question from a broader perspective and the terminology scholars use to define these buildings (Siedal, 2006). The general conclusions reached by these authors followed the traditional viewpoint of what is Romanesque and what is Gothic. These conclusions were established when the terms originated; however, the conclusions by modern scholars lacked, in many cases, the pejorative approach of the Renaissance and Gothic artists who originally coined the terms.

The majority of sources consulted in this study also examined the nature of these definitions, whether the pejorative nature of their creation influenced the way in which sacred architecture was categorized. Gothic churches excluded Romanesque churches in

their qualification of architectural ideals in the past, whereas many of the recent studies asked if this exclusion was accurate, or the product of hindsight (James, 1983; Hoey, 1996).

Background information on the Romanesque and Gothic styles of architecture came from a number of sources; including, the texts of Oxford Art Online (Fernie, 2015; Kidson, 2016) and visual analysis of images from the case study churches. While this provides a series of broad strokes allowing some analysis of the periods in question, more specific sources were needed to identify Durham Cathedral's place within the context of the Romanesque and Gothic styles, and whether that position deserved more clarity.

General Review of Literature

A review of relevant literature supports the general conclusion that Durham Cathedral is a distinctly Romanesque church (Bacola, 2015; Billings, 1843; Trachtenberg & Hyman, 2001). Scholars who share this belief have reached the same conclusion through different methods. These authors represent different fields of study, but all share a common interest in the architecture that we define as Romanesque, or in the traits that make a building Romanesque. In addition, the methods used to reach this conclusion vary between authors, but all exhibit the creation of an intermediate ideal. In this chapter, I review literature relevant to the definition of Durham Cathedral as a Romanesque church. In doing so I focus on sources that make the argument based on the rib vaulting at Durham Cathedral in addition to a general review of literature on the evolution of primary load bearing members (i.e. piers).

Billings, in his 1843 text on Durham Cathedral, approaches the issue of Durham Cathedral's classification from the point of view of an architectural historian concerned with church records. These records piece together a history for Billings, supplemented by his extensive measurements and plates illustrating the Cathedral. The method of Billings' work has been one of historical analysis interspersed with detailed measurements and drawings. In his research of church history, Billings relied heavily on the documents produced by previous scholarly works, many of which were translations and reprints of the founding documents for Durham Cathedral. This does cause some disagreement with later scholars and researchers as the bias of the articles used is distinctly in favor of the Cathedral's divine interventions[1]. While this may be an appropriately interesting anecdote, it does little to reinforce the chronology of the church other than provide dates. Fortunately, Billings spends little time on the history of the cathedral and devotes the majority of his efforts to the plans and measurements.

As Billings is a product of the time in which Romanesque and Gothic were coined as descriptive terms, some question must be raised as to the manner in which Billings uses the term "Romanesque." Whether that is a pejorative form of classification, Billings treats Durham Cathedral with a great amount of respect both as a living building, and as an architectural structure. In this case, Romanesque is the label given out of understanding for the evolution of the style from the Late Antiquity Romans. His work, he claims, provides the first drawings of Durham Cathedral to scale. Billings

[1] Miracles at Durham Cathedral include the incorruptibility of St. Cuthbert's body and the miracle of the collapsed centering in the shrine of St. Cuthbert the night before it was to be removed.

laments that this has not been the standard for architectural historians until his research, and because of his incredibly detailed descriptions and measurements that this thesis was able to move forward.

James' study on the vaults of Durham Cathedral's nave and choir (1983) presents a similar diagnosis for Durham Cathedral, defining it as Romanesque. Several interesting points are made evident. In his analysis of the building, James focuses on the architectural evidence for and against a sexpartite vault. Through this evidence, as well as historical documents, he follows the masons who worked on Durham Cathedral; concluding that several masters were in charge at various stages. This is reinforced in his discussion of Durham Cathedral's reliable chronology, going so far as to critique and review the major documents from the period of Durham's construction. With this method of architectural and historical analysis James can make conclusions based on the evidence he has gathered. These conclusions reinforce, in many cases, the chronology we currently use for Durham Cathedral's construction.

In his study of vaulting in Normandy and England, Hoey (1996) explores the purpose and aesthetic behind rib and groin vaults. Using a comparative analysis of several case studies, the question of intent is raised in church architecture. Specifically, this refers to the intentions of the architects when they chose whether vaults would respond to the vertical supports, or whether the vertical supports would respond to the vaults. In this evolution of architectural articulation, Hoey makes the argument that Romanesque and Gothic ideals are a more complex topic than previously considered, and uses examples in both England and Normandy to illustrate this point. Through these

examples, Hoey makes the argument that the ribs at Durham Cathedral were a means by which the Durham masons could integrate the vertical supports as well as the vault in one coherent idea that Hoey calls Romanesque.

Siedel (2006) considers the etymology of the term “Romanesque.” While the article is not focued exclusively on architecture, it does investigate the term “Romanesque” and its roots in the French and English language. The history of the term comes from the distinction of the native born ancient Romans (*Romano*) and their term for outsiders who had moved into the city (*Romanesco*).This idea of the foreign, Siedel argues, invokes an inherently negative connotation in the term Romanesque. This negative connotation becomes most prevalent when referring to Romanesque architecture as a springboard for Gothic architecture. Though the word had been used before, only in an 1819 text by William Gunn did Romanesque categorically come to define church architecture. Soon after this, the word Romanesque denoted the differences between the large variety of European medieval structures when compared with the fairly uniform Gothic Ile-de-France. While Seidel does not definitively place Durham Cathedral in a Romanesque or Gothic context, she does provide background on the reasons for classifying a building as Romanesque, and how this was done when the term originated. As Seidel argues, Gunn’s definition of Romanesque is based on a flawed reproduction of Roman ideals. In his own words, Gunn calls the work a, “vitious (=vicious--i.e., faulty) deviation.” (Seidel 2006, p. 110). In defining the term thus Gunn implies through Seidel an inherently pejorative connotation.

In a study focused on the hybrid piers of Durham Cathedral, Bacola (2015) accepts earlier arguments that Durham is a Romanesque church, and spends little time on the issue. Instead, Bacola focuses on an exploration of the aesthetics in Durham Cathedral's hybrid piers. For example, she makes the case that the hybrid pier in the southern transept of Durham Cathedral represents the resting place of St. Cuthbert's body in the original stone church. Through an analysis of archaeological and architectural evidence, Bacola proceeds to trace the chronology of St. Cuthbert's resting place as it changed during Durham Cathedral's construction. This provides an early chronology of Durham's construction, as well as several key elements that must have been complete before the body of the saint was transferred.

Evidence for Defining Durham as Romanesque

In reviewing the relevant literature, the general conclusion that Durham Cathedral is a distinctly Romanesque church rests on several traits identified by these authors. For example, a lack of structural sophistication in the method of rib vaulting in the cathedral is common in Romanesque churches (Billings, 1843; James, 1983). Sophistication, in this case, refers to the method in which the ribs are used. In rib vaulting, the ribs are used as structural arches to support the weight of the webbing as it is constructed. In Romanesque churches it is often the case that the ribs were built after the vault was completed or at the same time as the webbing. The result of this was to relegate the ribs to a decorative position and forced masons to use wooden centering for the entire vault as it was constructed. Durham, where the ribs have been built along with

the webbing, has ribs that are not cut on angles appropriate to support the weight of the vault (James, 1983). This lack of sophistication illustrates what other authors have written concerning the gradual transition from Romanesque to Gothic styles (Armi, 2004; Hoey, 1996; James, 1983). Also, the most influential author within the relevant literature, Eric Fernie (1984, 2014, 2015), has classified Durham Cathedral as a Romanesque church. Fernie has argued, as have many previous authors, that different elements defining Romanesque churches are present in Durham Cathedral. Most notably, Fernie argues, there is an abundance of articulation which seems to be the only consistent hallmark of the Romanesque period. Specifically, Durham Cathedral is identified as the best, as well as the only, extant example of English Romanesque high vaulting from this period. Romanesque high vaulting, in this context, refers to the large vaults of the nave in Romanesque churches as they transitioned in height from the lower ceilings of the previous basilica churches. No similar examples of this architectural style exist until a much later church in the 1150's at Kirkstall, leaving a significant gap for which scholars have no known examples (Hoey, 1996). Durham Cathedral, as mentioned earlier, had less sophisticated rib vaults, which were mirrored in some Romanesque churches, but were not common until the later Gothic period. This high vaulting over the nave was the most likely place in a Romanesque church for this exploration of the rib to occur. The church at Kirkstall, however, lacks some of the same architectural elements associated with English Romanesque high vaulting, such as rib vaulting. In this review, I discuss the definition of Durham as a Romanesque building, and the development of vaulting.

Hoey (1996, p.174) claimed, “The late eleventh and early twelfth-century builders of groin and rib-vaulted churches in England and Normandy constitute an essential chapter in that story [of architectural articulation in the medieval period], but only a chapter.” This position, however, fails to acknowledge the influence of the evolution of the Romanesque style and additional architectural elements of the Gothic style present in Durham Cathedral. Other authors in the field point to Durham Cathedral –originally constructed during the late 11th century, and completed and later renovated during the 12th century with a newer Gothic chapel- as an example for the evolution of the Romanesque style and the realization of the Gothic style. As such, there is general agreement that buttressing, rib vaulting, pointed arches, and lancet windows – architectural elements of the Gothic style- exist at Durham Cathedral. Fernie (1984) claims these architectural elements exist due to renovations after the original construction during the late 11th and early 12th centuries. James (1983) argues the existence of these architectural elements leads him to believe that the changes were not renovations, but were made to make the building conform to the structural and aesthetic intentions of the original builders.

The manner in which these individual elements were incorporated into the building supports these authors claims that Durham Cathedral fits more in line with the Romanesque churches than those of the Gothic. For example, the lack of sophistication mentioned by James (1983), provides context for this differentiation in architectural styles. More importantly, the development of the architectural elements (i.e. buttressing, rib vaulting, pointed arches, and lancet windows) present at Durham Cathedral show

more parallels in the Romanesque period than the realization of the elements in the Gothic period.

Evidence for defining Durham Cathedral as a Romanesque building has relied on an absence of many structural and stylistic elements, including; (a) buttressing, (b) structural rib vaulting, (c) pointed arches, and (d) lancet windows. In understanding the relationship between the Romanesque and Gothic architecture, Durham Cathedral exhibits traits of both styles. Durham Cathedral, therefore, provides researchers with an opportunity to study the intermediate architecture of the 12th century through an examination of the development of the rib vault.

History of Rib Vaults

Parallel to Durham, Speyer Cathedral at Speyer, Germany (1030 AD), S. Ambrogio at Milan, Italy (ca. 9th century AD), and St. Etienne at Caen, France (1060 AD) show clearly the development of vaulting and other traditional methods of structural support in church architecture. These are the best-documented extant examples, but they also provide a basis for other researchers' work in the field concerning medieval architecture. There are, however, many different elements to be analyzed, and within each of these several variables to consider.

Armi (2004), focusing on the development of the pointed arch, both in vaulting and in the support structure for the vaults, suggests that knowledge of techniques followed the masons (as they moved from one project to the other); in doing so, the brick-like use of stone became a crucial method to be traced with the pointed arch. This method, in which stone was laid in rows and patterns more often attributed to brick

construction, showed a lack of familiarity with stone as a material, and a preference by the masons to use brick. This phenomenon allows for tracing the development of the pointed arch as it moved north from the Italian peninsula. The development of architectural elements can be followed through time and locations, showing a developmental timeline based around the records we have of contemporary churches. Bacola (2015, p. 29) mentions that the master mason who first worked on Durham Cathedral was probably Norman in origin, but had worked in England for some time. This is attributed to the similarity between “notable Continental exemplars” as well as Anglo Saxon elements of monolithic stonework. Other authors focus on the structural development of arches, such as the point at which vaulting changes are necessary rather than aesthetic. For these authors, further architectural elements in the development of vaulting at Durham are prominently displayed for examination. For example, one author suggests that Durham, within its own construction, portrays a punctuated evolution of the rib vaulting. Namely the sixth bay of the nave at Durham Cathedral, in which the boss was cut in a manner to support the voussoirs, allowed the ribs to be structural instead of simply aesthetic as they were in the rest of the cathedral (James, 1983). A full generation of masons would have joined and left the construction of Durham Cathedral by the completion of the final rib vaulting. This would have been around the same time as the construction of the first Gothic apse at St. Denis, allowing masons to have learned the purpose and application of structural rib vaulting. As this sixth bay was dated to 1130 AD, masons would have been able to develop the rib as a structural support.

CHAPTER IV

DEFINING ROMANESQUE AND GOTHIC THROUGH CASE STUDIES

Romanesque and Gothic as They Apply to Sacred Architecture

This study will examine the manner in which churches are defined as Romanesque or Gothic. It will examine whether all Romanesque churches in this study exhibit an abundance of articulation, heavy use of barrel and groin vaults, rounded arches, large piers and columns, and thick walls. It will also consider if Gothic churches exhibit, developed rib vaults, pointed arches, thin columns and piers, and thin walls with flyers and enlarged buttresses.

History of S. Ambrogio, Milan, Italy[2]

Today the Basilica S. Ambrogio stands in central Milan just off of the Piazza S. Ambrogio, a short distance from Sforzesco Castle. In 374 AD, St. Ambrose was elected bishop of Milan, Italy, and began a great construction of churches that included the predecessor of the medieval church of S. Ambrogio, the *Basilica Martyrum*. The church had been left to the care of a Benedictine monastic community in 784; however, in 791 Charlemagne decreed that the church should be run by its own canons. Many of the dates of construction for this church are unknown or contested, though a few construction phases have been well defined. For example, researchers generally accept that the first apse was demolished sometime in the ninth century and that the present

[2] (Anselmi et al., 2015)

apse was built further to the east in that same century. Researchers also accept that the presbytery, side apses and a tower to the south of the nave were built at this same time. Between the years 1018 and 1050AD, masons replaced the columns of the nave with piers, vaulted the aisles and galleries, and built a wooden roof "over the main vessel," (Anselmi et al., 2015). The modern crypt and atrium are thought to have been built at this same time; however, although the lantern, and by extension the dome, were installed in 1098. Recent scholarship suggests that the nave vaults might be instead dated to the next century (Fernie et al., 2016). In addition rivalry between the monks and the canons in their struggle for power in S. Ambrogio resulted in the canons building their own tower to the north of the nave between 1128 and 1144. This construction was in response to the monk's tower of the 9th century, and changing political climates within S. Ambrogio as a monastic community. In 1196, the fourth nave bay collapsed under the weight of the lantern. This bay was rebuilt using reinforced arches, leading to a Gothic profile in the vaults of the nave. Reinforced arches have structural elements added to prevent collapse, usually in response to previous stresses on the vault or arch (Curl and Wilson, 2015).

To the north of the church lies the Canonica courtyard by Donato Bramante, left unfinished in 1499. Bramante had also designed a monastic complex that would be built on this site later in the 16th century. The existing side chapels were also built at this time, but not designed by Bramante. Later in the first half of the 17th century a great restructuring around the lantern occurred, with the crypt rebuilt in the 18th century. Finally, mid-19th century restorations allowed the church to regain its form before the

1196 collapse. Parts of the apse, lantern, and northern aisle damaged in World War II had to be subsequently rebuilt (Anselmi et al., 2015).

Plan of S. Ambrogio

Unlike the Latin cross plan churches common in Normandy, S. Ambrogio uses the Roman basilica plan (Figure 4.1). At S. Ambrogio, an atrium lies to the west of the church. This atrium encloses a small courtyard, cloister-like in appearance, and surrounded by an arcade. The church itself is rectangular in shape with a pair of towers (i.e. monk and canon) flanking the traditional western entrance to the nave. These towers are later constructions, with the canons' tower built to the North of the nave around 1120 and the monks' tower to the South built during the 9th century, both of different heights. The rectangular shape of the church is broken at the east end by a triple apse (i.e. central with two side apses). The central apse has a choir, while each side apse appears to possess a simple vaulted space serving as the ceiling of the side chapels.

Though the nave at S. Ambrogio has a single aisle to each side, it is the nave module which defines the system. Specifically, the three large vaulted bays of the nave, along with the fourth bay unit containing a dome above the altar, are joined by a fifth bay unit that encompasses the apse and choir that survived from a previous construction. The bays of the nave form the unit of measure for this church, as a result the dome is proportioned to the nave bays. In addition the choir and apse fit within the same dimensions as the bays. The exterior walls of S. Ambrogio appear to be load bearing, and the only visible fenestration on the plan is a set of windows at the end of each apse;

however these walls possess regular buttresses. The buttresses do show variation in that the ten larger piers, supporting the transverse arches, present larger buttresses in relation to the smaller columnar supports between the transverse arches. This basilica style of church plan was common in the Romanesque era in Italy, as a transfer of styles from the Late Antiquity. This is a key connection to previous era, tying together the chronology of the basic plan.

S. Ambrogio Interior Elevation

The interior elevation of S. Ambrogio is divided into major and minor bays (Figure 4.2). The major bays are separated by engaged columns that extend from the floor to the springing of the arches and ribs. These engaged columns form a single pier at the springing of the transverse arch. In contrast, the minor bays are separated by stacked columns that have capitals at the springing of the aisle arcade, the Lombard corbel frieze, and finally ending at the base of the gallery arcade. S. Ambrogio's transverse arches do not spring from corbels, but are instead integrated into the capitals of the engaged columns on the major piers. Each rib and transverse arch has its own columnar support engaged to its respective pier, with the front of the column perpendicular to the springing of the arch. The aisles, lacking the articulated ribs of the nave, instead find the transverse arches of their own bays matched to similar columnar arrangements to the nave. In addition, the arches over the portals in the aisles that lead to the chapels and other auxiliary spaces are articulated in this same manner. This is also the case with the gallery and the arches over their openings into the nave, though the columns from which

the arches spring are significantly shorter, and only the transverse arches of the gallery are articulated. As in many of the later churches of the medieval period, articulation between the vertical supports and the vaults exhibits uniformity. This would be expected in S. Ambrogio as it has undergone extensive renovations and accounts for much of the Gothic style present.

The dome above the altar, octagonal in shape, possesses a drum with one window on each of its eight sides (Figure 4.3). The windows are simple arches on seven of the sides; however, the window on the eastern side above the altar is cross shaped. Squinches, in the corners, support the dome and are in turn supported by piers allowing the transition from a square supporting structure into an octagonal drum and dome.

The vaults above the nave are of special importance, both in their decorative aspects and structural designs (Figure 4.4). The transverse arches that span the nave and divide it into bays are made of the same stone as the piers and columns. The ribs of the nave, however, are brick as are the archivolts of the gallery, the transverse ribs of the aisle, and the arched squinches supporting the dome. Notably, the ribs of the vaulting are "square in shape," and, "do not in Gothic fashion soar lightly through space, but carry into the vault something of the weighty values typical of mainstream Romanesque design" (Trachtenberg & Hymen, 2001, p. 203). Interruptions in the brickwork of the nave and aisles exist, though no consistent pattern appears, leading to the conclusion that these interruptions may reflect reconstructions or decorative additions. These vaults, in exemplifying elements associated with the Gothic style, (e.g. ribs) articulate those

elements in a Romanesque manner. This places the church squarely in the Romanesque period, not only in construction but in the method of articulation.

History of Speyer Cathedral, Speyer, Germany[3]

Speyer Cathedral is located in Speyer, a town with Celtic, Roman, and Germanic roots situated in the Rhineland-Palatinate region of modern Germany. Begun in 1030 by Emperor Conrad II, Speyer Cathedral stands as a testament to the beauty of Romanesque architecture. Dedicated to the Saints Maria and Stephan, with the crypt consecrated in 1041 under Henry III, this cathedral became the burial place for the Salian Emperors. Fortunately for the bishopric, the nave was completed in 1060, with a flat ceiling supported with large wooden beams. This ceiling would change, however, as Henry IV would implement renovations to Speyer Cathedral in 1082 by adding the current and elaborate vaulting system (Winterfeld 2015). These renovations would also see the nave walls remodeled, and the east end of the church rebuilt into a grander form (Trachtenberg & Hymen p. 208, 2001). In 1090, a small chapel would be built in the angle of the southern transept and the nave. This chapel would be divided into nine bays by four columnar supports (Winterfeld 2015).

In 1294, Speyer became a free imperial town gaining a measure of autonomy from the state. This caused much strife between the catholic bishopric and the now politically independent citizenry who disagreed with the religious rule of the bishop, as

[3] (Winterfeld, 2015)

the town would now answer directly to the Holy Roman Emperor rather than the Bishop of Speyer. The cathedral would see some days in which it would be challenged by the battles of the French; for example, French troops did significant damage to both the town and the cathedral, with two thirds of the nave being destroyed in 1689. It would be nearly a hundred years before the cathedral was again repaired. Leonard Stahl demolished the western block down to the lowest floor in 1755, though Franz Ignaz Michael von Neumann would rebuild the nave to its Romanesque glory in 1772. Renovations, however, would not be completed until 1854 when the western block was reconstructed (Winterfeld 2015). So what is the church's form today?

Plan of Speyer Cathedral

The church is a long Latin cross plan with single aisles to each side of the nave (Figure 4.5). The transept at Speyer Cathedral has no aisles, and unlike the nave, uses a square module based on the crossing, with a single module to the north and south to denote the transept.

Speyer Cathedral lacks a choir and has instead an apse at the east end devoid of radiating chapels or additional altars. Trachtenberg & Hymen (2001) describe how the elaborate east end of the cathedral – identified as a choir, crossing, and transept – is balanced by the heavy and overly large westwork. The westwork is visible in the plan via the wall thickness at the west end of the church. These definitions create an issue in describing the plan of Speyer Cathedral in relation to other Romanesque churches. A choir, as its namesake would suggest, is defined by its function, being a place for a choir

or other singers of import to liturgical services. In Speyer Cathedral, however, there is not a space designed for this purpose. What Trachtenberg & Hymen identified as a choir acts more as a chancel, in that the space divides the holiest of spaces in the apse from the spaces in which mundane visitors to the church would be permitted to enter. Though not visible on the plan, a *cancellus*, or latticework screen, might be present to denote the change in space as opposed to a formal space for the choir. This chancel space does have a barrel vault above and thus separates itself as a distinct element, rather than a simple extension of the apse or crossing. As a result I am unable to determine, if the high altar was originally located in the apse or the chancel. This distinction of the holiest spaces becomes more pronounced as the medieval period progressed, eventually manifesting in the *chevets* of the French Gothic churches.

Speyer Cathedral Interior Elevation

The bays, being structural subdivisions, are defined in Speyer Cathedral by the piers and transverse arches over the nave (Figure 4.6). The large bays, between the transverse arches, are then divided by the piers into a double bay in the aisle. This leads to the identification of a double bay system. A double bay system here allows the dead weight (i.e. the weight of the stone comprising the vaults) to transfer more evenly to the ground. It is this dead weight carried by the large vaulted bays into the piers that is mirrored by the dead weight carried by the load bearing walls and buttresses of the westwork and transept. Structurally the westwork and transept-apse carries significant dead weight on thick, load bearing walls. To aid in this, lateral forces are transferred

from the transept into exterior buttresses. The nave and aisles have thinner exterior walls pierced by small windows on the aisle and larger windows in the clerestory. This is made possible by the use of architectural units described above as the bay system. Because the load bearing sections of the nave wall line up with the inner columnar supports, the windows allow light into the aisles and nave.

In the first phase of Speyer's construction in 1030 the ceiling was flat with large wooden beams spanning the nave. The interior of the nave in one proposed reconstruction (Figure 4.7) suggests that there were large piers with half columns engaged within the large side of the pier. In the reconstruction it is not evident where the division of the bay is made, though semicircular arches above the clerestory windows are present.

It is only in the later remodeling of 1082, with the addition of stone groin vaults, that the definitions of the larger modules of the nave become apparent (Figure 4.8). Transverse arches are held in place on alternating piers, defining the bays, and are supported by paired columns stacked one atop the other. The lower of the two columns has a simple foliate capital, but the upper column, from which the transverse arch springs, varies between the capitals. Numbering the paired transverse arch piers of the nave from west to east; the first pair of columns is topped by crown capitals, the second pair by composite capitals, the third pair by Corinthian capitals, the fourth pair by a Corinthian capital to the north and a composite capital to the south, and the final pair with crown capitals (Figure 4.9). The transverse arches corresponding to the bay divisions, both in the nave and the aisles, appear to be semicircular. This semicircular

shape, prominent in early explorations of groin and rib vaulting, would later evolve into pointed arches – see Chapter VI--. There are further arches over the clerestory windows and where the groin vault meets the inner wall. The intermediate piers which do not support the nave's transverse arches instead have smooth sided corbels from which the arches spring to support the clerestory windows. Again this use of corbels signifies a Romanesque church, as the large load bearing members exhibit greater articulation in comparison to the intermediate supports.

History of St. Étienne, Caen, France[4]

Construction of the church, abbey, and cloisters began in 1066 because of William the Conqueror's perceived sin in marrying Matilda of Flanders, his cousin. This was an arranged marriage that Pope Leo IX took exception to. To secure a papal blessing, two churches had to be founded; one by William and the second by Matilda. Located off of *Rue Guillaume le Conquerant*, and only a short distance from L'Orne River, the *Abbaye aux Hommes* was constructed to perform the services required of a monastic life, beginning with the eastern end of the church. The eastern apse of the church, in its original Romanesque form, was consecrated in 1073; however, by the second consecration of the church in 1077, the choir, transept, and one of the large nave bays had been completed (Baylé 2015). In 1081, the third consecration of the church occurred as the remaining nave bays, including the westernmost nave bay with façade towers, were completed. Unfortunately, the Romanesque grandeur of St. Étienne was not

[4] (Baylé, 2015)

to last. In the late 12th century, the eastern end of the church, from the transept to the end of the apse was replaced by a Gothic choir and apse (Baylé 2015). This would not be the last time a part of St. Étienne was reconstructed, as the crossing tower collapsed in 1566. It was not until in 1601, that Dom Jehan de Baillehace began restorations on the transept and choir, also adding a quatrefoil balustrade to the nave galleries (Baylé 2015)[5]. The restorations by de Baillehace were completed in 1626. In 1790, when the monastic community dispersed St. Étienne at Caen sat as a beautiful example of the Romanesque and Gothic junction in time.

Plan of St. Étienne

Built on a Latin cross in its original Romanesque design, St. Étienne incorporates a single transept (Figure 4.10). The choir and apse of St. Étienne were rebuilt in the 13th century (Trachtenberg & Hymen 2001) in a Gothic manner, and separated from the Romanesque construction both temporally and stylistically. The westwork and towers have substantially thicker walls. These thicker walls are associated with the necessary load of the large westwork towers, though a closer look at the rest of the church shows the substantial piers and buttressing seem to be uniformly thick. This complex system of piers and vertical supports allow the walls to possess many windows, both in the Romanesque nave and the later Gothic choir and apse. In the Romanesque construction there is a single aisle to each side of the nave. This construction extends in the Gothic choir with an ambulatory surrounding the choir and apse, and serving the radiating

[5] Further sources on this restoration are inaccessible by the researcher at this time.

chapels. The arms of the transept do not exhibit uniformity with the width of the crossing, but instead reflect a larger rectangular unit made evident by the inclusion of the aisle architecture through the transept. This example shows a trend found in later church architecture in which ambulatories became more common as the standard shape of the apse changed.

St. Étienne Interior Elevation

The elevation of the interior contains piers separating the aisles and the nave, a gallery overlooking the nave of slightly shorter stature, and a small clerestory tucked between the vaults containing windows (Figure 4.11). Each of the large piers, that support the vaulting and the roof, are decorated with half columns with arches between them are framed in clustered columns. As with the church at S. Ambrogio these large piers divide the nave into major and minor bays, however unlike the church at S. Ambrogio, the minor bays are divided by clustered columns supporting the intermediate arches. As at S. Ambrogio the vaults spring from the capitals of the columns rather than corbels; but again unlike S. Ambrogio the columns that support the diagonal ribs spring from corbels instead of columns running the full length of the pier.

The nave at St. Étienne possesses sexpartite vaulting, distinguished by the transverse arches that spring from each pier (Figure 4.12). This vaulting system is unlike the systems at Speyer and S. Ambrogio which emphasized an alternating set of supports for a quadripartite vault. This does not eliminate the double bay; however, as the size of the nave module encompasses twice the area of the aisle. The aisles, much like those at

Speyer Cathedral, are quadripartite vaulting. The choir, a later construction, also possesses quadripartite vaulting, showing it to be a separate unit from the nave both in location and design. Unlike at Speyer Cathedral, the clerestory at St. Étienne possesses offset columns within the nave module. These columns frame the springing point of the transverse arch without diagonal ribs which appear to be independent of the aisle bay arrangement. In later discussion, I introduce the manner in which the curved shapes of the vaults and archways are arranged. As the majority of the arches, as well as the vaults, are semicircular, the arrangement provides a precursor to the Gothic architecture that would follow. In addition, the joining of the aisles at the transept via a pointed arch provides a basis for future Gothic architecture.

History of St. Denis, Paris, France[6]

The first church dedicated to St. Denis, located to the north of Paris, was built in the 5th century and has grown in multiple phases. The three major phases include: Carolingian, Early Gothic, and *Rayonnant*. In the 7th century, the church would be prominently used as the royal monastery, where the French kings would store their royal accoutrements and eventually be buried. The eastern apse of the church, in its original Carolingian form, was consecrated in 775. While a great deal of the Carolingian church was revealed about this church through excavations in the 1930's, none of the original church remains standing, save for a few column bases.

[6] (Gardner et al., 2016)

The Early Gothic phase was noted for its use of stained glass and denoted a shift in the purpose for the church. Abbot Suger (c. 1081-1151) decided to enlarge the church to highlight the importance of St. Denis as a royal monastery. The Western end of the church was extended (c. 1135-1140) followed by the Eastern end (c. 1140-1144). Built contemporary to the construction at Durham Cathedral, the eastern end provides a point of comparison to the Romanesque architecture built at the same time. In standardizing the elements making up the distinctly Gothic choir, church patrons witnessed an evolution in the style of church architecture. For example, radiating chapels were more open, and not separated from each other as they had been previously. In addition, these same chapels rose to the same level as the other spaces in the choir allowing more light and space to flow between the areas frequented by pilgrims and church parishioners (Gardner et al., 2016).

In 1231 Abbot Odo Clement (1229-1245) began a new construction campaign at St. Denis to rebuild the Carolingian portion of the church. This phase belongs to the period known as Rayonnant. This campaign of reconstruction kept the eastern and western ends of the church, attributed to Abbot Suger. Instead, Clement concentrated on the nave and transept with minor additions to Suger's work to secure the building both aesthetically and structurally. Built in a squared form, the transept expanded with double aisles on each arm. Finally, in response to the lower height of the 12th century ambulatory, Abbot Suger's *chevet* was raised to mirror the vaulting of the nave and the transept. The *Rayonnant* church was ultimately consecrated in 1281 (Gardner et al., 2016).

Plan of St. Denis

St. Denis, like Speyer Cathedral and St. Étienne, exhibits a Latin cross plan from its earliest iteration (Figure 4.13). The western end of the cathedral contains a large façade, a descendant of Carolingian westworks, with thick walls and supporting piers for what originally housed two towers flanking the entrance. Moving to the east, a small narthex originally lay before the entrance of the nave. Fortunately, though the plan for the Carolingian nave aisles and transept were lost to the reconstruction of the church starting in 1231 and likely completed in 1264 (Gardner et al., 2016), the choir and western facade of Abbot Suger survive (Figure 4.14). The four bay choir of the cathedral, in order to preserve the *chevet* designed by Abbot Suger, moves away from its squared lines and creates an asymmetrical lattice of vaults and spaces. At the eastern end of the cathedral we find a double ambulatory leading to radiating chapels set in a semicircle around the high altar of St. Denis. Each dividing column along the ambulatory matches to an inner column in the choir and an outer buttress on the exterior wall.

Choir Elevation of St. Denis

In the elevation of St. Denis' choir, there are many elements of renovation, such as the high walls and later *Rayonnant* clerestory. The ambulatory at St. Denis joins the choir and apse through an arcade of thin columns (Figure 4.15). Springing from the capitals of these columns, arches allow entry into the ambulatory. Above these arches, a

trio of engaged columns supports the springing of the ribs and the transverse arches. In the triforium a quartet of arched openings for windows are separated into two pairs by an arched moulding that encompasses each pair. In turn, these pairs each possess a column to the outside and a shared column to support them. The arched molding encompassing each pair finds support from an engaged column on the exterior and a shared engaged column on the interior. The clerestory consists of two pointed arch windows per bay, with a single large window in each of the small bays of the apse. In the elevation of St. Denis' choir, there are many elements of renovation, such as the high walls and later *Rayonnant* clerestory.

History of Durham Cathedral, Durham, England[7]

Durham Cathedral was the largest of three churches built in Durham, England, and was made to house the body of Saint Cuthbert of Lindisfarne, The first of the three churches was made of wood and contained St. Cuthbert's body for three years. Aldwinus, first Bishop of Durham replaced the first of these churches with a second church of stone in 990 (Billings, 1843). In 1083, Bishop William Carileph replaced the secular clergy of Durham with a Benedictine clergy. In doing so, Bishop Carileph succeeded in gaining the necessary political and monetary support to begin construction of a new cathedral. He believed that the small stone church was not grand enough for Saint Cuthbert. According to contemporary documents, the trenching began on 29 July, 1093, with the first stone laid on August 11 of that same year (James, 1983).

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[7] (Billings, 1843; Cambridge, Kidson, & Thurlby, 2015)

Bishop Flambard, who took over the Bishopric in 1099, was credited by Billings as having built the cathedral “from the foundation almost to the roof” (Billings, 1843, p. 5); though when he began his tenure, the choir, its aisles, and the transept had been completed. On 29 August, 1104, when St. Cuthbert’s body was moved from an undetermined location, the nave and the surrounding walls had been raised to the vaults (James 1983). The nave, however, was not completed until sometime between 1128 and 1133. Unfortunately, in 1235 the vaults above the shrine of St. Cuthbert in the apse of the cathedral threatened collapse. Therefore decisions were made by unknown individuals to create a second transept which became the Chapel of the Nine Altars. This transept would be completed in 1275.

In terms of renovations to the original cathedral, three major examples exist. A storm in 1429 destroyed the crossing tower. Repairs to this damage began in 1470, and would be completed by 1476. In 1484, construction on the belfry at Durham would begin. This belfry would be completed by 1494. The cathedral remained in this form until a 1775 renovation by the architect James Wyatt. During his renovation four inches of stone were removed from the surface of the north side of the church and the east side of the Chapel of the Nine Altars. Further changes to the crossing tower were completed in 1809 and 1812 by Atkinson, architect of Abbotsford. Though these renovations represent three examples of the changes at Durham Cathedral, further renovations and restorations continue to the present day.

Plan of Durham Cathedral

The far west side of Durham Cathedral begins with the Galilee Chapel, a small chapel supported by twelve clusters of four columns and a set of load bearing walls (Figure 4.16). The westwork contains a pair of towers supported on two sides by the load bearing walls and buttresses of the cathedral's exterior, while a large compound pier supports the innermost corner. Following this compound pier are alternating pairs of columns, six in number, followed by the large compound piers that support the central tower. The columns alternate between compound columns and round columns. The nave possesses an aisle to the north and south sides through which the building may be entered from under the westwork's towers.

Each transept arm is separated into two distinct areas by a trio of compound columns, the outer two of which are round on the inside edge and clusters of three columns to the outer edge. These columns separate the small side chapels of the transept from the transept proper. These columns are in line with the easternmost piers of the central tower.

The choir of the cathedral, surrounded by 5 pairs of columns alternating between large compound columns and small compound columns, shows variety in its decoration as the smaller columns are circular on the choir interior but triple columns in the choir aisle. The choir is raised above the level of the floor, and accessible from the two piers of the central tower as well as a pair of staircases between the third and fourth pair of choir columns. The choir aisles are at the same ground level as the nave. Located between the fourth and fifth pair of columns, the high altar sits immediately in front of

the shrine of St. Cuthbert located beyond on a raised area level with the choir. The shrine extends past the fifth column pair into the chapel of the Nine Altars.

On the easternmost side of the cathedral the Chapel of the Nine Altars extends beyond the width of the choir to half the extension of the transepts. The chapel is lower than the level of the choir aisles and nave and accessible through the choir aisle stairs. This chapel takes the place of an apse in the design of Durham Cathedral.

Sharing many similarities in form to the previously mentioned Romanesque churches, Durham also shares Gothic renovations with St. Denis. For example, the Chapel of the Nine Altars was built in the Gothic style. In contrast, it carries the echelon form of chapel arrangement rather than radiating chapels around an ambulatory (Fernie, 2014).

Nave Elevation of Durham Cathedral

The bays of the Nave are separated by the large compound piers into a double bay system (Figure 4.17). The middle of each bay is supported by the cylindrical columns with incised decoration. The piers stretch from floor to vaulting, with a set of three column shafts reaching the length of the pier. These three shafts are raised from the surface. The transverse arch of the vault springs from the top of these three columns in a thick band. This band has stepped archivolts surrounding it.

From the top of the cylindrical columns that divide the main bay into the two bays of the aisle spring two arches, one to either side. These arched openings allow

access to the nave aisles from the nave. Above these openings the arches have stepped archivolts and incised zigzag molding in two bands.

The gallery, above the aisle bays, mirror the division below, forming a set of four arches set in two pairs. A column to the outside edge supports each pair of arches, and a shared column on the inner edge supports the arch as well. A pair of engaged columns butt up against the arch supports and provide a springing point for a pair of decorative bands. These bands share the zigzag pattern that stretch in a single arch to encompass the pair of arched openings.

Above this the quadripartite vaulting springs from a set of corbels whose lower edge rests at the same level as the apex of the gallery openings. The clerestory windows are triple lancet windows inside of a trio of blind arches, with the two outer arches being less than half the size of the arch that encompasses the windows. The blind arches are supported by a quartet of engaged columns.

Choir Elevation of Durham Cathedral

The choir incorporates two large double bays separated by a large compound pier (Figure 4.18). Three columns engaged with the pier reach from floor to the springing of the transverse arch with the two diagonal ribs springing from the outermost of the three engaged columns. There is another small pair of engaged columns to the outside of these three at the gallery level that also support the wall arch of the clerestory.

The center of the double bay is supported by a large cylindrical column with incised decoration. This cylindrical column supports the arched openings into the choir

aisle. These arches have stepped archivolts. An engaged column on the pier supports the outside of the arch.

At the gallery level there are two pairs of openings, one pair to each of the smaller bays. The arched openings are supported on the outer sides by an engaged column, with a shared column supporting them where they join. A decorative band of archivolts encompasses each pair of arches with another engaged column to the outside of the arched openings to support them. Diagonal ribs spring from a trio of engaged columns at the gallery level above the large cylindrical column. One of these triple columns supports a transverse arch, with the two outer columns supporting diagonal ribs. On a final note, the clerestory level above the gallery possesses a trio of lancet windows within an arched opening in the vaulting.

Shrine of St. Cuthbert Elevation at Durham Cathedral

The shrine of St. Cuthbert contains one arch leading to the aisle and a large pier of engaged columns supporting the roof of the Chapel of the Nine Altars (Figure 4.19). Above the arch there exists a set of four archivolts with a further molding that reaches up to the gallery level. The gallery level contains three pointed arch openings supported by engaged columns at both sides of the arch and freestanding columns in between the arches. A semicircular molding encompasses the three openings and reaches to the clerestory level. A matching molding on the top of the arches highlights the similarity in form. The clerestory contains two matching pairs of lancet windows separated by three columns forming two large pointed arches.

The elevations of the nave, choir, and Shrine of St. Cuthbert exhibit many similar traits to their Romanesque contemporaries. In the Romanesque cases mentioned previously, evidence exists of large primary load-bearing members transferring weight directly from the vault to the ground. Unlike those churches, however, the nave vaulting at Durham Cathedral is original. The choir and shrine, though renovated due to collapsing vaults, maintained their Romanesque form.

Chapel of the Nine Altars Elevation at Durham Cathedral

The floor of the Chapel of the Nine Altars is lower than the floor level of both the choir and the shrine to the west (Figure 4.20). Stone steps at the end of the choir aisles that descend into the Chapel of the Nine Altars marks the transition between spaces. A further set of stairs leads up to the Shrine of St. Cuthbert from inside the chapel, one set located on either side of the shrine to the north and south. The elevation of the chapel consists of predominantly large clustered columns directly supporting the rib vaults and transverse arches interspersed with large stained glass windows. The north and south ends of the chapel are dominated by three large lancet windows arranged under a pointed arch with ornate stone tracery. The eastern wall of the chapel contains two levels of clerestory, with the first being divided into nine large lancet windows that correspond to the seven altars on that wall, with the three innermost windows sharing the largest altar (Figure 4.21). The second level of clerestory matches the northern and southern windows with an additional single lancet window above the first, whereas the central altar and its three windows are matched with a large rose window.

CHAPTER V

THE PIER SYSTEM

In this chapter, I examine the pier system of the case study churches. I define pier systems as the system of vertical supports that carry the forces present in the roof, vaulting, and walls to the ground. I have identified three major structural supports that constitute this system: (a) piers (i.e. freestanding large vertical members that support high vaults and transverse arches), (b) walls, and (c) buttresses (i.e. large vertical supports that are freestanding beside or engaged to the exterior wall of a church or cathedral). Each of these supports perform the same transfer of force to the ground, however they do so in different ways. For example, piers, like columns, transfer force directly to the ground in a vertical manner. Walls, in contrast, provide both a vertical transfer of force and a horizontal transfer of force from interior arches. Finally, buttresses transfer force in a vertical manner, but also transfer force horizontally by their placement at 90 degrees to the wall, or using flyers. In addition to these three structural supports, another element is necessary to qualify this transfer of force, the form of the buttressing. Evidence for the importance of these supports and form of buttressing can be found in Mark and Prentke (1968) and their analysis of the forces present on Gothic buttressing and walls (Figure 5.1).

Parts of the Pier System

Piers developed throughout the medieval period. By the time of Durham Cathedral's construction, piers had become the dominant form of vertical support in church architecture. Looking at the case studies chosen, this would imply that the development of the pier system would begin with S. Ambrogio, become more clearly expressed in Speyer Cathedral, be expressed fully in St. Etienne, and show a new stage of evolution with the Gothic in St. Denis. When added to this chronology, the pier system at Durham Cathedral exhibits evolution from the piers, walls, and buttresses of St. Etienne and movements towards the full realization of the Gothic pier system at St. Denis.

Evidence for this transition away from walls can be found in the thickness of the elements in the pier system, and the form of the buttresses. The thickness of these elements has changed over time in response to their function as a part of the pier system. As vaults increased in height, larger piers were required to support them. In response to this shift in priority from walls to piers, walls were built thinner and piers took prominence. As a response to reducing the thickness of walls, buttresses were used to provide the stability previously afforded by walls of greater thickness. Flyers removed the need for direct contact between a buttress and a wall allowing more light into the church through the large stained glass windows common in the Gothic period.

During the construction of St. Denis and the Gothic transition, buttressing and its forms allowed for the use of thinner and more aesthetically designed piers and columns. To better differentiate this transition in the Romanesque period, Table 5.1 contains my

categorical assessment, with 1 being “most Romanesque” and 5 being “most Gothic.” For example, the pier system (e.g. the pier size, wall thickness, buttress size, and form of the buttresses; Table 5.1) at St. Denis provides more evidence for its Gothic nature than any of the Romanesque predecessors (Figure 5.2). As a result, almost all elements for St. Denis identified in Table 5.1 were categorized as “most Gothic.” St. Denis presents thinner piers resulting from enlarged buttresses and a form of buttress that transfers the force horizontally away from the walls rather than vertically through the piers. In contrast, Speyer Cathedral has thicker piers than those at St. Denis. As a result, most elements for Speyer Cathedral in Table 5.1 were categorized as “more Romanesque.”

Having explained the categorization system used in Table 5.1, it is now possible to compare pier systems between the different case study churches. The pier system at Speyer Cathedral contains piers that stretch from floor to vault, walls connected to the piers via quadrant arches, and lacks buttresses that are separate from the wall. This allows the weight of the vaults to be carried from the piers to the ground, with the horizontal force from the vaults carried into the walls through the quadrant arches above the aisles. St. Denis’ Gothic choir, by comparison, has thin columns that reach from floor to vaults, thin walls with large windows, and buttresses that transfer the distributed weight of the vaults to the ground through a series of flyers attached to the wall. This comparison highlights the differences between the Romanesque pier system at Speyer and the Gothic pier system at St. Denis. In the former, the wall provided the essential vertical support for the vaults, and in the latter that same vertical support had been transferred to the buttresses.

The pier systems at S. Ambrogio, St. Étienne, and Durham exist somewhere between the truly Romanesque and Gothic church architecture. S. Ambrogio has large piers that are made of multiple columns transferring weight from the vaults to the floor. These weights are then transferred via a quadrant arch to the exterior walls, which are in turn supported by further buttresses to the walls' exterior. St. Étienne has piers which transfer the weight of the vaults to the ground, but are made of multiple columns rather than one large pier. Quadrant arches then transfer the weight to the exterior walls, which are supported by integrated buttressing. Durham Cathedral, by comparison, shows extensive use of thick piers to carry the weight of the high vaults, flyers to move the weight from the piers to the walls where large integrated buttresses are present. St. Étienne and Durham Cathedral do not share similar structure in the walls and buttresses in terms of thickness, with the walls and buttresses thicker at Durham. However, the form of buttresses at Durham Cathedral more effectively compensates for the horizontal transfer of force than that supported by the walls and buttressing at St. Étienne. S. Ambrogio, by comparison, has thinner walls than Durham Cathedral, necessitating thinner piers and thinner buttresses. Comparing this to Durham Cathedral, shows evolution in pier systems, as the system at Durham retained piers with large masses supported by thick walls and buttressing. This church's system, however, was novel in its form of buttresses and thickness of buttressing to effectively transfer weight to the ground. If one assumes that the chronology of the case studies was to affect the categorical assessment, it would be the case that the oldest of the case study churches was most Romanesque and the newest most Gothic. I argue instead that the earlier

churches should have middling scores, as the Romanesque was not developed completely during their construction, whereas Durham Cathedral, as an example of the high Romanesque, should have the most Romanesque score (i.e. 1) demonstrating enlarged piers and thick walls in tandem.

If we carry forward our comparison of Romanesque and Gothic forms, the pier should be a stepping stone. As the pier replaced the wall as the primary load-bearing member, it carried forward the technology that allowed later churches to be built to such large sizes and allowed room to move within them. While this transition is vital to the development of the Romanesque, and by extension, Gothic forms, it is the manner in which these churches show said progress that allows a developmental chronology.

If one were to investigate the walls at the case study churches, it would be evident that Durham Cathedral possessed the thickest walls (Figure 5.3). This is a trait commonly associated with Romanesque architecture, and most closely shared with Speyer Cathedral through a visual inspection of ground plans. In comparison, the thinnest walls are found at S. Ambrogio and St. Denis. This creates an interesting juxtaposition, as S. Ambrogio is distinctly Romanesque and St. Denis is distinctly Gothic. Wall thickness, therefore does not provide a reliable indication of dating or sophistication, as exemplified in S. Ambrogio and St. Denis. The thickness of the walls at Durham and Speyer Cathedrals reflect the need to support heavy vaulting and roofing dead weight (Armi, 2004). At S. Ambrogio the thin walls reflect the lack of heavy vaulting and high walls, but not necessarily roofing dead weight. Similar techniques are

used at St. Denis, but include more efficient vaulting combined with newer buttressing techniques.

For the moment it is worth mentioning that the technological advancements of the Gothic style allowed the walls to be thinner, while the Romanesque walls, in most cases, showed the trademark thickness of their predecessors. This suggests that the Romanesque is a transitional phase, as suggested by William Gunn when he first codified the term (Seidel 2006, p. 110). This does not take into account such examples as S. Ambrogio, however, as this church has thin walls through a design choice causing the church to stand out among the other churches used in this thesis. While the exception, rather than the rule, S. Ambrogio does suggest a closer examination of wall thickness is necessary to explain the terminology further.

The evolution of the buttress, by extension a more elegant wall, followed closely the development of the pier. Durham Cathedral, as an intermediate example between the Romanesque and Gothic, has both large piers and large buttresses (Figure 5.4). None of the other case study churches exhibit both of these elements in combination. S. Ambrogio provides a starting point in the examination of the buttrersses in the Romanesque period. These buttresses are thick compared to the walls at S. Ambrogio, but are not as thick as those of later Romanesque churches (i.e. Speyer Cathedral, St. Étienne, and Durham Cathedral), a product of a low ceiling and reduced wall load. Moving to Speyer the buttresses became an integrated part of the wall, whereas walls gained thickness. St. Étienne took this one step further, using thick buttresses and thinning the walls between them to allow light into the building interior. Durham would

evolve from this position by creating proto-flyers to move the weight from the interior to the thick walls and buttresses. Finally, St. Denis is the realization of the independent buttress with flyers and thin walls allowing large stained glass windows to light the space. Once again, by comparison, St. Denis has thicker buttresses than Durham Cathedral, while S. Ambrogio has thinner buttresses than both St. Denis and Durham Cathedral. In St. Denis this results from the form of the buttressing (i.e. the use of flyers), while S. Ambrogio has thinner buttresses due to decreased dead load from directly above the walls. The final case study church, St. Étienne, has the thinnest buttresses along with an intermediate wall thickness.

Piers and Their Evolution

As with the evolution of vaulting technology, the technology of primary load bearing members evolved over the medieval period. Buttresses, while used in many structures before the medieval period, developed a new element, the flyer. While originally quadrant arches would transfer the forces outward across the aisles, into the walls, and by extension into the buttresses, flyers allowed this force to be transferred directly to the buttress, and avoid the masses needed in superfluous quadrant arches. By removing these heavy masses, and reducing the need for large supporting arches in a gallery or aisle, lighter stonework could be used, and the walls raised to greater heights. This, when combined with the previously mentioned thinning of the walls and buttresses due to reductions in vault weight, allowed the transition into Gothic architecture. Gothic

architects were then able to add large ornate windows, supported by a minimum of tracery, their structure held together by the thinner walls and lighter loads.

The term “flyer” is also a term of question, as the traditional view of a flyer is an external element attaching a wall to a freestanding buttress. If that definition is questioned, specifically the concept of an exterior flyer, and instead we consider the internal arches at Durham Cathedral prototype flyers in their expression above the aisle galleries, then Durham again shows elements of evolution towards the Gothic. There are consequences, however, to considering these to be quadrant arches. One such consequence is evident on visual inspection of the plates by Billings (1843, Figure 5.5) in which the arches above the gallery do not appear to be attached to the roof, but instead float as a flyer on the exterior of a Gothic church would. Here lies one of the complications of using engravings as a means of judging the arches above Durham’s galleries, it is not evident whether this was a product of design, or a product of the artistic interpretation of Billings.

To compare the Romanesque and Gothic in this element is to compare form and function. While we will deal with the form shortly, the function is made evident by their size. The function of a primary load-bearing member is to support the majority of the weight of the vault and roof by transferring that weight to the ground. In many cases, comparison of the thickness of the walls and buttresses inform researchers about the relationship between the two elements, and the weights they carry.

As the buttressing thickness demonstrates the transfer of force to the ground, the form of these buttresses demonstrate the efficiency of this transfer (Mark & Prentke,

1968). S. Ambrogio, Speyer Cathedral, and St. Étienne share similar forms of buttressing. Earlier forms of buttressing, seen in these churches, comprised either quarter arches in the gallery or lacked arches except for those distributing direct load from the roof. This form of buttressing lacked efficiency, as it primarily transferred loads from directly above or within the buttresses. These loads were unable to be efficiently transferred off of the large piers and columns to the ground. Durham Cathedral and St. Denis share a more complex form of buttressing. St. Denis' form of buttresses include flyers that allow the force of the high walls and rib vaulting to be transferred away from the building into the buttresses. Durham Cathedral, as an intermediate example between the two forms, shows simple, but effective, flying buttresses hidden within the gallery above the nave (Figure 5.5).

Piers and Their Evolution at Durham Cathedral

Durham Cathedral, when compared to its Romanesque contemporaries, shows this evolution from quadrant arches towards flyers. Previous Romanesque construction did not make use of these flyers in their original form, and only with later Gothic renovations did these churches use flyers with their buttressing. Durham, on the other hand, used proto-flyers incorporated into its gallery from the original construction. While these flyers were less efficiently built, evident by the use of heavy supporting arches in addition to these buttresses, they were early flyers, and did exhibit the characteristics present in later Gothic flying buttresses. The piers at Durham Cathedral, as a result, were large diameter affairs, supporting the majority of the vault's weight

directly due to its inefficient webbing and ribs. These piers are matched by similarly large intermediate columns, providing the same function, though arches built into the gallery and clerestory places some of the force into the large load bearing piers. This is especially true when Durham's masons built high walls, and even more so when Durham's masons built towers.

In this specific case, Durham Cathedral presents itself as a transitional church. This is made possible by its close association with the form of buttressing present at St. Denis. If one assumes that a transitional church will be more primitive in some cases, and more developed in others, evidence for both can be found in this case. By showing a superior form of buttress flyer, Durham cathedral closely associates itself with the early Gothic churches. This does not, however, qualify the church as Gothic when other traits are taken into account. St. Denis exhibits elegance in form through thin piers and high vaults that Durham Cathedral does with thick piers and large stonework. If Romanesque architecture was just a building block for the Gothic churches, as claimed by Gunn, this assumption does a great disservice to the evolution of architecture present in the Romanesque period.

In this chapter, I introduced the pier system as a way of describing the case study churches. I defined pier systems as the vertical supports and form of buttressing carrying the forces present to the ground. Piers developed much in the medieval period, in fact by the time of Durham Cathedral's construction, piers had become the dominant form of vertical support in church architecture. This speaks to the evolution of the pier system during the years spanning the Romanesque and Gothic styles. Thick walls, as a part of

this system, are a trait commonly associated with Romanesque architecture; however, the thinnest walls in the case study churches were found at the oldest and youngest of these churches. The evolution of buttressing followed closely the evolution of the pier in the exploration of more elegant wall structures. Durham Cathedral, as an intermediate example between the Romanesque and Gothic, has both large piers and large buttresses. As the buttressing thickness denotes the amount of force expected to reach the ground, the form of these buttresses demonstrate the efficiency of that transfer. Taken together, the parts of a pier system offer much support in defining these case study churches.

CHAPTER VI

RIB VAULTS

Here we examine the rib vaults of the case study churches. First, I begin with a discussion on the chronology of vaulting as it applies to the case studies, then I move into the method of construction of a rib vault and its technological impact on vaulting methods as a whole. Finally, I discuss the structural implications of different shaped rib vaults as they pertain to our case studies.

Chronology of Vaulting

Vaulting technology also developed throughout the medieval period. Developing first were large barrel vaults, extensions of an arch stretched to fit a large space. With movements away from the Roman Basilica plan, builders used the intersection of two barrel vaults to create groin vaults. This would evolve further from groin vaults via a more efficient use of centering in the construction process into rib vaults.

The pointed vault, developed before the pointed arch came into prominence in the Gothic period, began with the bricklayers of Lombardy who saw the pointed web as a means of raising interior heights without sacrificing the structural integrity of the building or the limits of the materials (Armi, 2004 p.25-42). In the case studies presented in this thesis, pointed arches first appear in the construction of vaults, where flattening vaults forced builders to point the non-transverse ribs, and in most cases the webs as a response to the new form. This is exhibited at several of the case study churches, but is

first seen at St. Étienne in the sexpartite vaults of the nave. This is an important development as it allowed vault builders to open larger spaces for a clerestory that would bring more light into buildings otherwise lit by candlelight. By the time of Durham Cathedral's construction, barrel vaulting technology was relegated to small spaces, or in some cases, the connecting of two spaces. Evidence for this relegation to small or connecting spaces can be found at Speyer Cathedral, where the chancel remained a barrel vault in spite of renovations to the nave vaults. Barrel vaults are rare in these case study churches, in part because renovations in these same churches occurred after their original construction. The nave and aisles at Speyer Cathedral exhibit groin vaults. Rib vaults, as a later renovation, are found in all of the case study churches except Speyer Cathedral. This is reflected in the naves and aisles of these other case study churches (i.e. S. Ambrogio, St. Étienne, Durham Cathedral, and St. Denis).

Comparing this to Durham Cathedral shows an evolution in vaulting technology as no barrel vaults exist at Durham Cathedral. Groin vaults, present at Speyer Cathedral in the nave, are also absent at Durham Cathedral. Whereas the vault renovations at Speyer Cathedral come earlier than the rib vaults at Durham Cathedral, the latter cathedral uses rib vaults exclusively. This could imply that by the time of Durham Cathedral's construction, the aesthetics of the world were changing, and the previous barrel and groin vaults were no longer the epitome of architectural achievement in vaulting technology. In fact, Durham Cathedral is argued to be the first example of rib vaulting in Europe (Hoey, 1966, p. 164).

In contrast to barrel and groin vaults, rib vaults at St. Denis appear even more evolved than those at Durham Cathedral. As researchers have noted, the key development in the case of Gothic vaulting is the use of ribs as a structural device (Armi, 2004). St. Denis has such structural ribs in the choir. Looking at Durham Cathedral, evidence suggests that this was not the case when the original vaults in nave were under construction. As is evident in the work of James (1983), problems exist at the center of each vault preventing the ribs from being structurally sound (Figure 6.1). In this figure, example A shows the manner in which most of the ribs at Durham Cathedral are cut. The boss in example A has sides cut to be parallel with the voussoirs. If these vaults were structural, the voussoirs would be pushed to the side and the vault would collapse. In contrast, the boss example B is cut to be perpendicular to the transfer of force from the boss to the voussoirs. While less aesthetically pleasing, example B performs the function of a structural member.

Construction of the Rib Vault

To vault a space, builders would create wooden centering to support the new construction. This framework would be removed once the last stones were laid and the plaster dried. In rib vaults, this centering could be reduced to a minimum as the ribs themselves took on the role of the centering for the intermediate spaces between the ribs, or webbing. The ribs are made of several precisely cut stones called voussoirs. In the construction of vaults, the stages necessary do not change in barrel, groin, or rib

vaulting. They do change in scale, however, as the centering stage is reduced with rib vaulting such as those seen in St. Denis' choir and Durham Cathedral's example B.

Structural Implications of the Shape of Rib Vaults

Rib vaults, while useful in many ways, were not an overnight perfection, as the examples at Durham Cathedral show. Armi (2004) points to the development of pointed arches and, by extension, pointed vaulting as the major breakthrough that allowed the Gothic transition. Early vaults, developing after the barrel vault was perfected, had some trouble integrating a perpendicular shape to create groin vaulting. In doing so, masons often created vaults that were flatter in nature, and thus less structurally stable over large areas. This lack of structural stability led to many churches needing to renovate their vaults at a later period. Armi attributes this to, "A more efficient web angle also causes less stress on the freestanding piers and requires a thinner wall and buttresses on the exterior to absorb the weight of the vault [sic]." (Armi 2004, p. 70).

Masons eventually concluded that flatter arches transfer weight less evenly and as a result require thicker piers. This is an important distinction showing the evolution of techniques, but Armi also points to the common misconception that barrel vaults were inherently inferior to groin vaults. This is not the case, as he implies that the masons in charge of the vault building saw them as equally valid decorations, useful in their own ways in specific scenarios (Armi 2004, p. 55). As mentioned in Figure 6.1, examples of the evolution of vaulting in structural form do exist at Durham Cathedral. Other

cathedrals introduced in this thesis might also demonstrate a similar evolution, but the limitations of this study preclude more accurate measurements at this time.

In addition to the consequences of flatter arches, pointed vaults preceded rib vaults. Due to the more efficient use of space, and eventually the use of the rib as a structural member, webs became thinner, less rubble, and most valuably, lighter. This lighter webbing meant that church builders could concentrate on building the vaults faster and higher. Decreased weight required less buttressing allowing the reduced weight to be used for higher vaults rather than heavier vaults. This shell like webbing would become a hallmark of the Gothic period, and continues to be used to the present day.

Vaulting and its Evolution

As vaulting technology evolved, and vault webs thinned, benefits of this technology were evident in medieval church architecture. Pointed vaults possessed structural advantages when transferring forces vertically. Semicircular arches were found to transfer proportional amounts of force both horizontally and vertically at the springing of the arch. Pointed arches, in contrast, transfer force more efficiently downward. This became relevant to vaulting when the manner of vault building changed. Originally vaults were built with solid masses in their webs. As time progressed, masons realized that this webbing could be made thinner, and more shell like, resulting in lighter vaults. The most significant result of this thinning of the vault webs, major scaffolding was no longer as necessary and lighter centering methods could

be used (Armi, 2004). As a result of this shift towards lighter vaults, the efficiency of pointed arches had an additional side effect. Less horizontal transfer of force meant that walls could become thinner, and the buttresses, while more prominent due to thinner walls, could be made thinner as well (Armi 2004, p70).

Vaulting and its Evolution at Durham Cathedral

In this chapter, we discussed the evolution and structural impacts of vaulting. At Durham Cathedral, we compared two instances of ribs in the nave and the problems that existed with the original form of rib vaulting. One example (Figure 6.1) shows the inherent problems with early rib vaulting, and the reason these ribs must have been built with the webbing. If Durham Cathedral's rib vaulting is an example of early innovations, as the chronology of the rib vaults suggest in our case study (Anselmi et al., 2015; Armi, 2004; Baylé, 2015; Cambridge, Kidson, & Thurlby, 2015; Gardner et al., 2016; Winterfeld, 2015), then ribs would not be fully understood in a structural sense. As James (1983) mentions, the method of building vaults may have changed with the invention of the rib, but there is a clear evolution of Durham's ribs from the groin tradition of vaulting.

If Durham Cathedral's ribs were evolved from the groin tradition of earlier churches, then the ribs would not be structural, but built at the same time as the webbing. This, in turn, would mean that the ribs had no reason to be properly cut and centered to support the weight of the vaults. As evident in figure 6.1 example A, this occurred at Durham Cathedral. By contrast, properly supported ribs, a mark of the

Gothic style, would forgo aesthetic stonework in favor of proper structural support as seen in the only example at Durham Cathedral (example B). Because of example A we can suppose that Durham Cathedral's vaults evolved from earlier solid mass forms. Furthermore, if Durham Cathedral is to be seen as a transitional church, then it should also display evolution of vaulting techniques used over time. As example B was built roughly one generation after the rib was first introduced at Durham, it is the case that this evolution is present (James 1983). By having one example, rather than a renovated nave that holds multiple examples, example B demonstrates that the original masons of Durham Cathedral had learned the new ways in which structural ribs could assist in their work. This would become a precedent as shortly after the completion of the nave of Durham Cathedral (estimated completion ca. 1128-1133), Abbot Suger would begin work on St. Denis' Gothic choir (1140-1144).

In this chapter I have discussed a short chronology of vaulting, and then moved into the method of construction of a rib vault and its technological impact on vaulting methods as a whole. To conclude I discussed the structural implications of different shaped rib vaults as exemplified by the work of Armi (2004). This information, combined with previously mentioned technological innovations in piers and buttressing, sets up the Gothic transition and allows researchers to form conclusions on Durham Cathedral's place within that transition.

CHAPTER VII

CONCLUSIONS

In the previous chapters, we examined the plan and elevation for each case study, explored the types of piers present, and described the evolution of rib vaulting. Each of these activities allow us to explore what makes up Romanesque architecture In addition, this allows us to go into some detail about the transition to the Gothic style of architecture. Some conclusions, based on the evidence put forth, can now be drawn.

Defining Romanesque and Gothic

If it is the case that Romanesque and Gothic architecture is not the sum of its predecessors and successors, then the question is raised of the real value of this architecture. The purpose of this thesis, in exploring the definition of the term "Romanesque," is to question that definition. Without the Romanesque exploration, and Gothic realization, of rib vaults many beautiful buildings would not exist. Later styles would not have used the exploration of architectural principles such as pointed arches and flying buttresses to allow light through large interior spaces. Because of these design and construction techniques, researchers should move past the inherently negative connotations associated with the original terms. In doing so they are more likely to question if these classifications are still accurate.

Romanesque architecture has been defined in the past by a series of common traits that stretch across the whole of the Romanesque period. These elements include

round arches, large piers, barrel and groin vaults, and thick walls with engaged or absent buttresses. Gothic architecture, by comparison, includes such elements as pointed arches, thin columns, structural rib vaults, and thin walls with freestanding buttresses attached via flyers. If we define Romanesque churches as those in which Romanesque traits are present during initial construction, and Gothic churches as those in which Gothic traits are present during initial construction, then we must define transitional churches as those in which there are examples of both Romanesque and Gothic traits present during initial construction. While this is a convenient manner of defining the churches presented as case studies from a categorical standpoint, it does not tell the whole story. Looking at the scoring system used for Chapter V (Table 5.1), a great deal of information presents itself for the observation of Romanesque and Gothic traits in the five case study churches. Scores were assigned in order of Romanesque precedence (i.e. Romanesque traits such as thick piers, thick walls, small buttressing, and poor efficacy in buttress form were given lower numbers) with the assumption that churches with the lowest total scores would be the ones with the most Romanesque features. By contrast, the churches with the highest scores would be ones with the most Gothic features. To compensate for some of the bias in myself, Dr. Dane Bozeman with advanced training in research methodologies assisted in assigning ordinal values.

As expected, there was some variety when summing the ordinal values to create overall scores. Given that these churches are listed in chronological order, it would make sense to see them in that same order when the scores are created. There was an expected trend, with Speyer Cathedral showing the most Romanesque traits and St. Denis

showing the most Gothic traits; however, some interesting phenomenon presented opportunities for discussion. For example, if Durham Cathedral is indeed one of the transitional churches mentioned earlier, this church should (a) have a score between the Romanesque churches and the Gothic church chosen in this study for comparison and (b) should also have the highest score of all Romanesque churches. As is evident from the scores, this is not the case.

This discrepancy in scores can be explained due to a number of factors. The main outlier, S. Ambrogio, was reviewed in its current state. In this state it has been renovated several times, with the first beginning in the early 11th century and the last ending in the 20th century, and also suffered damage from heavy bombing during the Second World War. In addition, the basilica plan of S. Ambrogio allows different design techniques to be used in supporting the weight of the building. The weight of the roof is supported vertically by the piers and buttresses which are built in a manner to support more vertical weight than transferred weight from the vaults. With the heavy post-Romanesque intervention of local leaders and repairs, it is not surprising that this church takes on a less Romanesque profile. In addition, as the High Romanesque style was fully developed at Durham Cathedral, it would make sense that the middling score would be from different extremes.

In contrast, St. Étienne consistently maintained middling scores in the elements of the pier system, the only exception being the size of the buttressing. This score is due to the buttresses extending only a short distance from the walls of the church. However, in the case of all other variables, St. Étienne consistently exhibited traits commonly

associated with the Romanesque churches that have been renovated in the Gothic style. St. Étienne finds itself equal in numerical score to Durham Cathedral. However, Durham Cathedral's score is not a result of consistent Romanesque traits. In fact, I argue that Durham cathedral does not stand out simply on displaying the proto-Gothic traits, but instead the manner in which it displays those traits.

While the values in table 7.1 represent an ordinal scale, there is no consistent distance between the individual values. For example, while the forms of buttressing in S. Ambrogio, Speyer, and St. Étienne are similar in nature, the introduction of the buttresses at Durham Cathedral and their inclusion of early flyer technology is a remarkably big step towards the Gothic transition. S. Ambrogio, Speyer, and St. Étienne are scored 1, 2, and 3, respectively on pier form. However, the score of 3 associated with St. Étienne's pier form is not as closely related to the score of 4 for Durham Cathedral as Durham Cathedral's score is to the 5 of St. Denis. While the piers at Durham Cathedral are quite thick and take the brunt of the weight from the vaults and roof, it is in this exploration of flyers that the buttressing and thick walls show evolution towards the Gothic.

In Table 7.2, by contrast, the values have been scored according to their similarities rather than order of precedence. It is evident from the new total scores that the chronology of these churches presents a gentle arc. As the early Romanesque churches show more average Romanesque traits they possess lower scores, though a great change occurs at Durham Cathedral. Whereas the earlier churches maintained their scores via averages, Durham maintains its score via two extremes. The more

Romanesque traits (i.e. the piers and walls) are countered by the evolution of the more Gothic traits (i.e. buttresses). While the Romanesque churches maintain similar scores, it is more evident that Durham Cathedral's pier system is a large step towards the Gothic pier system of St. Denis. Durham Cathedral shines as a prominent example of the developed High Romanesque style evolving into the Early Gothic. If the scores for a High Romanesque church should be low, but the scores for a Gothic church should be high, then a church exhibiting both elements should have a middling score made of two extremes.

Vaults and Piers as They Define Durham Cathedral

As a transitional church, the vaulting application has a heavy impact in the influence of Durham Cathedral. Looking to the chronology of the case study churches, Durham Cathedral has the earliest example of ribs incorporated into the vaulting throughout the nave, choir, aisles, transept, and Chapel of Nine Altars. If we then shift our focus to ribs that are universally considered Gothic, such as those at St. Denis, there are scholars making several claims relevant to Durham Cathedral as well. Crosby (1948) claims that St. Denis' ribs, in spite of their prototype form, are "proto-Gothic, if not Gothic," and thus the question must be raised if Durham Cathedral's prototype ribs might also be used to define the church as an intermediate example (p. 14). Crosby further argues that St. Denis must be considered Gothic when considering the whole building, including the "heavy, often awkwardly constructed," rib vaults (Crosby 1948, p. 14). By extension, this would mean, we should continue to define Durham as

Romanesque when considering the entire building, in spite of the fact that it demonstrates early attempts at rib vaulting throughout the Cathedral. This may further discourage researchers from asking more, however, as Durham Cathedral's rich examples for the evolution of vaulting architecture provide many examples worth study.

The key difference in the Romanesque application of flyers at Durham and the later applications in Gothic contexts is the manner in which the buttresses were engaged with the outer wall. With Romanesque applications, such as those at Durham Cathedral, the buttresses were engaged heavily with the walls, leaving little room for fenestration outside of a clerestory. Later applications, such as those at St. Denis, utilize extended flyers and buttresses that are thinner, and allow more spaces where light can enter the church. This is evident at Durham Cathedral as well in the Chapel of the Nine Altars, where the more efficient buttressing allows more fenestration.

While the term Romanesque has become a convenient way to refer to the architecture of the 10th through 12th centuries, it is an incomplete qualification. To call the Romanesque churches a stepping stone between the architecture of Late Antiquity and the French Gothic is to ignore the developments that occurred during this period. This method of qualification, and the inherently pejorative nature in which the term was used, calls into question the motives of the architectural historians who coined the term. Was this qualification a degradation of the work accomplished by the architects and masons of the medieval period, or perhaps an elevation of later forms of architecture? Did these architectural historians intend to elevate the architecture of the Renaissance, and the Classical Greco-Roman architecture, as a manner of discounting the work done

by their predecessors? While I cannot definitively answer this question, my research leads me to the conclusion that any response would be based on speculation. Also, is the term Romanesque inclusive or exclusive? The work of Gunn and other authors suggests Romanesque is an exclusive term, that being Romanesque excludes these churches from the development of Gothic architecture. Other scholars argue for a better definition. I agree with these scholars and look forward to future research approaching the subject. Hopefully, the answer to this question will lead to other questions about the methods used in architectural evaluation of past structures.

Personal Impact on the Researcher

Finally, from personal inspection, Durham Cathedral presents a juxtaposition of Gothic elements in a Romanesque setting. In walking through the south aisle of the choir, I began to notice pointed arches over the aisle. While this was not uncommon in many of the other buildings I visited on that particular trip, it was a Gothic element that stood out against the rounded rib vaulting. This struck me as odd, and presented the question of Durham Cathedral's age. I had not yet researched in depth the differences in the vaulting of Durham Cathedral and other Romanesque churches, but did find the desire to learn more.

In learning more, and comparing Durham Cathedral to other case study churches, I find that the transition period between the Romanesque and Gothic can be exemplified by Durham Cathedral. With proto-Gothic elements such as the development of the flying buttress, the first example of rib vaults in Europe, and the pointed arches over the choir aisles, Durham Cathedral requires further study. In future research there exists a chance

to redefine the transitional period, though it will be difficult given a lack of surviving examples. It is this researcher's hope, however, that this may be done for the benefit of future architectural scholars.

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APPENDIX A

FIGURES

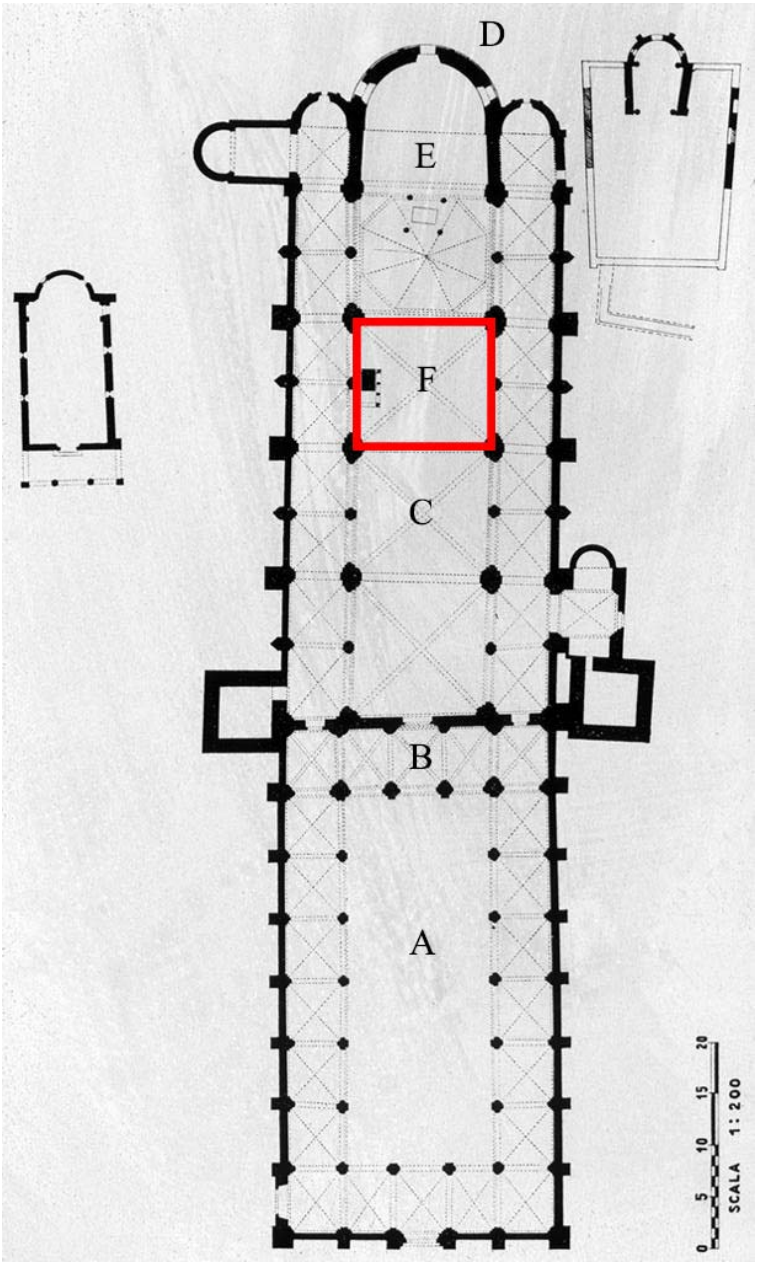


Figure 4.1 Floor plan of S. Ambrogio, Milan, Italy (copyright Reggiori, F. and E. Cattaneo; La Basilica di Sant'Ambrogio. Milan, 1966. p.93, fig XXVII). A=atrium; B=western entrance; C=nave; D=triple apse; E=choir; F=major bay unit.

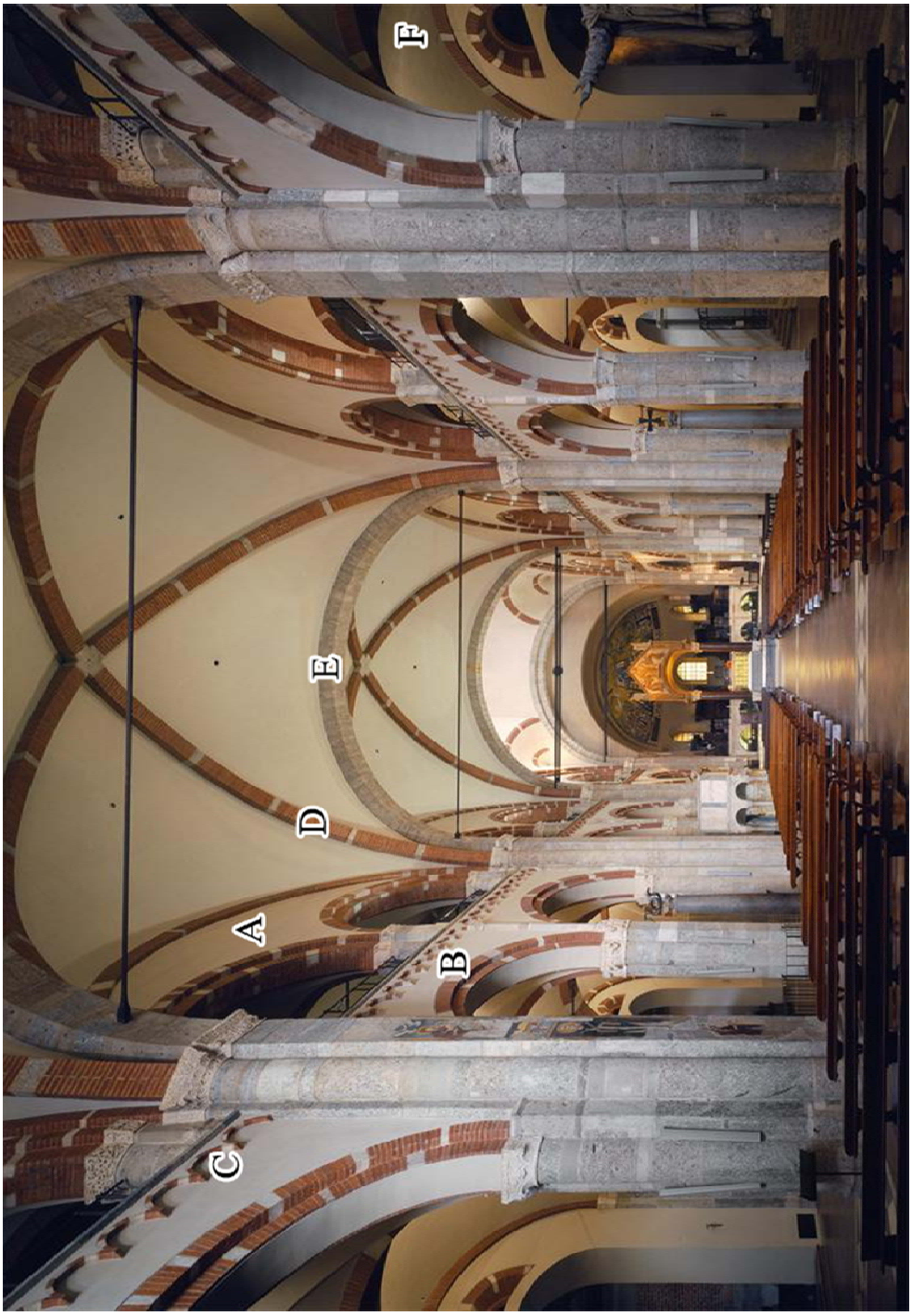


Figure 4.2 Current interior of S. Ambrogio, Milan, Italy (copyright 2006 SCALA, Florence/ART RESOURCE, N.Y.). A=major bay; B=minor bay; C=Lombard corbel frieze; D=rib; E=transverse arch; F=aisle.

Figure 4.3 Dome of S. Ambrogio, Milan, Italy (copyright Dr. Sara N. James, Mary Baldwin College). A=simple windows; B=cross window; C=squinch.

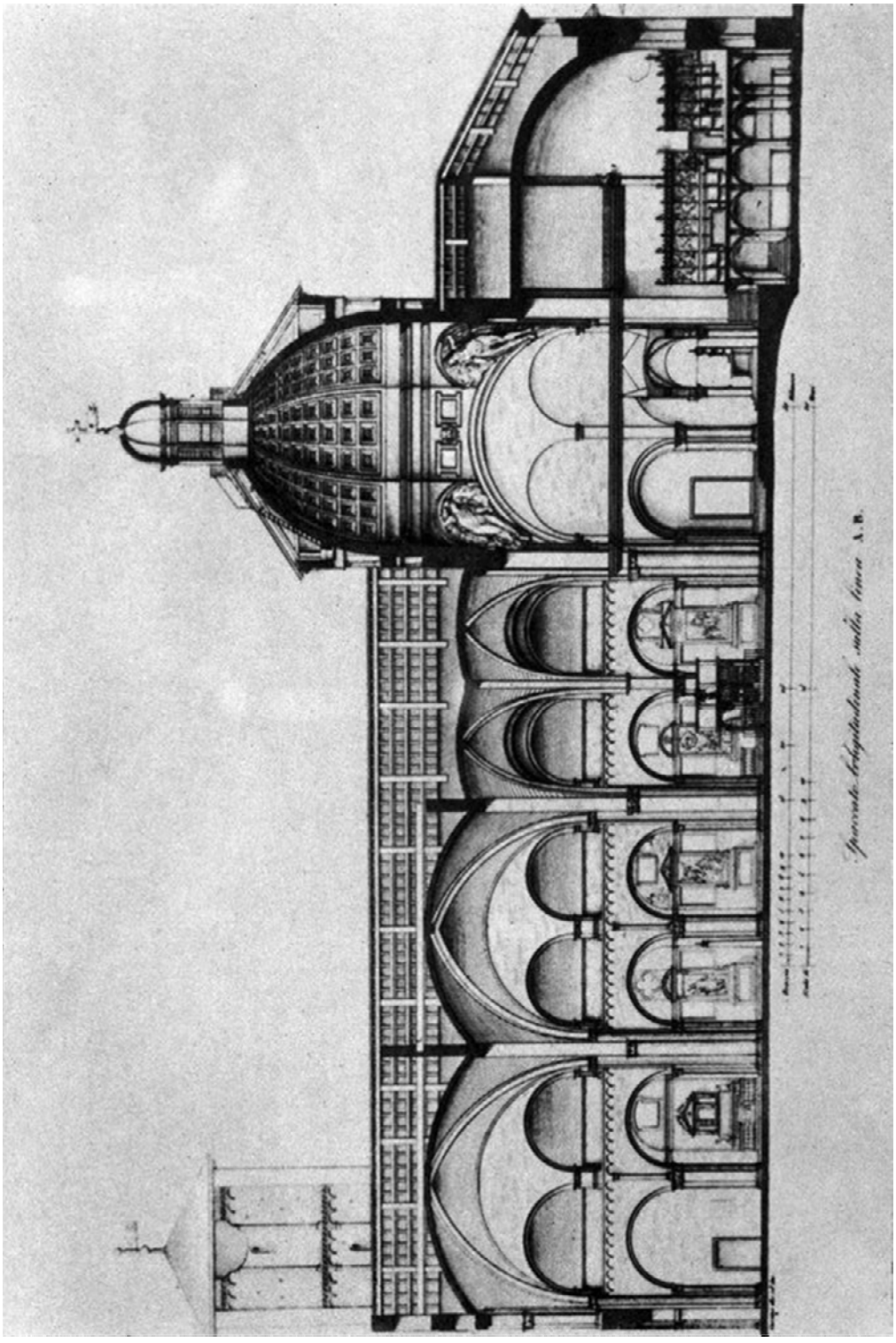
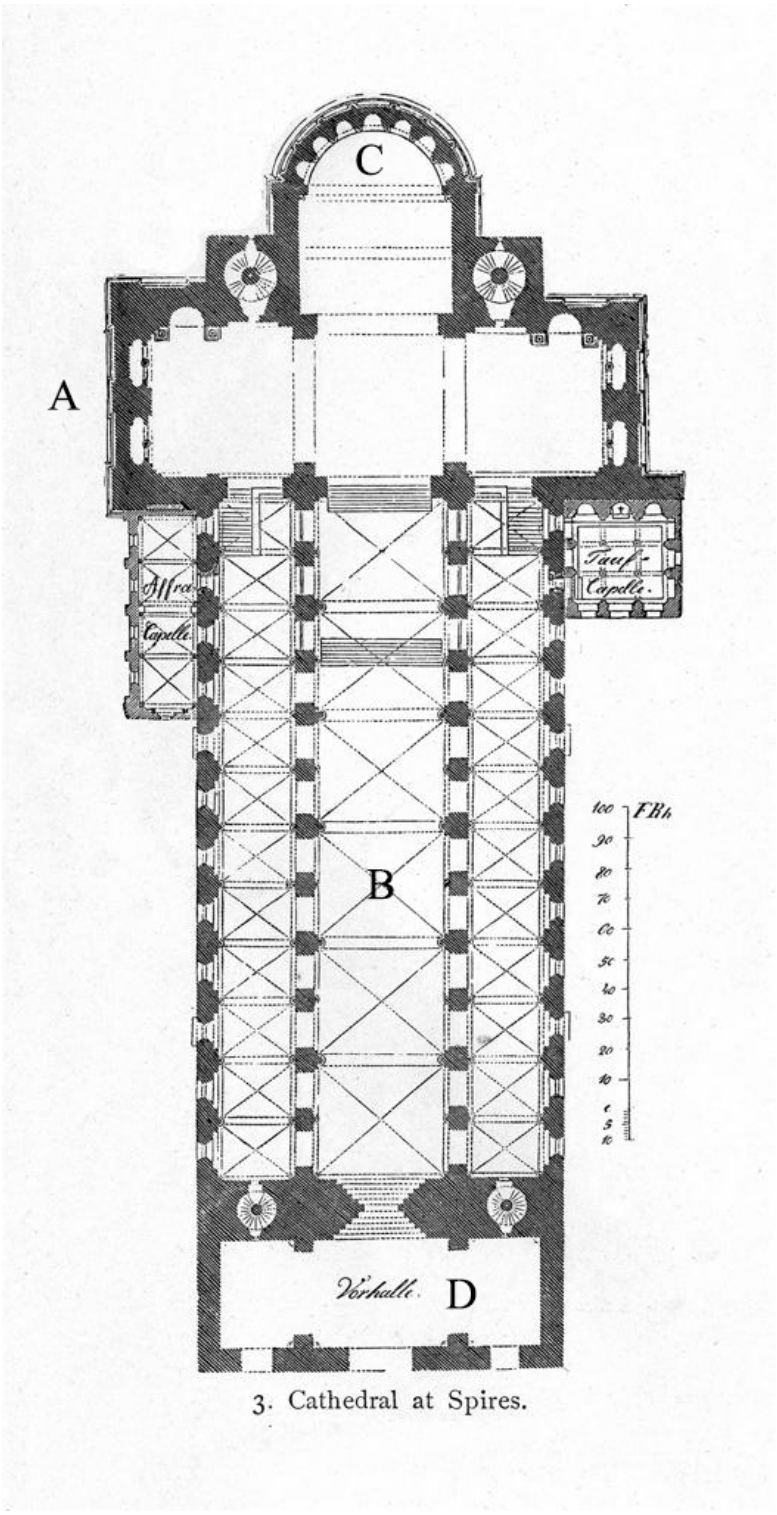


Figure 4.4 Reconstruction of 10th century S. Ambrogio, Milan, Italy (copyright Reggiori, F. and E. Cattaneo; La Basilica di Sant'Ambrogio. Milan, 1966. Pl. 99).



3. Cathedral at Spires.

Figure 4.5 Floor plan of Speyer Cathedral, Speyer, Germany (copyright L. Prang and Company, 1879).

A=transept; B=nave; C=Eastern apse; D=westwork.

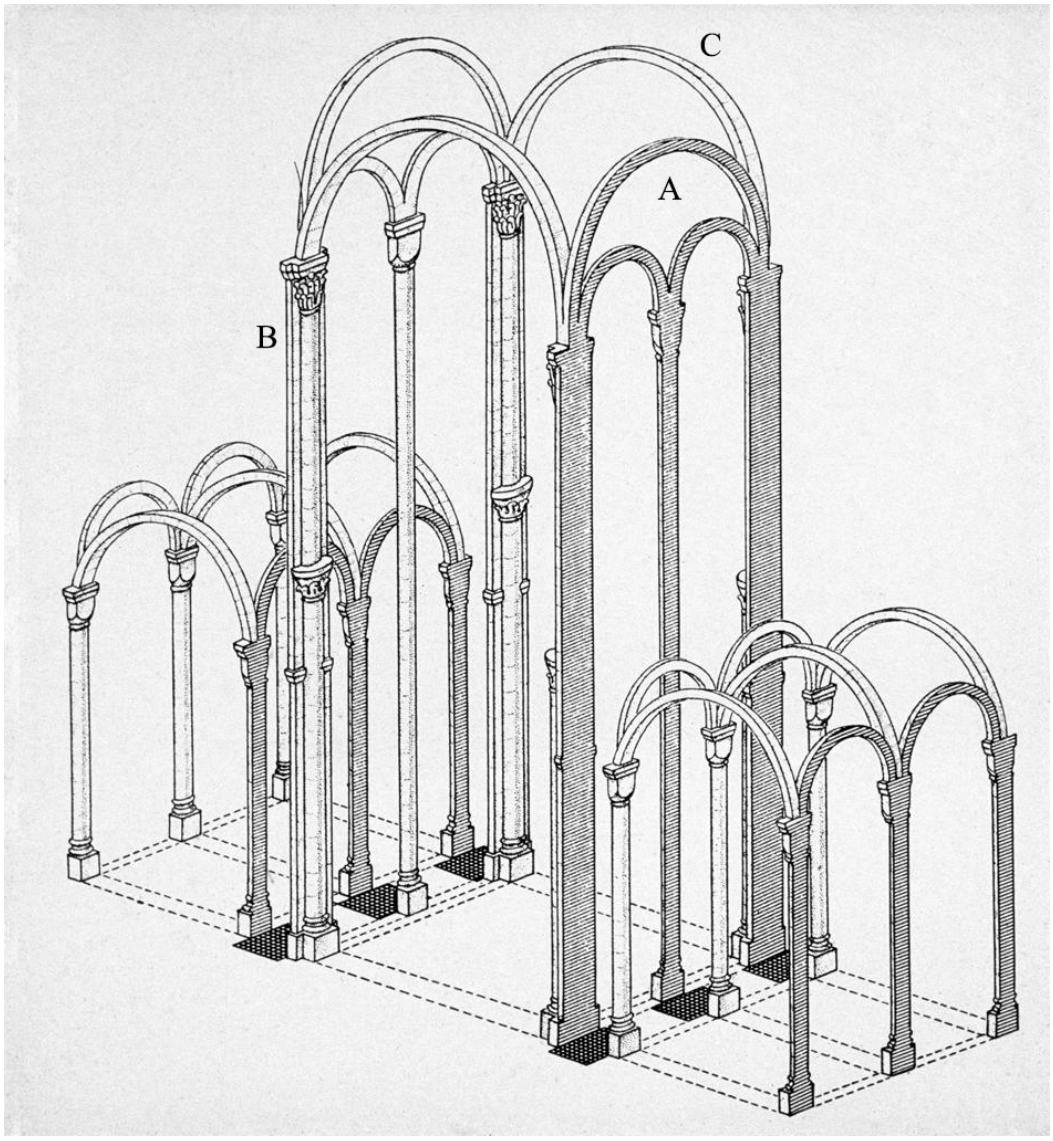


Figure 4.6 Vertical supports and arches at Speyer Cathedral, Speyer, Germany (copyright Journal of the Society of Architectural Historians 17.2 (1958); Horn, W. "On the Origins of the Mediaeval Bay System," 2-23; p. 18 fig. 39). A=major bay; B=piers; C=transverse arch.

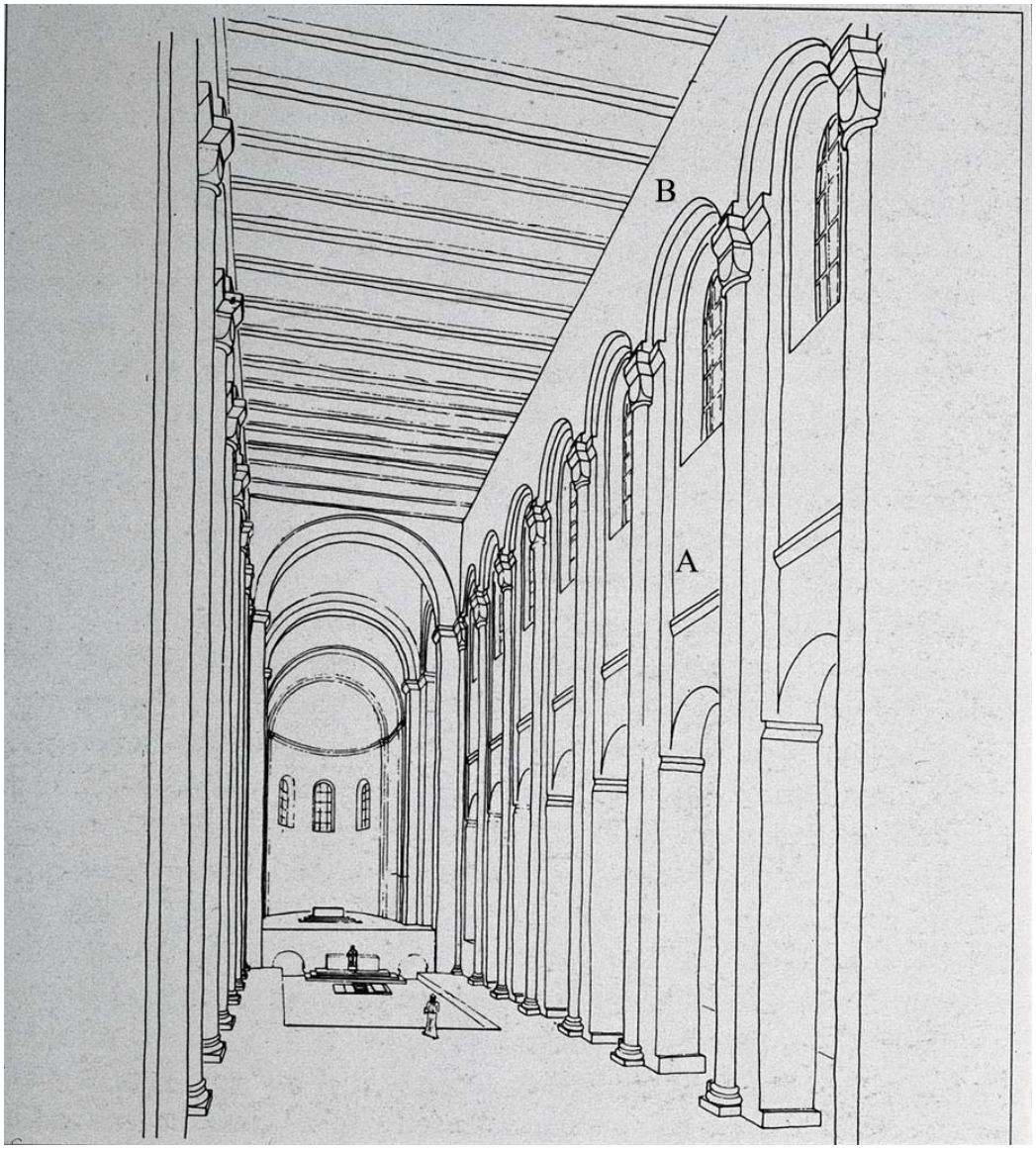


Figure 4.7 Interior of Speyer Cathedral before renovation in 1082 (copyright University of California, San Diego). A=large piers with half columns; B=arches above clerestory.

Figure 4.8 Interior of Speyer Cathedral, before 19th century renovations (copyright University of California, San Diego). A=large piers with half columns; B=arches above clerestory; C=groin vaults.

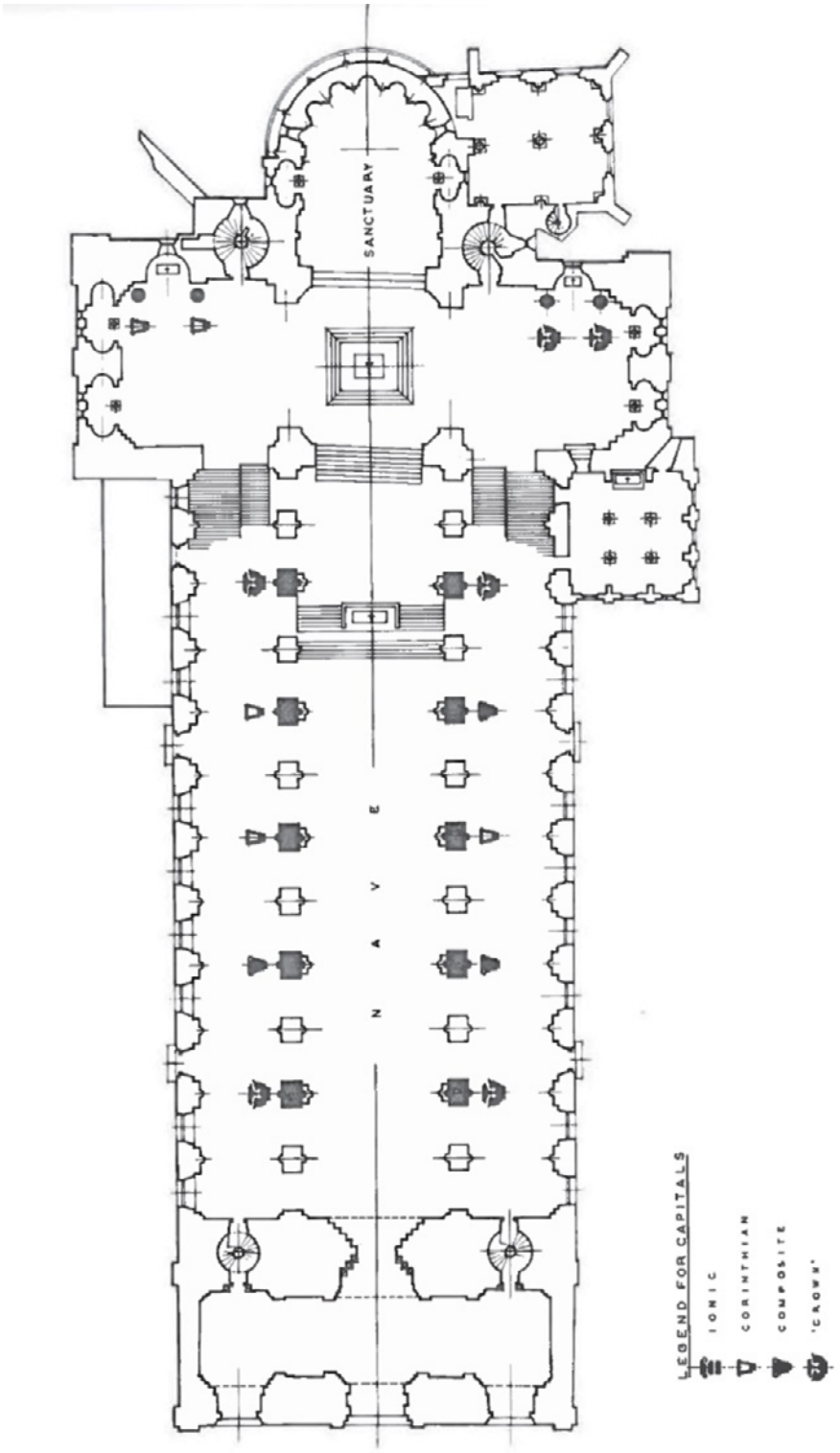


Figure 4.9 Capital types in Speyer Cathedral (from Onians 1988)

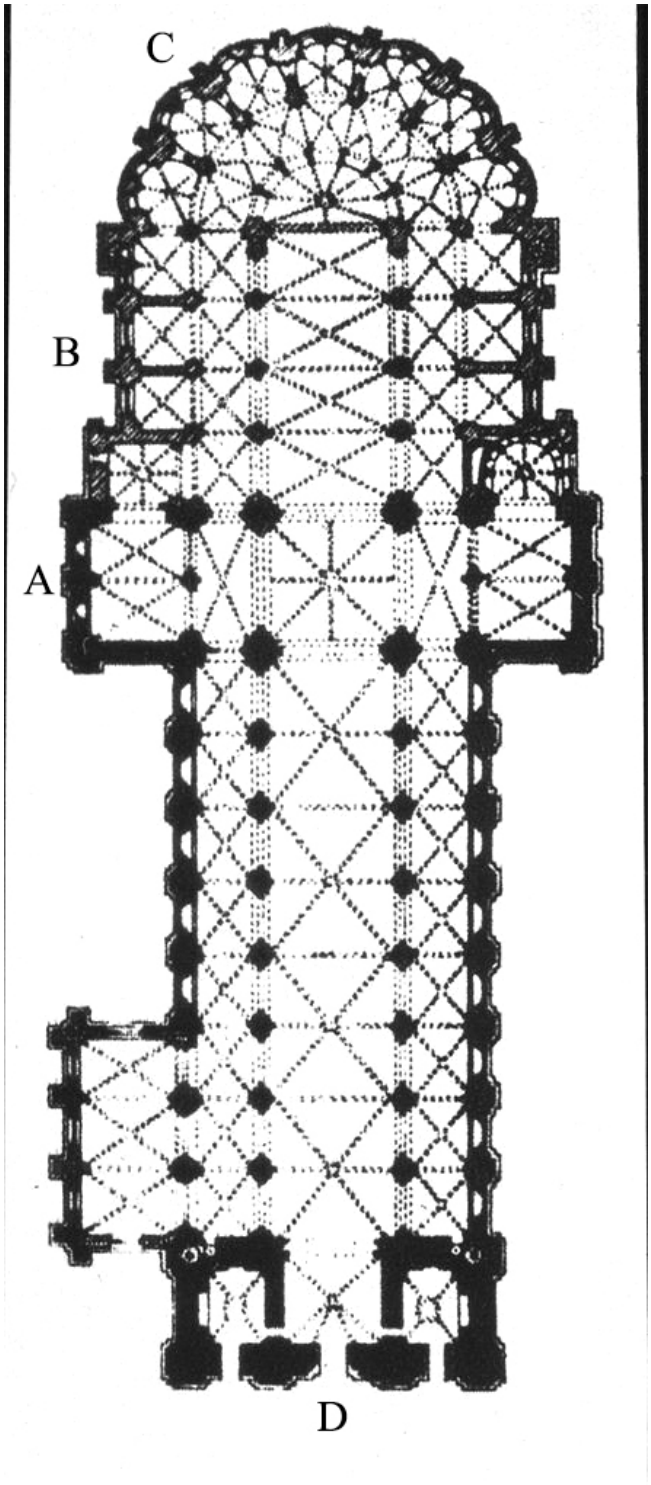


Figure 4.10 Plan of St. Étienne, Caen, France (copyright University of California, San Diego). A=transept; B=choir; C=apse; D=Westwork.

Figure 4.11 St. Étienne Nave Interior (copyright National Gallery of Art, Washington DC). A=piers; B=gallery; C=clerestory; D=clustered columns supporting ribs.

Figure 4.12 Nave vaults, St. Étienne, Caen, France (copyright National Gallery of Art, Washington DC).

A=sexpartite vaulting; B=transverse arch; C=clustered columns.

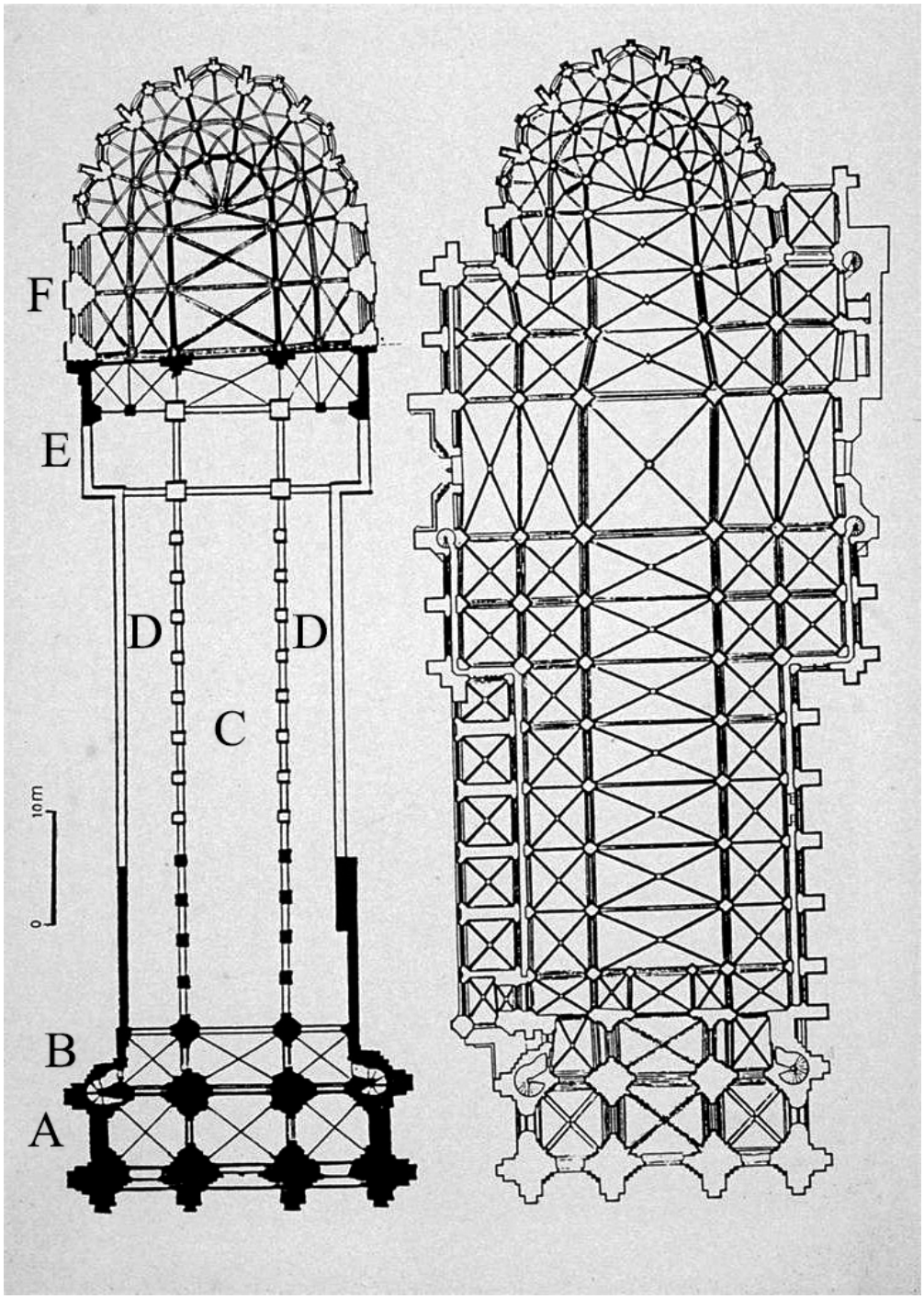


Figure 4.13 Theoretical plan of Abbot Suger's St. Denis (left), with modern building (right) (copyright University of California, San Diego). A=westwork; B=narthex; C=nave; D=aisles; E=transept; F=choir.

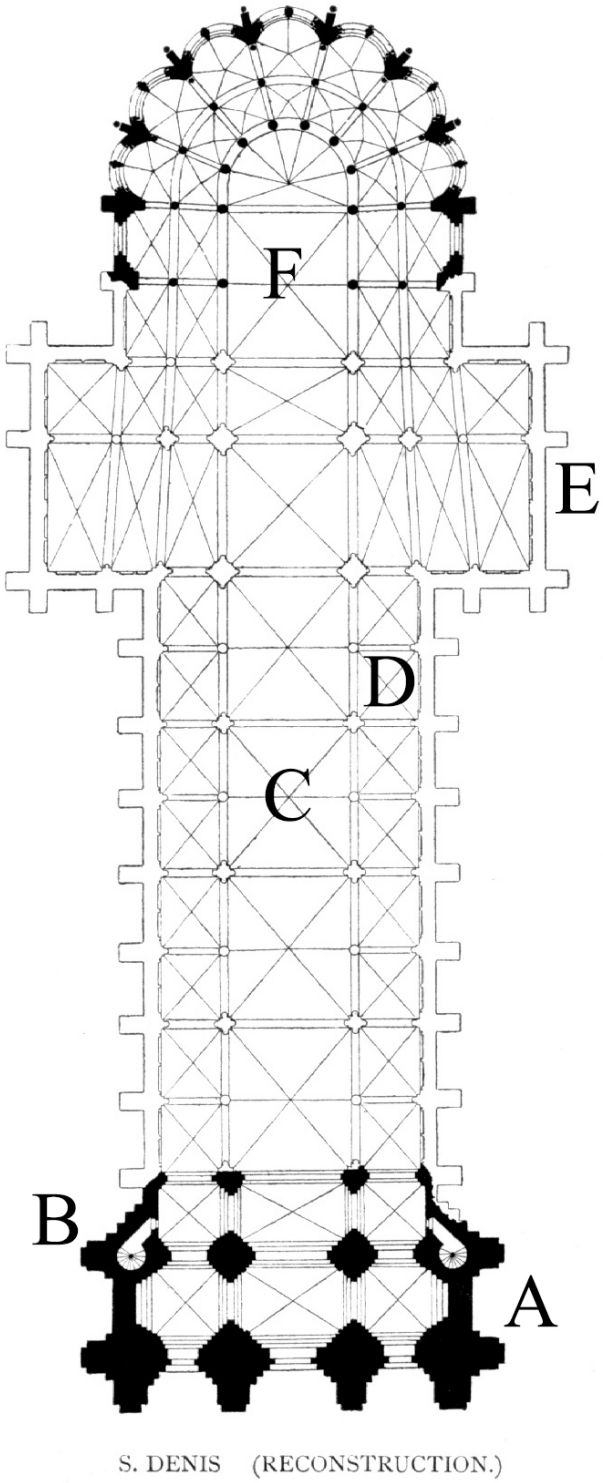


Figure 4.14 Possible reconstruction of Abbot Suger's St. Denis, emphasis on surviving elements (public domain). A=westwork; B=narthex; C=nave; D=aisle; E=transept; F=choir.

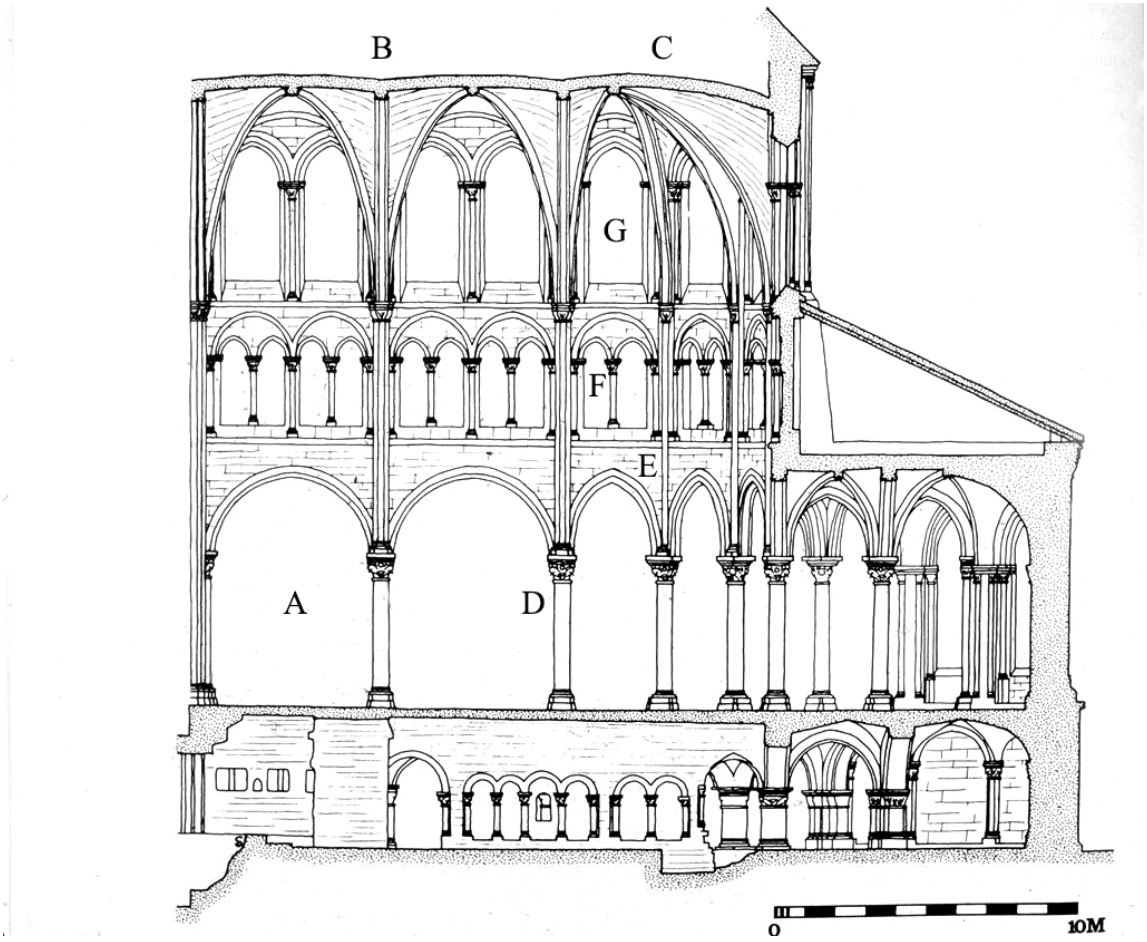


Figure 4.15 Choir elevation of St. Denis with crypt below (copyright Donald Sanders). A=ambulatory; B=choir; C=apse; D=arcade of thin columns; E=arches allowing entry to the ambulatory; F=triforium; G=clerestory.

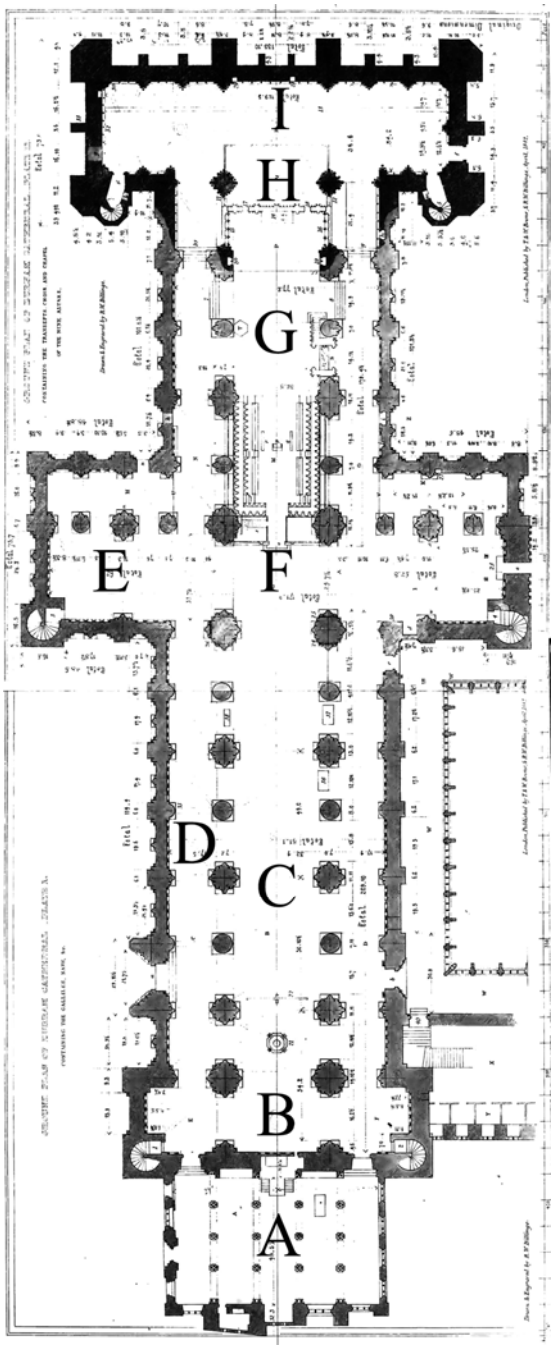


Figure 4.16 Plan of Durham Cathedral, Durham, England (from Billings 1843). A=Galillee Chapel; B=westwork; C=nave; D=nave aisle, E=transept arm; F=central tower; G=choir; H=Shrine of St. Cuthbert; I=Chapel of the Nine Altars

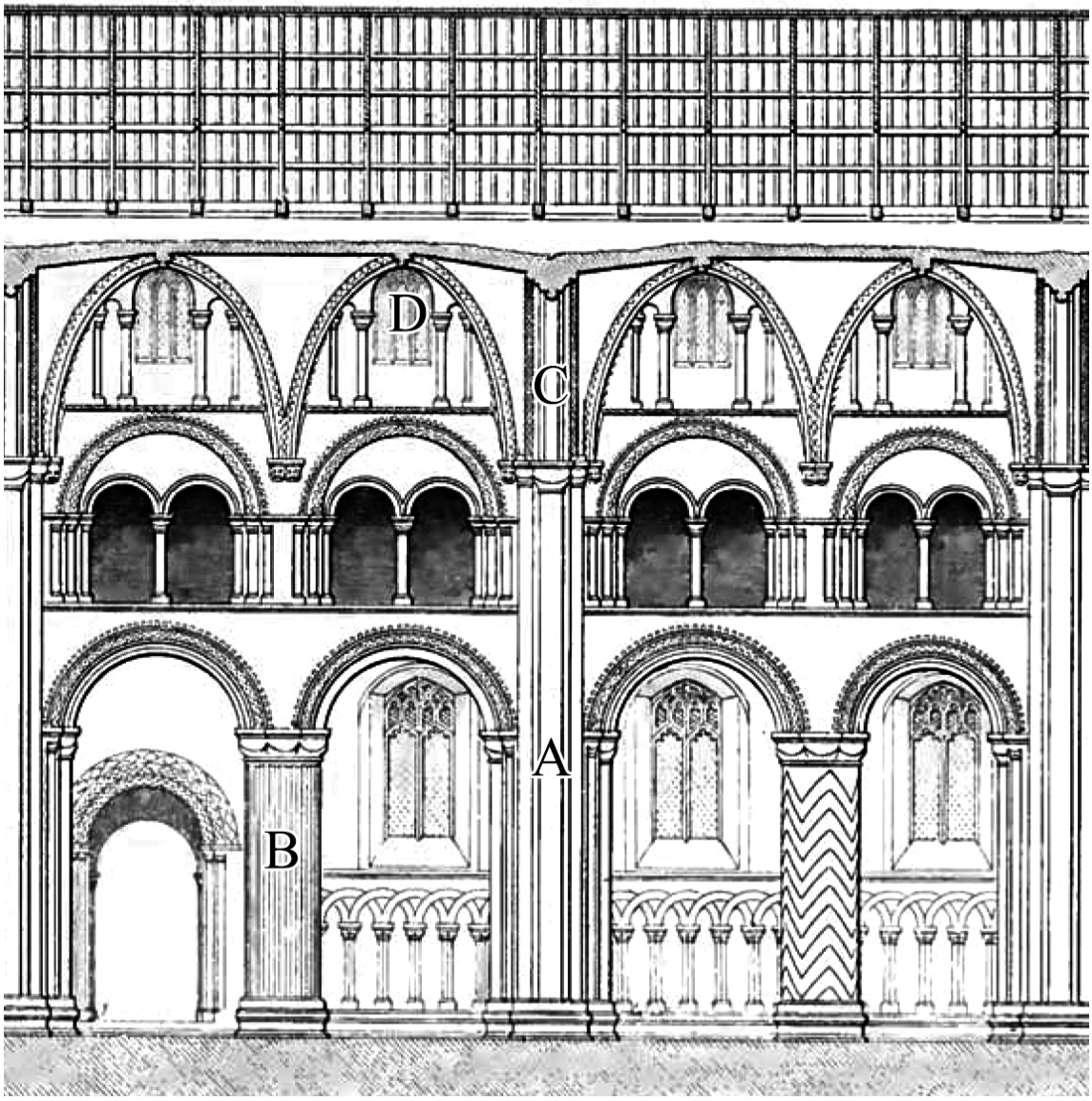


Figure 4.17 Nave elevation (from Billings 1843). A=large compound piers; B=cylindrical column; C=transverse arch; D=clerestory windows

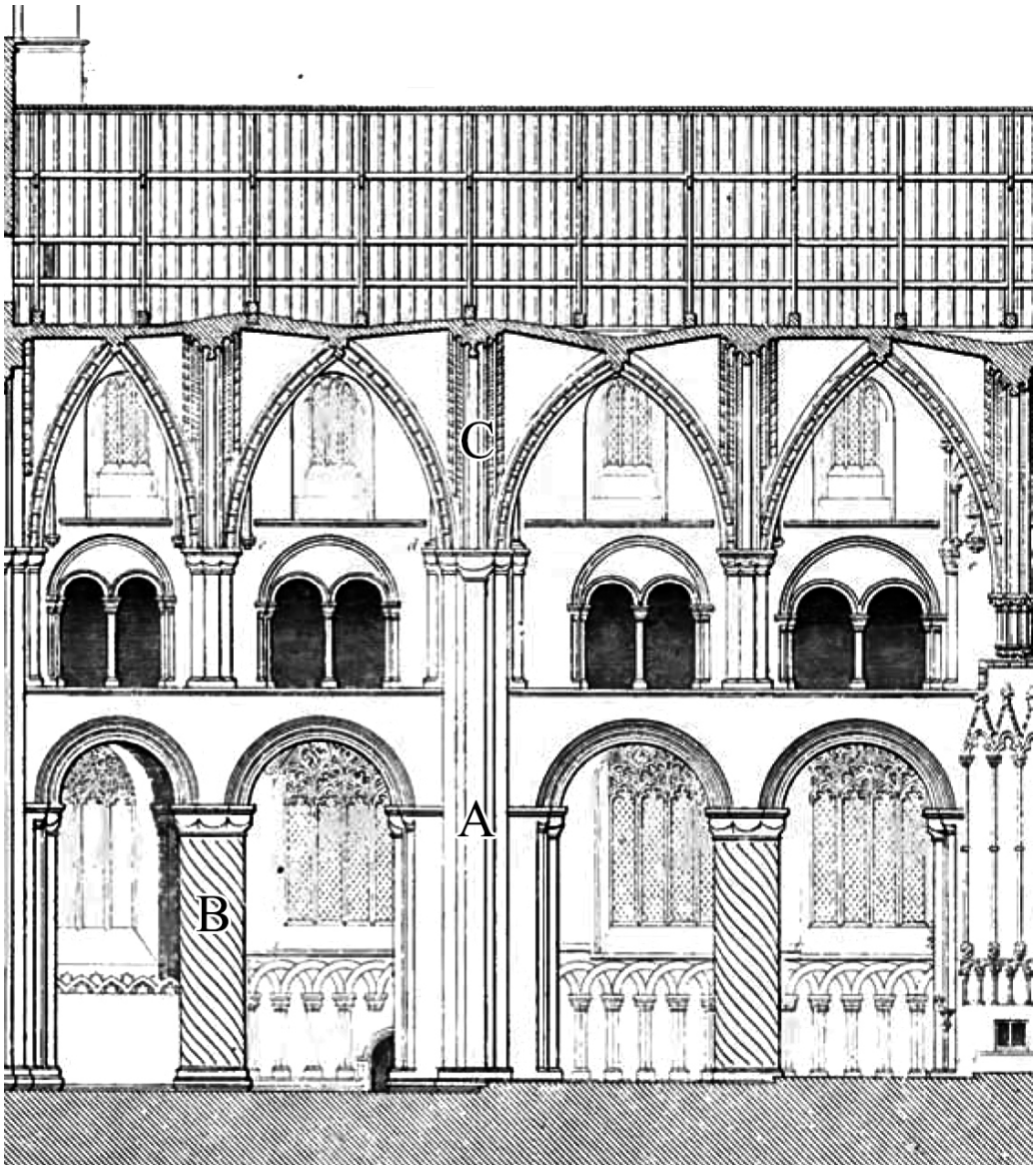


Figure 4.18 Choir elevation (from Billings 1843). A=large compound pier; B=cylindrical column; C=transverse arch.

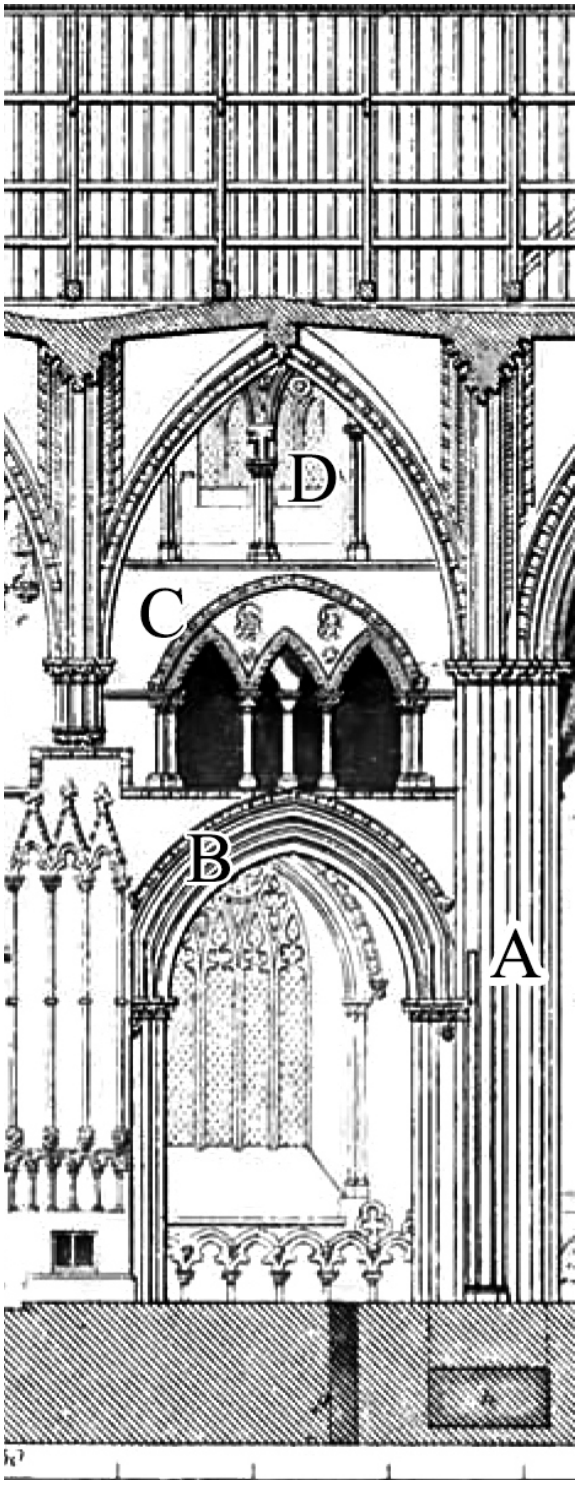


Figure 4.19 Shrine of St. Cuthbert elevation (from Billings 1843). A=clustered column; B=archivolts; C=semicircular molding; D=clerestory.

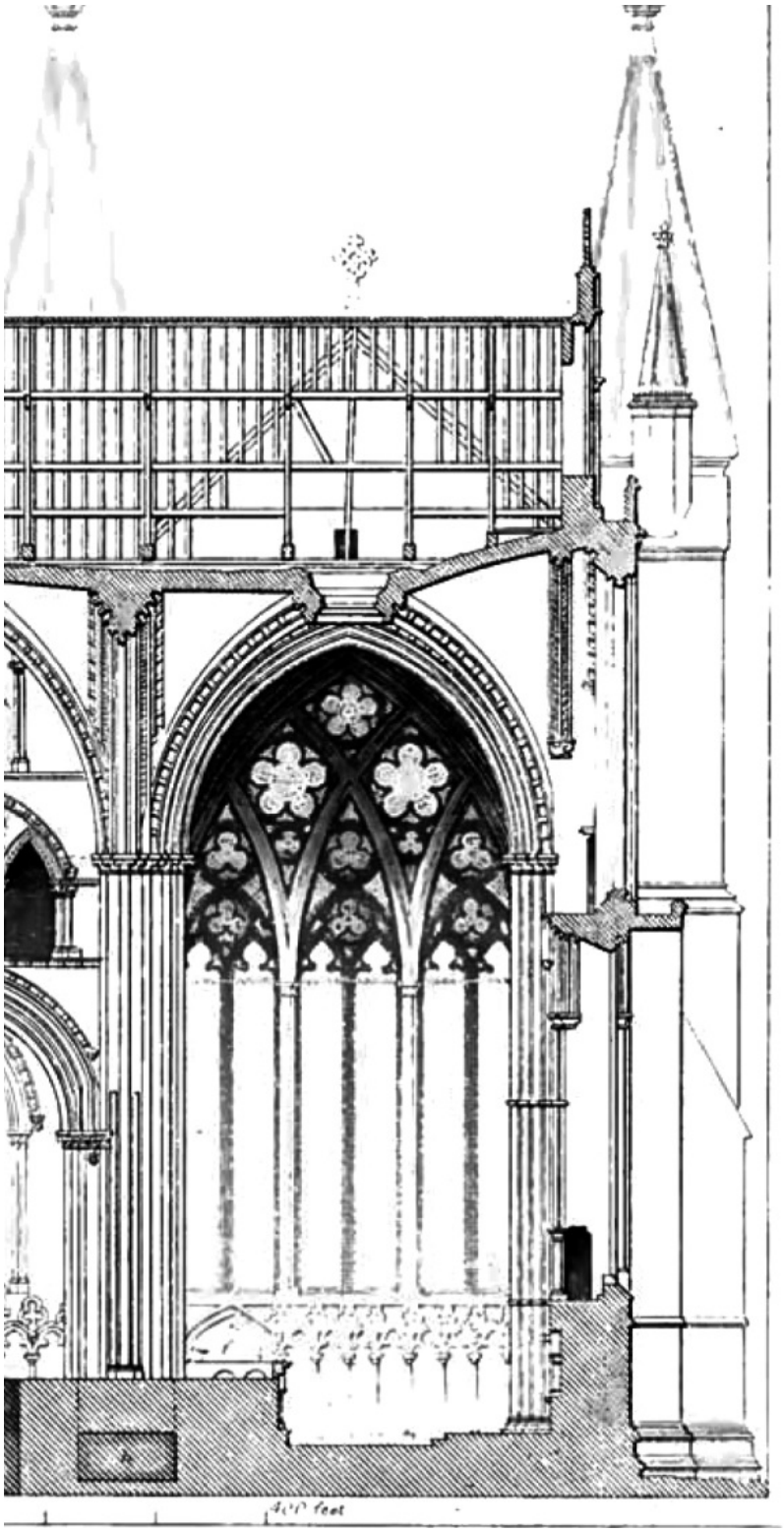


Figure 4.20 Chapel of the Nine Altars elevation (from Billings 1843)

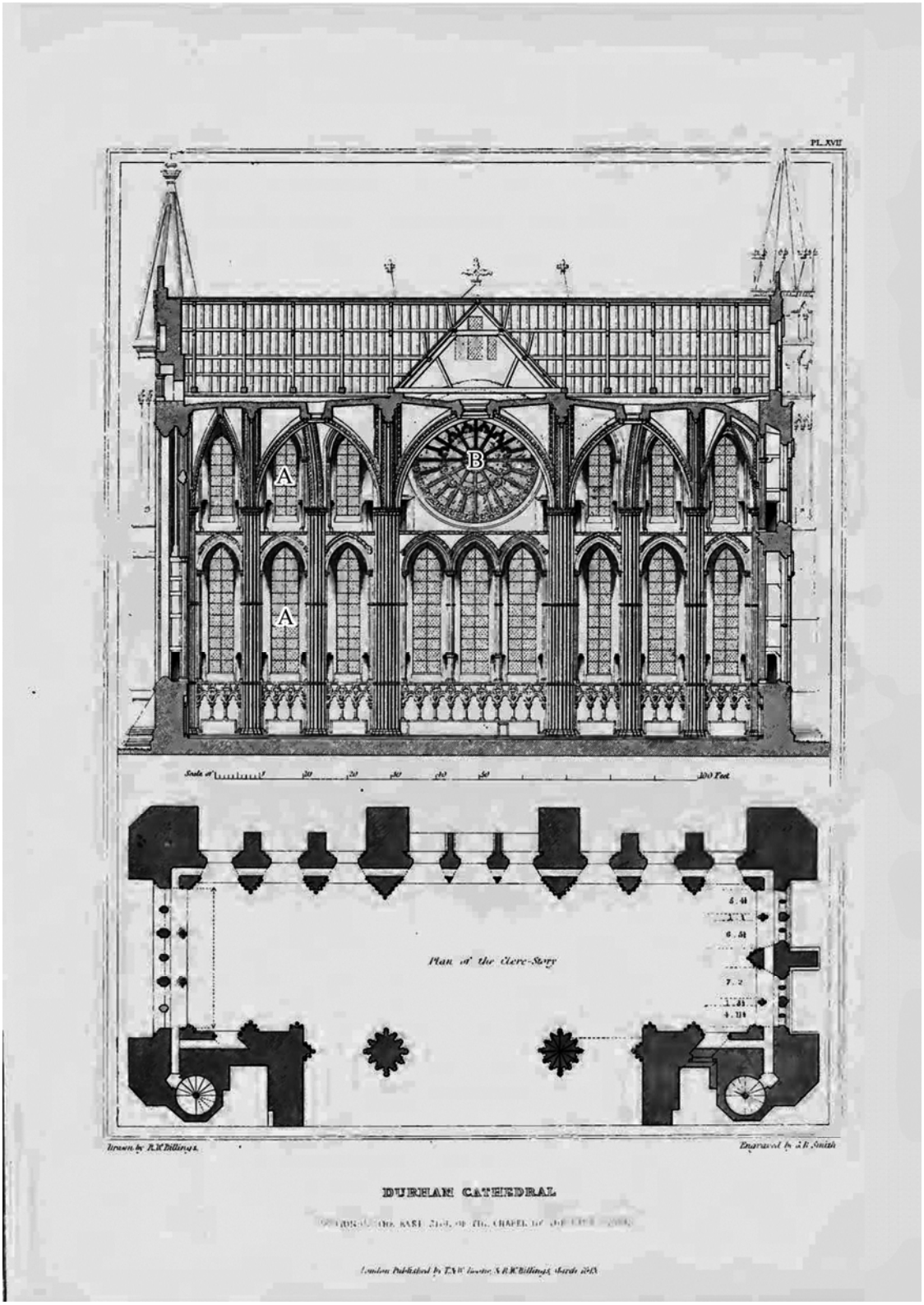


Figure 4.21 Chapel of the Nine Altars elevation facing east (from Billings 1843). A=clerestories; B=rose window.

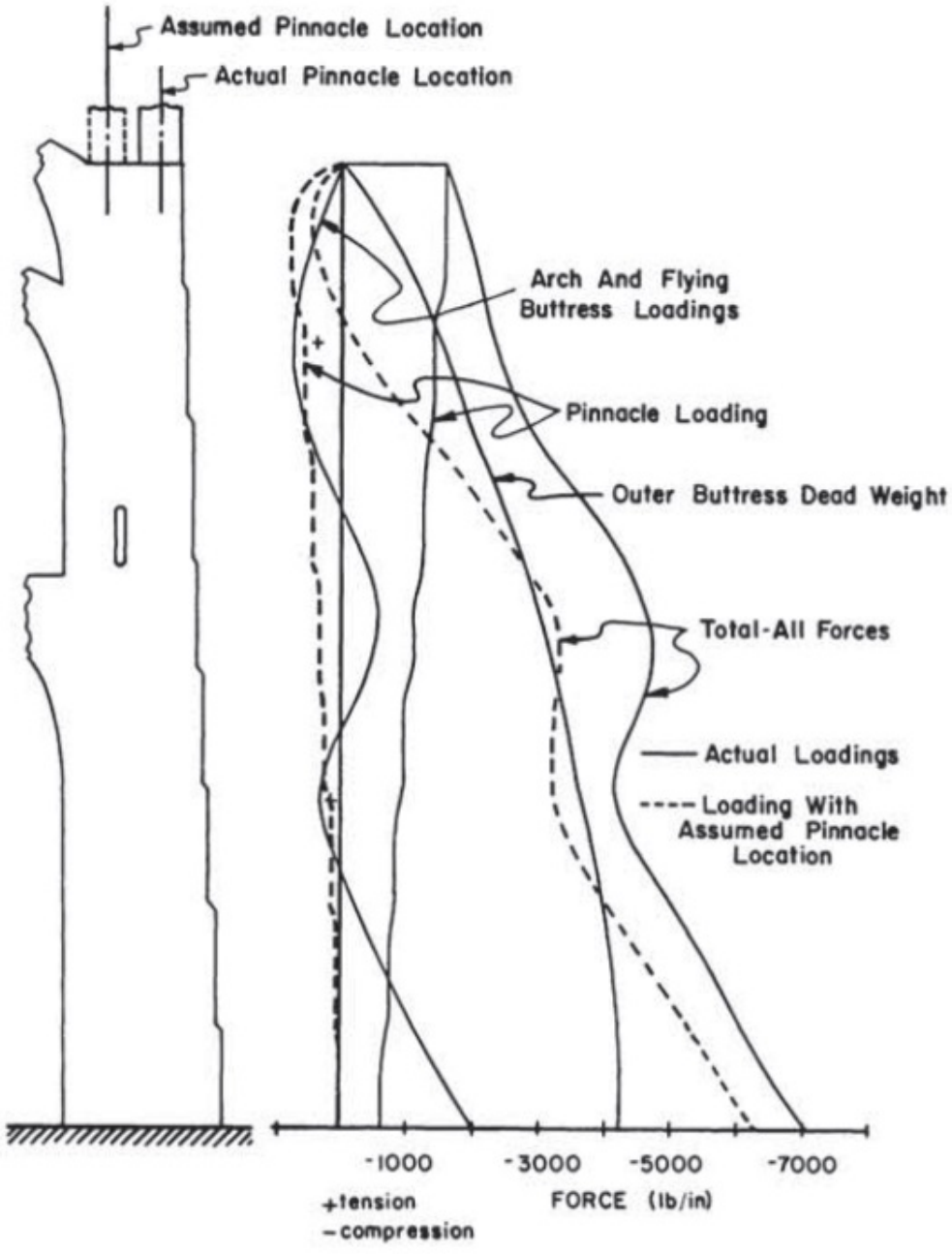
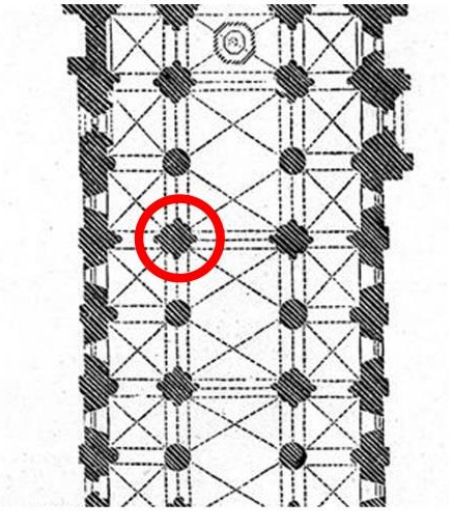
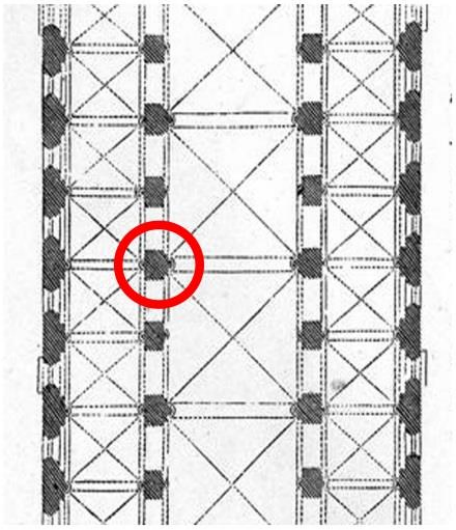


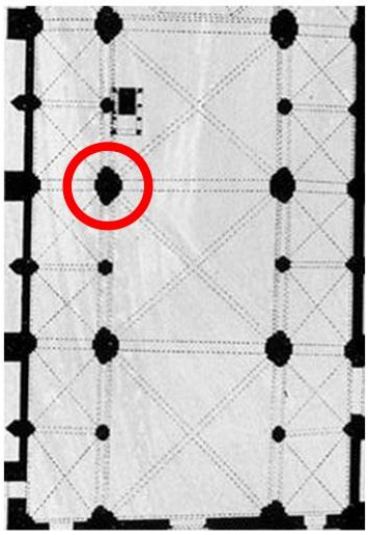
Figure 5.1 Scale model of Amiens Cathedral with representative weights (from Mark & Prentke 1968)



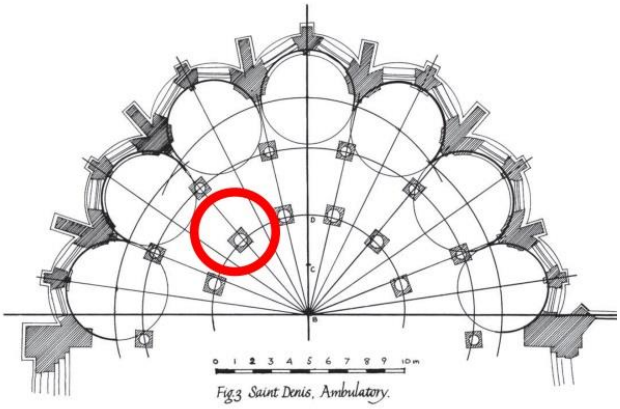
Durham Cathedral



Speyer Cathedral



Sant'Ambrogio



St. Denis

Figure 5.2 Four case study churches and their piers (St. Denis after Crosby 1966)

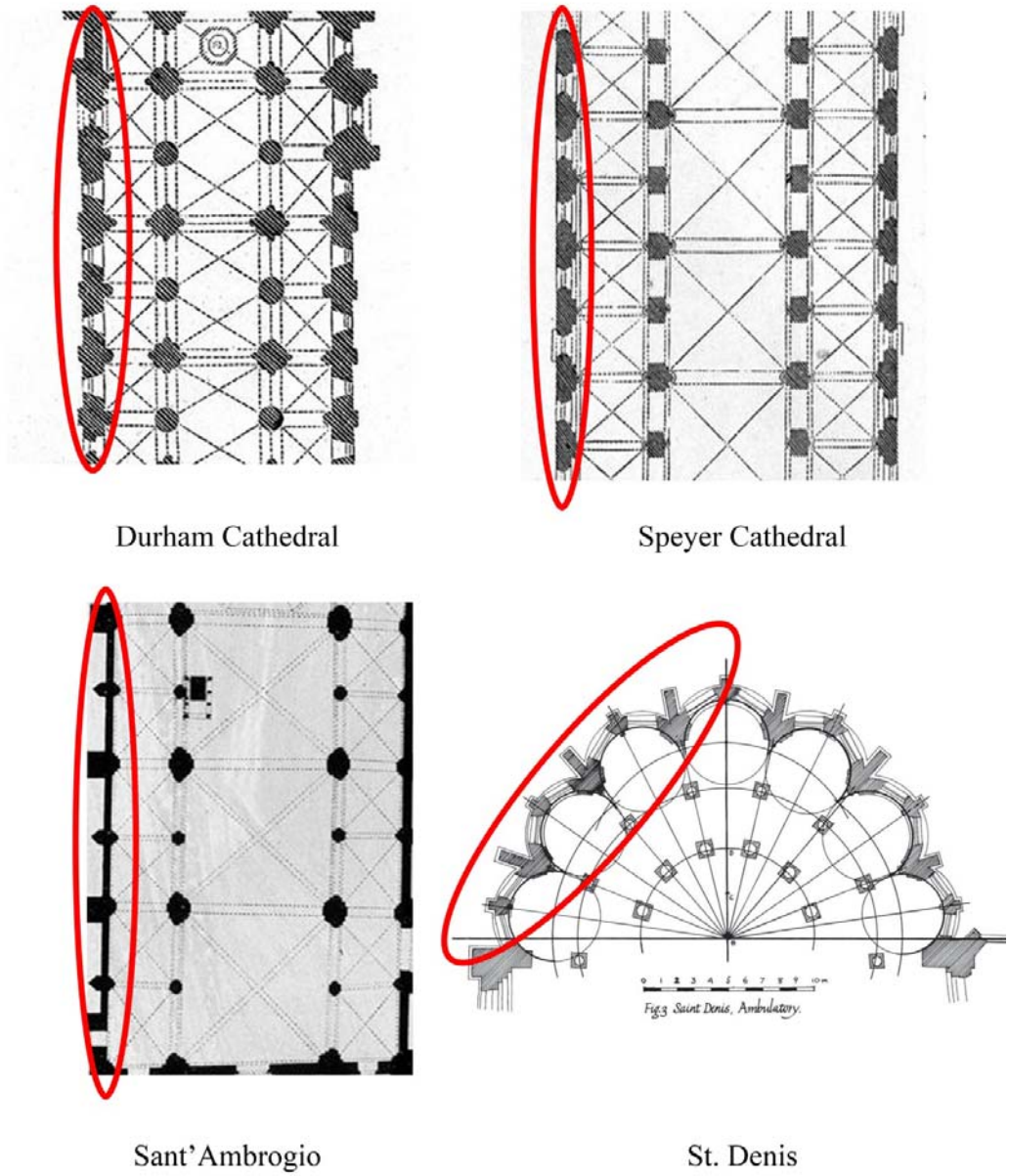


Figure 5.3 Four case study churches and their walls (St. Denis after Crosby 1966)

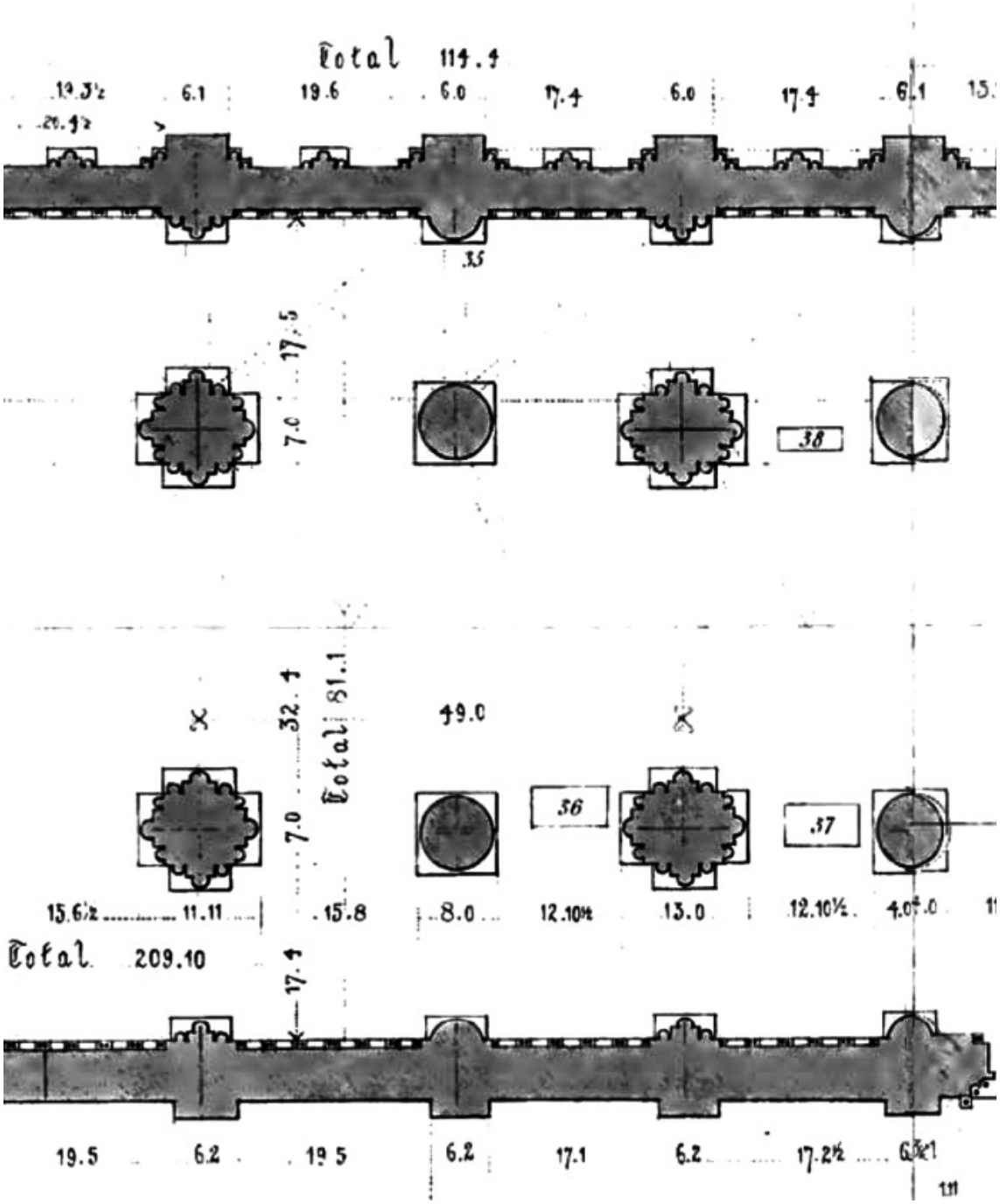


Figure 5.4 Detail of piers and buttresses in Durham Cathedral nave (from Billings 1843)

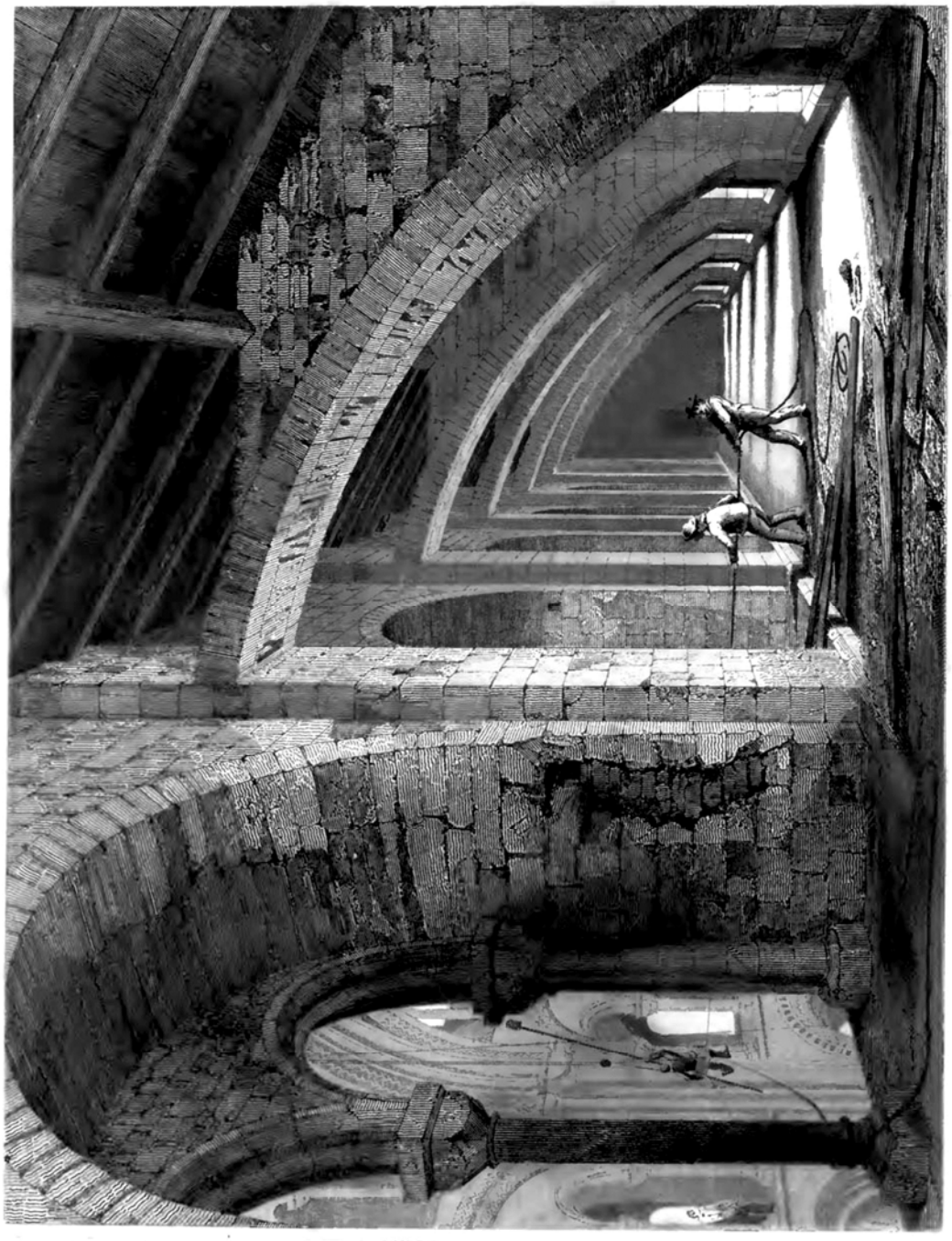


Figure 5.5 Durham Cathedral nave gallery interior (From Billings 1843)

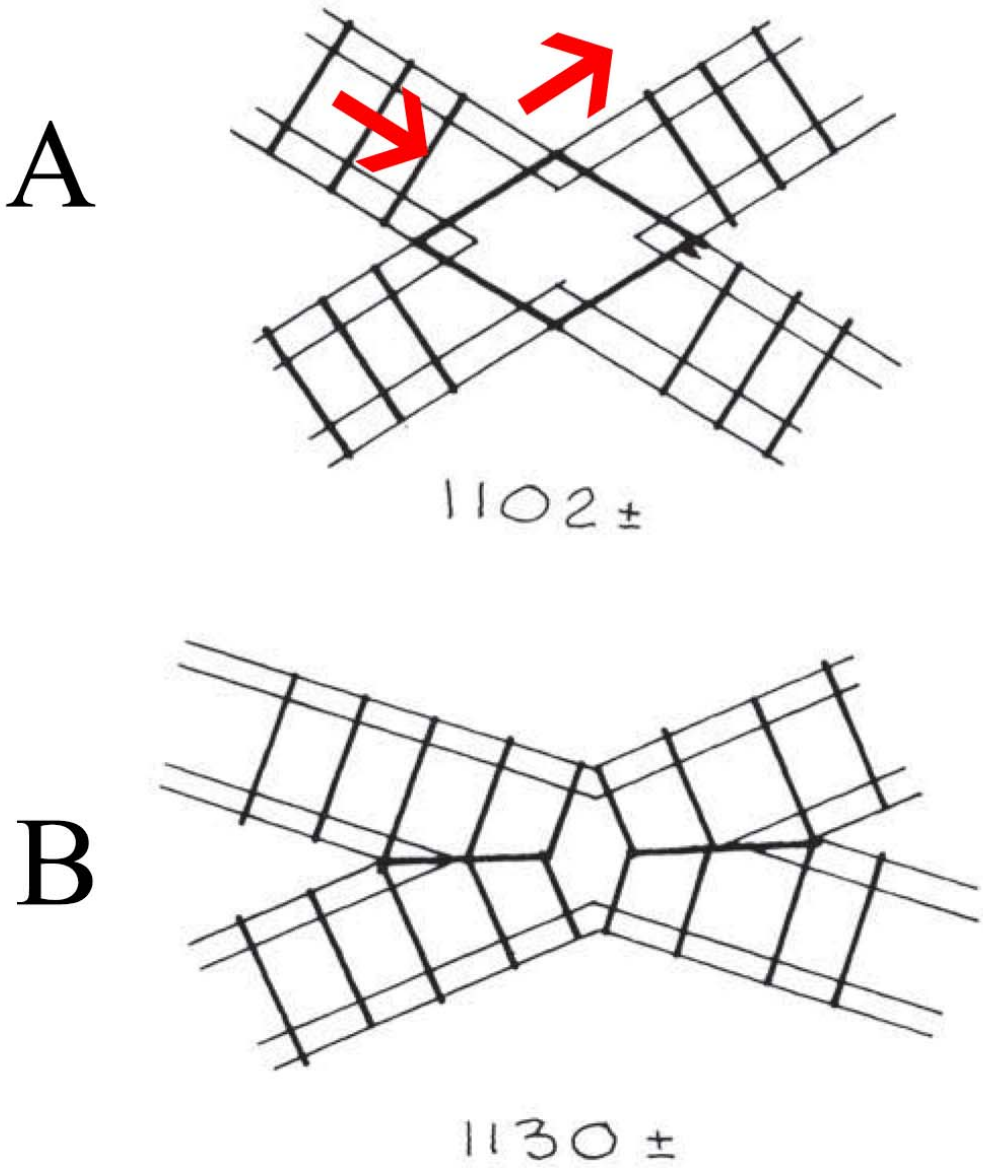


Figure 6.1 Nave bosses at Durham Cathedral with approximate dates of construction (James, 1983)

APPENDIX B

TABLES

Table 5.1 Distribution of Categorical Assignments for 5 Case Study Churches by the Elements of the Pier System

Church	Pier	Wall	Buttress	Form of buttress
S. Ambrogio	4	5	3	1
Speyer Cathedral	2	2	2	2
St. Étienne	3	3	1	3
Durham Cathedral	1	1	4	4
St. Denis	5	4	5	5

Table 7.1 Distribution of Categorical Assignments for 5 Case Study Churches by the Elements of the Pier System with Total Score

Church	Pier	Wall	Buttress	Form of buttress	Total score
S. Ambrogio	4	5	3	1	13
Speyer Cathedral	2	2	2	2	8
St. Étienne	3	3	1	3	10
Durham Cathedral	1	1	4	4	10
St. Denis	5	4	5	5	19

Table 7.2 Scored Assignments for 5 Case Study Churches by the Elements of the Pier System with Total Score

Church	Pier	Wall	Buttress	Form of Buttress	Total Score
S. Ambrogio	3	3	2	1	9
Speyer Cathedral	2	2	2	2	8
St. Étienne	2	3	2	2	9
Durham Cathedral	1	1	4	4	10
St. Denis	5	4	5	5	19