Medieval Islamic and Gothic Architectural Drawings
Masons, Craftsmen and Architects

Arash Etemad Yousefi
Bachelor of Architecture (2002)
University of Toronto

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Signature of Author ______________________________
Department of Architecture
May 18, 2005

Certified by ______________________________
David Friedman
Associate Professor of the History of Architecture
Thesis Supervisor

Accepted by ______________________________
Julian Beinart
Professor of Architecture
Chair, Department Committee on Graduate Students

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Names of Readers and the Principal Advisor:

Thesis Advisor: David Friedman, Associate Professor of the History of Architecture.

Reader: Erika Naginski, Assistant Professor of the History of Art.

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Abstract

As medieval designers and craftsmen have left us with no textual evidence of their thinking processes, their drawings offer valuable sources through which their approach to design and construction can be investigated. Focusing on the early architectural drawings of the medieval period, this thesis will explore the intersections between Late Gothic and Timurid architectural practices.

Both Timurid and Gothic designers were also skilled builders. Their education provided them with a good understanding of the pragmatics of architecture, while affecting the ways in which these individuals combined theory and practice to produce novelties in architectural form and style. Two 15th/16th century scrolls from Timurid Central Asia and the considerable number of Late Gothic drawings provide materials for a comparative analysis of Gothic and medieval Islamic design practices and the use of drawings. Beginning with a discussion of vaults, this thesis will examine the precise methods by which designers applied geometry in drawings to explore complex forms. The emphasis on intricate vaults in both Late Gothic and Timurid architecture attest to the similarities between these traditions, while presenting the opportunity to explore their differences. A consideration of the function of drawings in medieval design practices will lead in the second part of this thesis to a broad assessment of the profession of architecture in medieval Central Asia. The hierarchies within the building trades, the roles and responsibilities of designers and their education will be among the topics that will be discussed.

Thesis Advisor: David Friedman
Title: Associate Professor of the History of Architecture

MEDIEVAL ISLAMIC AND GOTHIC ARCHITECTURAL DRAWINGS

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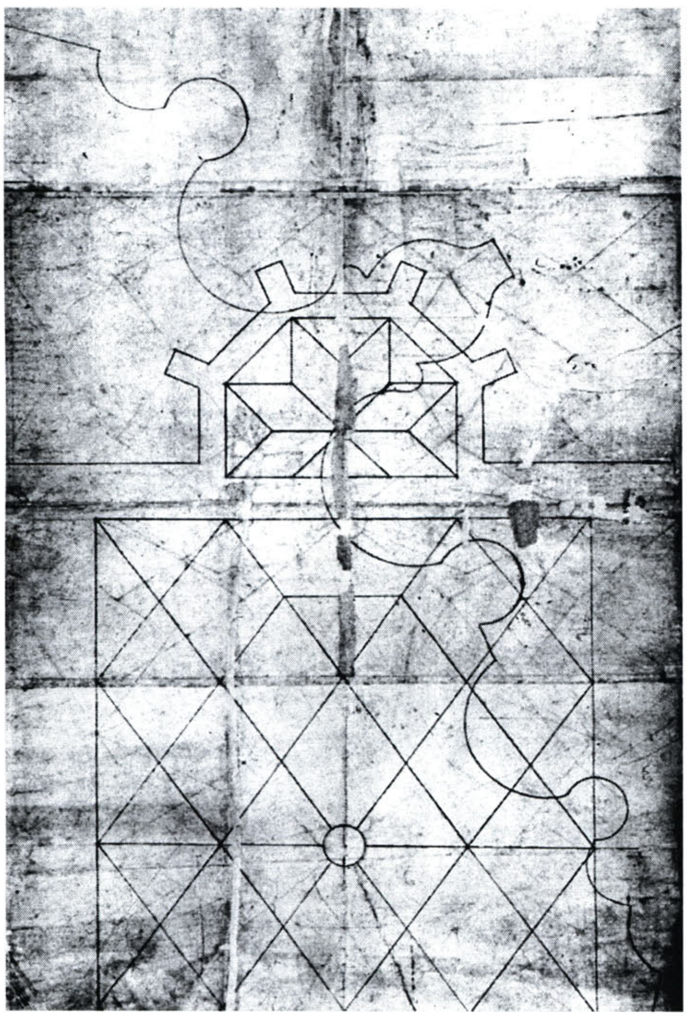

Arash Etemad Yousefi

To the memory of my grandfather, Gholam Hosein Etemad Yousefi

Contents

Introduction

The origins of architectural drawings as they reflect their applications in contemporary building practices can be traced to lodge-books and drawings made by medieval masons and master-craftsmen. While the organization of medieval guilds cannot be conceived as models for the structure of modern-day architectural firms, medieval architects and designers utilized architectural representations in much the same ways as contemporary architects do. The triad (plan, section, elevation) was in use during the medieval period; a fact that is proven by the multitude of drawings which remain from Gothic workshops. And, the drawings in Villard de Honnecourt's sketchbook attest to the similarities between early architectural representations and contemporary drawings.[1] As media through which both the conceptual and technical difficulties of design are confronted prior to construction, drawings justify their intervention in the practice of architecture. Furthermore, drawings reveal valuable insights into the thinking of their authors, an attribute that is extremely useful for cultures that did not leave textual descriptions of their design theories.

The scholarship of Islamic architecture is dominated by studies that focus on the power and influence of patrons, and the ways in which this authority translates into the construction of their monuments. This trend in scholarship, which is ultimately a consequence of the scarcity of sources which convey the thought processes of the craftsmen, seldom reveals the medieval design methods and processes of construction.[2] When there has been such evidence, such as the treatise by the mathematician Kashi, this material has been dismissed as "exceptional" and not relevant as accurate representation of architectural practice.[3] Consequently, the procedures by which buildings were

[1] One drawing in Honnecourt's 13th century sketchbook shows a section through the exterior wall of the Reims cathedral, showing the buttresses in elevation. Except for a few glitches, one can see that the idea of a sectional drawing is fully embodied in this illustration, in which the relationship between elements that are shown in elevation and those that are cut in section are clearly articulated at the point where the wall meets the mullions. Illustration is in *Origins, Imitations and Conventions*, p. 37.

[2] L. A. Mayor's words, written in the 1950s still haunt the works of most scholars: "Because of the scarcity of detailed day by day local chronicles, lack of personal diaries, guild accounts, contemporary treatises on technical matters ... the history of Islamic architecture will remain up to a point anonymous." *Islamic Architects and Their Works*, p. 29.

[3] This has been the basic sentiment towards Kashi's work. Michael Rogers's warnings are typical: "How far was this prescriptive and how far a commonplace example to explain a series of mathematical functions? Kashi was certainly not an architect, nor can mastery of such mathematical functions have been

designed and constructed, the responsibilities of architects and the various phases through which buildings evolved from a schematic design stage to construction, have remained primarily as speculative endeavors.

In this thesis, drawings from two 15th/16th century scrolls will be examined in order to understand medieval Islamic theories of design and construction. The large collection of Late Gothic drawings that remain as testimonies to their authors' advanced understanding of drawing methods provide material for a comparative analysis of Gothic and medieval Islamic architectural practice and the use of drawings in design. The close connections between Late Gothic and medieval Islamic architectural design and practice have been discussed in Gulru Necipoglu's seminal work, *Topkapi Scroll: Geometry and Ornament in Islamic Architecture*. The strictly two-dimensional character of Gothic drawings is a distinct mark of their age, and can be identified as the primary connection between Gothic architectural representations and Islamic drawings. While Necipoglu's text provides valuable information about the conception of medieval Islamic building methods, this thesis will question her premise which assumes a direct correlation between Late Gothic and Islamic building practices.

Muqarnas and its representations within Timurid scrolls present both substantial graphic and architectural material through which the relationship between developments in architectural form and drawing methods can be investigated. As no textual or graphic evidence explains the ways in which the masons transformed the two-dimensional layout of muqarnas projections into three-dimensional forms, muqarnas drawings are specially tantalizing sources for exploring medieval Islamic geometric knowledge. Parallel to Islamic architectural representations are the drawings of Late Gothic masons, whose obsession with vaults is manifested in their works. The stage at which drawings were introduced into processes of construction, the relationship between form and its two-dimensional representation, and the use of geometry by masons to transform drawings into architectural elements, are some of the themes that will be explored in an analysis of muqarnas and vault constructions in Islamic and Late gothic architectural practices.

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as essential part of the architect's training." Review of *Timurid Architecture in Khurasan* by M. Rogers (1989), 134-35.

A consideration of the function of drawings in architectural practice will bring us to a broad assessment of the profession of architecture in medieval Central Asia. The hierarchies within the building trades, the role and responsibilities of architects and designers, and their education will be among the topics that the second chapter of this thesis will address.

As literary and graphic sources do not yield any substantial evidence that asserts the primacy of architects within Timurid building practices, the identity of individuals responsible for innovations in architectural form will pose compelling questions. These questions bear directly on deciphering the authorship for the large collection of architectural drawings which remain from Timurid workshops, beginning from the 15th century. Are these drawings the work of master-craftsmen and architects or were they made by a separate crew of draftsmen, working in environments in which no contacts with the rules and regulations of construction or onsite experience were necessary? Could the plan drawings have been the work of clerks, and muqarnas drawings made by stucco-workers? The search for the identity of the authors and their professional rank also questions the status of their drawings as "architectural drawings." Certainly, such drawings as those included in the Topkapi and the Tashkent scrolls were made by individuals who understood the processes and complications of architectural design as this can be seen in the graphic modes used within the drawings. This thesis emphasizes the intersections between the roles of craftsmen, the clerks, their supervisors, and broadly asserts the primacy of crafts within medieval Islamic building traditions.

Chapter One

The Design and Construction of Vaults

Late Gothic and Medieval Islamic Architectural Drawings

The most commonly represented architectural element found within medieval Islamic graphic sources is the muqarnas and its many variations. In these sources, muqarnas is always rendered in an orthogonal plan view in which the tiers of the vault are collapsed into one plane. That so many representations of these vaults exist is surely a factor of their complexity. Characterized by their intricate web of interlocking stars and polygons, the muqarnas vaults of Timurid buildings would not have materialized had not the medium of drawing made it possible for their formal difficulties to be first resolved on paper.

In a recent publication entitled, *The Topkapi Scroll: Geometry and Ornament in Islamic Architecture*, Gulru Necipoglu analyzes the drawings of a 15th century scroll, in which more than half of the drawings illustrate muqarnas and other vault projections. In her all-encompassing study, Necipoglu interprets the Topkapi drawings as they reflect aesthetic, practical and ideological aspects of their time and the culture that produced them. That Necipoglu's efforts are nothing short of monumental is proven by her insistence to include in her treatment of the Topkapi drawings an extensive and seemingly unrelated set of themes; an effort which surely would require a mastery of a vast literature, including philosophical and scientific texts from medieval Islam. Specifically relevant to the discussions of this essay are the first three chapters of her book, in which she discusses the drawings of the Topkapi scroll as "Mirrors of the Timurid-Turkmen architectural practice." In these parts, Necipoglu concentrates on the practical training and the professional role of the medieval Islamic architects. Her work leads her to stress the close connections which unite Late Gothic to medieval Islamic architectural practices.

She begins by analyzing Gothic and Islamic architecture at the macro level. Recognizing parallel evolutionary processes within their architectural development, Necipoglu states: "Both the Late Gothic and the late Timurid-Turkmen architectural idioms evolved from structural innovations that were eventually transformed into elaborate decorative sophistications, and a shared preoccupation of increasingly elaborate vault patterns and details."[4] Examining practical mathematical texts which were especially made for the use of the medieval Islamic craftsmen, Necipoglu assesses the basic geometrical education of the average builder which constituted of their familiarity with a "graphic" form of geometry. Identifying similar geometric texts in Europe, she concludes that Gothic masons were educated and employed design methods which highly resembled those of their Islamic counterpart. A section on vaults reinforces Necipoglu's thesis.

In an attempt to explore the applications of drawings in medieval design and construction, this chapter will study the drawings of vaults made by Late Gothic and medieval Islamic craftsmen and builders. As the most recent and thorough analysis of Islamic drawings, the work of Necipoglu will serve as a framework for both understanding this topic, while questioning the premise which assumes completely parallel patterns in Late Gothic and Timurid architectural practice and design.

Although it is difficult to capture in precise terms Necipoglu's arguments, a close reading of her text will highlight some of the major themes of her discussion: First, her analysis of medieval drawings asserts the predominance of plans in both Gothic and Islamic collections, and goes on to emphasize the strictly two-dimensional geometric operations which govern the design processes in both traditions. Second, she identifies "the direct translatability of drawings from plans to elevations" as a dominant trait within both Islamic and Late Gothic architectural drawings.[5] This allows her to justify for the lack of elevations in Islamic sources. She states: "the need for precise elevations was reduced within both Gothic and Islamic building traditions," since vault forms could be easily constructed from plans. She assumes a linear relationship between the representation of a vault as a plan drawing and the three-dimensional reality of a vault, which involved translating the plan into its complex shape. Third, similar methods of projecting vaults were employed by Gothic and Islamic builders, as in both their drawings multiple levels of space were frequently collapsed onto a single plane. Necipoglu elaborates:

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[4] *The Topkapi Scroll: Geometry and Ornament in Islamic Architecture*, p. 42; from here onwards referred to as *Topkapi Scroll.*
[5] Ibid, p. 43.

> Topkapi scroll shows that a similar process (to Gothic practices) of projecting spatial forms from two-dimensional templates was at work in Timurid-Turkmen architectural practice ... Elevations (of vaults) were often deduced by means of geometric procedures from ground plans, as was common practice in the Gothic building tradition. Through methods of parallel projection multiple levels of space frequently were collapsed onto a single drawing just as two-dimensional designs were projected onto walls and vaults by means of imagined parallel rays.[6]

Necipoglu underlines one of the most significant characteristics of Late medieval architectural drawings in which a two-dimensional mode of operation dictates the conception and representation of space. However, the assumption that Late Gothic and medieval Islamic representations of vaults testify to the same methods of projections can be questioned through drawings and sources that explain the construction of vaults.

While "deducing (the projection of a vault) by means of geometric procedures from ground plans," was common to both Islamic and Gothic builders, a close examination of late Timurid and Gothic drawings reveals fundamental differences in both the formal character and the exact geometric methods employed by masons and craftsmen working within each tradition. The distinctions can be established both at the conceptual level, when a design for a three-dimensional vault was first imagined in the mind of the builder, and also at a technical level, when the craftsmen struggled to represent them. The precise methods by which craftsmen within each tradition extrapolated the three-dimensional forms of vaults further emphasize the differences between Gothic and Islamic applications of geometry in the design of vaults.

The discussion of Gothic vaults can be expanded by considering the relationship between Late Gothic drawings and their translation into doubly curved ribs, which characterize the Late Gothic architecture of Northern European buildings. The geometrically elaborate fan and lierne vaults of Gothic buildings in England will provide further evidence for understanding the geometric methods of Late Gothic designers. Characterized by their stereometric complexities, the construction of vaults in Late Gothic English buildings forms a whole other category of design techniques and application of geometry. Although no drawings remain from English lodges, an examination of architectural evidence reveals their builders' methods. As this essay will

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[6] Ibid. p. 43.

show, extrapolating the three-dimensional composition of a Late Gothic vault from its plan required geometric exercises which differed from the simple, "linear (and one-directional) projection" methods used by Islamic builders. We will begin by reconstructing a conceptual basis for the muqarnas and will move on to analyze the Late Gothic vault.

Muqarnas

Muqarnas drawings are strictly limited to the representations of their plans. One drawing from the Tashkent scroll can be analyzed to highlight the two-dimensional logic which governs the construction of a muqarnas plan (fig. 1). Contained within a square frame, this muqarnas is distinguished by its varieties of star patterns. It consists of a quarter of a vault with multiple tiers of star-shaped units, which emanate from a fan-shaped stellate hood. Traditionally, symmetrical muqarnas quarter vaults were mirrored along their borders to produce full or half vaults. The full vault would be ideal for a domed space, while half vaults appear in arched portals, iwans, and niche-like recesses such as mihrabs. In this example, the asymmetrical composition of the drawing along its frame borders indicates that the quarter unit was not intended for a full vault. The underlying geometric order of the drawing becomes visible when the center and the radii, according to which the stars and polygons are arranged, is drawn, as can be seen in a comparable example from the Topkapi collection (fig. 2).

The strictly two-dimensional logic of a muqarnas drawing is emphasized by its graphic notations and layout. The only features that signal the three-dimensional extension of the two muqarnas drawings, mentioned above, consist of their fan-shape organizations and the combined use of color coding and stippling to differentiate height relationships within the tiers. While the rays that organize the components of the muqarnas – which only become visible with the drawing of their geometric grids – can be understood as integral parts of the two-dimensional order of its plan, they do not indicate that the muqarnas is a three-dimensional element. Neither the modulation of the muqarnas, nor its break-down into cellular units function as enough to communicate the spatial extension of these drawings. As can be seen in the Tashkent scroll muqarnas, the cells of one group of stars retain consistent dimensions throughout (fig. 1). The fan-shaped distribution of the plan, which would suggest that a change of scale in the two-dimensional plane of the drawing would produce smaller units towards the apex with larger cells at the base, does not occur. To someone who has not seen a muqarnas and is unfamiliar with its drawing codes, the plan of the muqarnas remains as a flat composition, unyielding to the three-dimensional reality of their final execution as stalactite vault forms.

The geometric operations that produce a muqarnas plan are based on the rules of "constructive geometry" – the branch of geometry with which the medieval masons were supposedly familiar.[7] While Islamic texts on practical geometry offer no examples of muqarnas, drawing the plan of a muqarnas is related to exercises in constructive geometry. This is manifested in the geometric identity of the individual units that comprise the modular structure of muqarnas. When deconstructed into its basic geometric components, a muqarnas plan is composed of basic geometric shapes. The various kinds of Stars and polygons that make up a muqarnas could be construed based on guidelines that texts such as al-Buzjani's *'Amal-e Handasa*, demonstrate.[8] That these medieval manuals offer no direct instructions on the construction of the muqarnas implies that muqarnas forms had developed independently from the theoretical framework that these geometric manuals create for them. Devising an accurately designed muqarnas was another matter, and mathematicians often complained about artisans who were reluctant to adopt precise methods for their designs.[9]

The connections between muqarnas constructions and two-dimensional designs for decorations are discussed by Necipoglu. She explains the formation of the muqarnas as a natural extension of exercises in two-dimensional tile patterning:

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[7] A considerable literature has questioned the medieval Islamic masons' and craftsmen's knowledge of geometry. While some scholars, (Michael Rogers for example), entirely denounce any possibility of access that the medieval Islamic craftsmen and architects had to geometric texts, others (most emphasized in Wasma Chorbachi's writings) believe that medieval Islamic builders were familiar with such books. The latter's view is supported by a number of textbooks specifically addressed to artisans.

[8] Two practical geometries remain from medieval Islamic period. The first is a tenth century book written by Abu al-Wafa' al-Buzjani, and entitled *Kitab fima yahtaju ilayhi al-sani' min a'mal al-handasa* (About that which the artisan needs to know of geometric construction). The second is a tentatively 14th century text entitled *Fi tadakhul al-ashkal al-mutashabiha aw al-mutawafiqa* (On interlocking similar or congruent figures), and written by an anonymous author.

[9] Buzjani states in his introduction: "I know that artisans (*sunna'*) construct figures in round forms unmethodically ... In order to create fine works, the artisan has to quite working by the eye-measure. Instead, he must determine the dimensions of sides of the pentagon, hexagon, decagon, or other figures as we explain in this book."

> The regular division of space into similar and congruent three-dimensional cells, or space tilings, was a natural extension of experiments with plane tilings. Just as the simplest orthogonal muqarnas compositions exhibit an affinity to two-dimensional surface patterns generated by rectilinear grids, the far more complex radial muqarnas projections of the Topkapi and Tashkent scrolls can be read as spatial interpretations of two-dimensional patterns with interlocking stars and polygons. Extending the idea of filling a plane with congruent stars and polygons into three dimensions must have been a natural outcome of exercises in practical geometry and mensuration manuals, which proceed from construction in the plane to constructions in space.[10]

Similar to the design of a muqarnas, the organization of a Late Gothic vault began with the construction of its plan. The arrangement of this vault was often based on simple geometric exercises. The basic constructive methods, which involved the rotation of modular squares and polygons to determine the location of the ribs of a vault, had by the middle of the 13th century become standard design methods employed by Gothic masons throughout Europe.[11] Preserved at the Vienna museum (ABK. 17 065), one drawing illustrates at a schematic level the design for the Rider's stair, later to be constructed by the famous architect Benedikt Reid (figs. 3 and 4). While this drawing is a sketch, it is significant to note that it has been constructed with the aid of a compass, emphasizing the strictly geometric character of Gothic buildings. In this drawing, sixteen segments of arc (with one radius) determine the location of the ribs. What is not apparent at a first glance is the location of the centers of the arcs. However, as the arcs are drawn as full circles, their intersection then determine the centers of the next series of arcs. The drawing is a sketch which illustrates the main locations of ribs and would still require other drawings to determine precisely the type of stones that would be necessary to complete the construction.

The medieval drawings of vaults, such as the Rider's stair and the many patterns which describe muqarnas in Islamic sources, however, were not intended to remain as two-dimensional elements within buildings. Muqarnas drawings characterized by their complex array of star and polygonal shapes were ultimately transformed into spatially complex stalactite vaults, an example of which can be seen in the portal muqarnas at Taqi al-Din Dada shrine complex located in Bonderabad (c. 1473, fig. 5). Similarly, Late

[10] *Topkapi Scroll*, p. 173.
[11] *Actes Du XXII Congress International D'Histoire de L'Art* 1, p. 528.

Gothic vault drawings only partially communicate what the final result of their constructions entailed. The drawing of the Rider's Stair produced a fully three-dimensional vault as can be seen in one illustration (fig. 6). It is precisely through an examination of the procedures and methods of transforming a two-dimensional representation of a muqarnas and a drawing of a Late Gothic vault into their three-dimensional forms that differences between Islamic and Gothic examples are revealed.

The strictly two-dimensional language of muqarnas drawings, coupled with the lack of other forms of representation limit our knowledge of medieval Islamic building traditions. In an attempt to understand the system of muqarnas projections, two sources outside the realm of the craftsmen's drawings provide relevant information: the work of one Russian scholar, who discusses the construction of muqarnas based on his observations of a contemporary builder's techniques in Uzbekistan; and a rare treatise on practical arithmetic, written by a 15th century mathematician, in which a section on the calculation of the muqarnas concludes the text.

A longtime enthusiast in the arts and crafts of Central Asia, Iosif I. Notkin's articles on architecture address the design and construction of muqarnas as it was practiced by medieval Islamic craftsmen. While most of his work remains inaccessible to English readers, a few are translated or summarized in the work of other scholars. His analysis gain special credence since Notkin visits a contemporary Uzbek master-craftsman, Ustad (master) Shirin Muradov (1880-1957) who still practices according to traditional methods.[12]

In order to unravel the conceptual and technical complexities of the muqarnas, Notkin begins by reconstructing a muqarnas drawing which he found within the Tashkent collection.[13] Notkin's efforts confirm that the construction of an intricate muqarnas drawing usually involved a level of approximation, which had to be accounted for as muqarnas units were delineated at full-scale before their assembly. Notkin comes to this realization only after his attempts at locating a perfect geometric model for the muqarnas meet with failure. He notices, "deviations (of some of the cells) from the organic

[12] Notkin asserts little change in the structure of muqarnas in the last five centuries. This implies that the work of contemporary practitioners still preserve the traditional methods of the builders. *Muqarnas* 12, p. 151. See below for further investigation of this theme.
[13] *Muqarnas*, vol. 12, pp. 148-171.

coordination of the successive rows and the appearance of atypical elements, where the corbelled tiers were connected to the façade of the building."[14] He also observes that, "often the stars remain disconnected, as if to offer the reader the opportunity to interpret them in several possible ways." His analysis shows that the kite-shaped cells, resembling rhombuses, acted as fillers whenever geometrical difficulties interrupted the perfect order of the muqarnas.

In the Tashkent muqarnas drawing, the manipulation of the units of muqarnas can be seen in the spaces between the rows of stars that are organized according to the major radial axis (fig. 1). The left-over spaces in between the major axis were often filled with polygons that best fitted the spot and sometimes vary at different location within the drawing. The tendency of the Islamic builders to determine the final design of muqarnas at the site of construction is also noted by Necipoglu. Echoing Notkin's discoveries, she differentiates between design elements that are fixed, and the filler units which are loosely arranged and may have been decided upon as last-minute design choices. She elaborates: while in "the fan shaped stellate hoods, the first rows of muqarnas units attached to the hoods, and the circular orbits of stars obey a rigid geometry, the spaces in between the stars and along the outer edges of the repeat units are often completed with polygonal or small prismatic filler units whose less precise geometry would allow them to be adapted to the varying profiles of arches during construction."[15] Despite the difficulties of the muqarnas, it is still noteworthy that their builders strived for accuracy, while viewing "approximation" as a sign of bad craftsmanship. Posing the muqarnas as a riddle, an inscription diagonally placed on the surface of a muqarnas drawing from the Tashkent collection reads (fig. 6):

> May it be known to the friends who are practitioners of this craft [art] that in counting this muqarnas it is necessary to pay careful attention so that you may know about it as it ought to be and not think that this [fellow] has made a mistake.[16]

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[14] Ibid, pp. 151-152.
[15] *Topkapi Scroll*, p. 236-237.
[16] *Muqarnas*, vol. 12, p. 153. Translation by W. M. Thackston.

Perhaps the most revealing section of Notkin's analysis is a passage that describes the practice of the craftsman as he prepares the plaster slabs that constitute the structure of a muqarnas.[17] Notkin's description is elaborate:

> On the floor under the prospective muqarnas vault, a plaster slab was constructed, known as *takhmim* (Arabic for approximation), on which a full-scale working sketch of the muqarnas vault was scratched. On this two-dimensional pattern, where the edges of each muqarnas row were indicated with lumps of clay or ceramic bars, plaster plates of alternating two- and three-centimeter horizontal thickness were cast for all the tiers of the vault. These plates (constituting shelves parallel to the floor) were bonded to the wall and to the vault with plaster and, if necessary, were supported by wooden struts that bore their weight. Correspondence to the plan on the *takhmim* was verified by plumb-line. Thin vertical plates provided additional structural strength to this construction. The plates were created between the corbelled horizontal layers of shelves according to the plan indicated on the *takhmim*. On this skeletal framework, rendered with quick-drying plaster, a thin, hand-made carving of muqarnas cells was executed which fitted into the spatial grid of the horizontal and vertical openings, forming a unified whole.[18]

Three pictures illustrate Notkin's description, while showing the significant stages within the construction of muqarnas. Illustrated in one picture are the shelves that are cut out and made to lie on a drawing of a muqarnas that is scratched on the plaster slab (fig. 8). While the outer edges of the slabs, representing the work surface, were determined by the jagged contour of the drawings, their backs had to be adjusted in relation to the curving surface of the squinch, so that the muqarnas plates retain the proper offset distance in order for the next slab to be properly accommodated. Another picture illustrates the triangular zone of the squinch that is equally divided by the horizontal shelves, determining the vertical module of the muqarnas (fig. 9). The next picture shows the craftsman at work, carving the individual muqarnas cells which fill the vertical gaps between the projecting shelves (fig. 10). Two archaeological remains emphasize the purely decorative character of the muqarnas, while giving credence to Notkin's statement that the construction of the muqarnas followed the same rules in Timurid Central Asia as

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[17] The laying out of the muqarnas on the stucco floor at full-scale bears some resemblances to the Gothic techniques of drawing profiles of templates, also at full-scale on the floor of their workshops. However, the Gothic template and the muqarnas plates are two different phenomena and cannot be seen as entirely similar. The template drawings of Villard de Honnecourt, which will be discussed in the following chapter, attest to the differences.

[18] *Muqarnas*, vol. 12, p. 151.

it does today.[19] One is the Madrasa (with mausoleum) of Saray Mulk Khanum in Samarqand (1397) in which the muqarnas in the central chamber is shown to be suspended from the brick core of the building (fig. 11). Another example is the Masjid-i Jami in Ardakan (second half of 15th century), in which the partly damaged muqarnas in the semi-dome reveals its supporting structure (fig. 12). To the left of this picture can be seen the remainder of a damaged horizontal plane that supported one of the lower tiers of the muqarnas.

The illustrations in Notkin's document reveal the character of the muqarnas, while emphasizing the differences between these vault-forms and the Gothic vault. The structural logic of the muqarnas is dictated by the horizontal planes that create the tiers. Notkin discovers the importance of the horizontal tiers when trying to reconstruct a muqarnas drawing. He also recognizes the most difficult part in reconstructing a muqarnas "determining the boundaries of the corbelled tiers which reflect the spatial conception of each sketch."[20] He elaborates: "At times three or four tiers can be counted simultaneously, leading to ambiguous situations (for example, the sloping kite-like units at the junctures of the rows become vertical rectangular plates which are not always marked on the plans.)"[21]

In their attempt to decipher the formal logic of the muqarnas, most studies have stressed the plan geometries of these elements. This approach stresses the geometric grids that structure the plan of a muqarnas. The understanding of muqarnas based on their plan geometries can be seen in the last section of Necipoglu's text in which Topkapi drawings are classified according to their geometric order (fig. 2).

While identifying the grids within a muqarnas plan yields important clues about the two-dimensional construction of its drawing, such analysis reveals at best a partial – if not a misleading – understanding of the character of the muqarnas and its methods of construction. The radial grids that organize the muqarnas plans of the Topkapi and Tashkent drawings provoke a visual impression that emphasizes a sense of vertical

[19] In Timurid architecture, decoration was for the first time entirely pulled apart from the structural core of buildings. While in Seljuq architecture muqarnas could be understood as a structural feature, in Timurid period it was transformed into props superimposed on the brick core of buildings. As the decorative character of muqarnas increased in the Timurid period, where muqarnas was primarily built with stucco, so did its formal complexity.

[20] *Muqarnas*, vol. 12, p. 151.

[21] Ibid.

continuity within the composition of these elements. This is contradictory to the conceptual basis of the muqarnas, whose tiers essentially have a horizontal order. What is obscured in these renditions is the tier-based spatial organization of the muqarnas, whose contours become lost in the heavy thicket of lines that define the geometries of individual units. The conflicting relationship between the vertical rays and the horizontal character of muqarnas can also be seen in the technical difficulties which are embodied in its construction and which involve distinguishing the place at which each tier is separated from another and the height of this difference. For this reason, the graphic symbols of stippling and color coding become very important tools for both communicating the spatial logic of the muqarnas as well as understanding its conceptual basis.

Conspicuously absent from early collections of Islamic architectural drawings are representations of elevations. While the absence of such drawings can be unjustifiably explained as the lack of forethought and capability of their craftsmen to understand and utilize this mode of representation, a better explanation is that such drawings were not seen as essential to the processes of design and construction in medieval Islam. In a contrasting manner, the heavily sculptured character of Gothic structures required their builders to make many elevations of the buildings, through which they coordinated different parts of the facades. Gothic examples of elevations are abundant. The elaborate nature of these drawings can be seen in two partial elevations of Strasbourg Cathedral dated to the 14th century (fig. 13). While Gothic masons did not represent vaults as fully detailed section drawings, they nevertheless drew profiles of vaults as sketches, according to which they then calculated the spatial relationships between the critical points in the plan. That no such drawings survive from the medieval Islamic period emphasizes the differences between design patterns and use of drawings in Islamic and Late Gothic architectural traditions.

The absence of drawings that demonstrate the vertical projections of muqarnas still begs the question: Does the construction and conceptual structure of the muqarnas imply an order that completely rendered the depiction of their vertical profiles as unnecessary? Necipoglu suggests that elevations were used by Islamic builders: "elevations (or sections of vaults) were often deduced by means of geometric procedures from ground plans, as was common practice in the Gothic building tradition."[22] The illustration of the craftsman in Notkin's article asserts the intuitive character of medieval Islamic building practices as the craftsmen is shown to be sculpting the vertical modules of the muqarnas tiers which he has already outlined through a series of horizontal templates. Whether any standard methods existed for the construction of the vertical module cannot be known from the drawings. The only textual source in which the construction of the muqarnas is described is a 15th century treatise, written by mathematician Ghiyath al-Din Jamshid Mas'ud al-Kashi's (d. 1429). This document provides a unique description of the ways in which the vertical module of the muqarnas was constructed.

In the third and last section of Book IV of his treatise, entitled *Key of Arithmetic* (*Miftah al-Hisab*), Kashi explains the procedures for calculating the surface area of a muqarnas module.[23] This segment of Kashi's text emphasizes the distinctly modular character of the muqarnas, while shedding light on the conceptual and verbal skills of its author whose occupation as a mathematician surely influenced his interpretation of space and forms. Kashi's calculation of the muqarnas begins by defining the muqarnas:

> The muqarnas is a roofed [*musaqqaf*] (vault) like a staircase [*madraj*] with facets [*dil'*] and a flat roof [*sath*]. Every facet intersects the adjacent one at either a right angle, or half a right angle, or their sum, or another than these two. The two (facets) can be thought of as standing on a plane parallel to the horizon. Above them is built either a flat surface, not parallel to the horizon, or two surfaces, either flat or curved, that constitute their roof. Both (facets) together with their roof are called one cell. Adjacent cells, which have their bases on one and the same surface parallel to the horizon, are called one tier [*tabaqqa*].[24]

Next in his description, Kashi identifies "the measure of the base of the largest facet," as the "module (or as *miqyas* in Arabic) of the muqarnas." He uses this definition in the mathematical procedures which he outlines for calculating the surface of the muqarnas.

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[22] *Topkapi Scroll*, p. 42. The clarification in the brackets is mine.

[23] According to Dold-Samplonius's summary, Kashi's text can be understood as an encyclopedia of elementary mathematics intended for everyone. Arithmetic is seen as the key to solving all problems which can be reduced to calculations. Chapter nine of the last book entitled *On Measurements*, includes the section on muqarnas. It has three parts: measuring the Arch and the Vault, measuring the Qubba (dome), and measuring the muqarnas. The oldest extant copy of the manuscript is dated 965 H. (AD 1557/8). *Centaurus*, vol. 35, pp. 193-242.

[24] All quotations of Kashi's text have been taken from Dold-Samplonius's translation of this text. *Centaurus*, vol. 35, p. 226.

Kashi also uses this term to classify four types of muqarnas whose complexities distinguishes one type of muqarnas from another: "The Simple [*sadhaj*] muqarnas, which the masons call minbar-like, the Clay-plastered one [*mutayyam*], the Curved one [*muqawwas*], and the *Shirazi*."[25]

Not only does Kashi's definition of the muqarnas and its four types give a sense of the medieval mind, it also conveys the strictly modular character of these vault forms which defines their essence. By both referring to the "tiers" of the muqarnas and the analogy which he draws between the muqarnas and a staircase, Kashi also emphasizes the horizontal order of these elements. Towards the end of his analysis, Kashi describes the way in which the craftsmen (or the masons as he calls them) determine the outline of the vertical module that are placed in between the horizontal layers of the muqarnas (fig. 14):

> You should know that the masons draw a rectangle, whose width is equal to the module of the muqarnas and whose length is twice the width, like rectangle ABGD. They draw from one of its angles, angle A for example, a line AE, such that it contains together with AB an angle equal to one third of a right angle (that is make BAE equal to 30 degree). Then they divide AE into five sections and mark EZ from point E equal to two of its sections and EH also equal to EZ. They draw two (circular) arcs around the two points Z and H with radius ZH, which intersect inside the rectangle at point T. Then they draw the (circular) arc ZH around point T, which is without any doubt equal to one sixth of the circumference.
> They produce the two lines DA and DG (and extend them) by a small amount until the points Y and L, and draw LK parallel to BG and YK parallel to AB. Thereupon they construct many panels [*lauh*] of gypsum [*jiss*], such that each one of the them corresponds to the surface KYAZHGL with ZH as an arc, and put each two of these around one cell, such that the side GH is perpendicular.[26]

Kashi's text reinforces Notkin's conclusion that the construction of the muqarnas involved a degree of approximation by their masons. In order to ensure that the varied elements of a muqarnas could be fitted together, the final resolution of the vertical module occurred while the muqarnas was under construction. After introducing the "coefficient" according to which the surface of the muqarnas modules could be arithmetically calculated, Kashi concludes:

> Sometimes they (masons) shorten or lengthen the foot of the panel, i.e. line GH. They need to do this, when they put it behind the arch [*taq*], in order that it fits.

[25] *Centaurus*, vol. 35, p. 226.
[26] Ibid., p. 232.

> Thus for measuring similar cases it is appropriate to decrease and increase the coefficient with the amount that was decreased or increased from the foot of the panel.[27]

Gothic Vault

In order to understand the design of Late Gothic vaults, we will have to determine the ways in which plans were utilized to extrapolate their sections. The projection of the Late Gothic vault from its plan to section involved determining the length of the longest rib (or the sequence of ribs) within the composition of the vault. The next step was drawing the principle arc of the rib. Drawings were absolutely necessary for these calculations:

> The vault system in the late 14th cent. required a precise and fool proof projection method which would provide for an exact determination of the lengths of ribs positioned at different angles (and meetings at random locations in space). Only with such a system was the erection of vaults feasible in which numerous elements springing from different levels could be pre-cut and joined easily.[28]

As Francois Bucher has asserted, it was the continuity of the ribs and their meeting at random locations in space that presented the Gothic masons with the greatest difficulty. Bucher discusses the relationship between the plans and sections of vaults in his examination of the drawings of a late 15th century codex (1544-67) identified as the Dresden Sketchbook. The vault plans depicted in this codex are delineated with the profile of their principle arcs. The principle arc of the Gothic rib is defined as the single radius that determines the curvature of all ribs. It was to determine this radius that the procedures outlined below were essential.

Represented on folio 10 of the Dresden codex is the plan of a simple vault. Drawn above it, is the projected profile of its principal arc (fig. 15). The critical points in the plan are marked on the profile with corresponding numbers and letters. While the plan of this vault utilizes a simple geometry which consists of two rotated squares, additional geometric exercises were necessary to transpose the plan into its section. In order to determine the profile of the principle arc of the ribs, the first step consists of identifying the sequence of the ribs which produce the longest span from the springing to

[27] *Centaurus*, vol. 35, p. 234.
[28] *Actes Du XXII Congres International D'Histoire De L'Art Budapest,* vol. 1, p. 534.

the apex. In this drawing, this sequence is easily determined since the drawing illustrates a relatively simple arrangement. This becomes evident when this drawing is compared with another drawing from the same codex (fig. 16). In order to delineate the profile of the principle arc in this vault, the path of the rib on the lower left corner is traced from its springing point to the roman numeral I, which is marked along the path of the rib (fig. 15). This distance is marked on the horizontal line above the drawing. The second critical point is identified as number 2, and the distance from the first point to this point is also measured and added to the first segment. Making a sharp turn at 2, the rib is carried to its apex marked with a 3. The addition of the three segments represents the longest traveling distance a rib has to traverse before it arrives at the highest point in the vault at number 3. A single arc connects these points and is the primary profile for the arcs for all the ribs.

The procedure described above is the principle method through which the profile of a vault in most Late Gothic buildings was determined. It is important to note that as the ribs began to curve in two directions, an example of which can be seen in the Rider's Stair drawing (fig. 3), the simple procedure described above increased in complexity. This complexity, however, did not result in alternate methods for calculating the rib arch; it merely became more difficult because the number and arrangement of the ribs added to the number of operations. That geometric procedures used for calculating the principle arc of the vault did not change due to the complexity in vault forms is proven by examples from the Dresden Sketchbook in which similar methods of projections are used to obtain the arc of the principle rib of both singularly curving ribs and ribs with doubly curving profiles. Though, as Bucher points out, much of what the Gothic mason did was based on trial and error and the use of cutout models that three-dimensionally represented the shape of ribs, which greatly facilitated their visualization.[29]

The necessity for the geometric exercises detailed above primarily arose as a consequence of the form of ribs in Late Gothic buildings, and the technical difficulties which had to be overcome in their construction. The projective methods as they were employed by the Gothic masons were devised in order to translate the flattened length of the rib as it was seen on the plan view to its true length, which could only be seen in the

[29] *Actes Du XXII Congres International D'Histoire De L'Art Budapest,* vol. 1, p. 536.

section. The intersections between principle ribs and shorter ribs at unpredictable locations in space required further calculations. As the structural logic of the rib in a Gothic vault enforces it to follow a continuous path, its character can only be understood by visualizing the curve from the apex to the springing of the rib at which point the column capitals temporarily interrupt this continuous pattern. As can be seen in the majority of Late Gothic structures such as in Wladyslaw Hall at Hradschin (1493-1503), the column capital was completely dispensed with and the continuity of the ribs was carried to the ground level. The Gothic ribs, therefore, belong to a conceptually different order of formal and structural elements from the muqarnas, that emerge out of stacking horizontal planes parallel to the ground floor. The contrasts are well demonstrated by comparing the assembly of the muqarnas in Notkin's photograph with a drawing from the Dresden sketchbook that shows a Gothic vault (fig. 9 and fig. 17). The structural logic of the muqarnas is best represented by the contours of its plan, while vertical continuity of the Gothic ribs can only be understood when these elements are drawn in section.

The sheer complexity of Late Gothic vault design and construction techniques is best represented by reviewing vault samples from the northern regions of Europe, primarily England at the closing of the 15th century.[30] While no drawings remain from English lodges, it is difficult to imagine that the perfectly crafted, stereometrically complex lierne or fan vaults within Tewksbury Abbey (1375) or the cloisters at Gloucester cathedral (begun 1378) were made without the aid of drawings and an advanced knowledge of geometry (cloisters at Gloucester, fig. 18). The evolution of vaults from simple High Gothic examples to English lierne and fans vaults, and the factors that led to the increase in formal complexity of the later vaults, have been summarized by Robin Evans.

In his analysis of Gothic architecture, Evans is primarily concerned with the question of geometry and its applications in building technology. His conclusions are relevant to the topic of this essay, for he suggests that in order for English builders to construct lierne and fan vaults, which characterize the architecture of England during its Late Gothic period, these masons had to be informed about "projective geometry" – a

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[30] In her characterization of Late Gothic vault design techniques, Necipoglu has not addressed the structurally innovative vault forms of Late Gothic English buildings.

branch of geometry entirely foreign to medieval Islamic vault builders and one that is primarily associated with the Baroque period in Europe.[31] Through his analysis, Evans highlights the critical point at which the design of vault surfaces took precedence over the ribs, and recognizes this instance as one that was instrumental in the development of Late Gothic English vaults. Whereas in early Gothic architecture (12th to the 14th century), the definition of ribs dictated the design of surfaces, which often involved an ad hoc filling to build the cells between precisely cut ribs, the Late Gothic stereometric sophistication is distinguished by favoring the surface.[32]

True complexity in vault design, however, was signaled by the transformation of the ribbed into lierne and fan vaults, and later with the intersection of fans. What transpired was continuity of surfaces. The choir vaults at Wells and Gloucester mark this changing point. In these buildings, the vaults could no longer be considered as networks of independent ribs, intersecting in space. Instead, "for the first time in Gothic, the vault was made as a jointed masonry shell instead of a frame of ribs with infill."[33] With the intersection of the fans, the rib system transformed. Vaults appeared to be latticed surfaces in which, "all the ribs seemed to be attached to a giant cambered sheet, a segment of a cylinder hat stretched from springing to ridge down the entire length of the choir."[34]

The design and construction of boss stones within English vaults exemplify the stereometrically complex architecture of the Late Gothic period. What was distinctly difficult about the design of these connective pieces was a factor of their function and position within the vault. Set at the points of intersections of the ribs within a fan or a lierne vault, these pieces had to accommodate the sweep of successive ribs and their

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[31] Projective geometry applies to an application of geometry that is best suited for quantifying the shape of forms in space. On the characterization of projective geometry and its distinctions from Euclidean geometry, Evans states: "In Euclidean geometry it is always as if the figures in the books could be applied like templates directly to a material, whereas the figures of projective geometry belong to some absconded, mercurial item that remains out of reach." Projective Geometry is also the method used by Philibert Delorme in his *trait* for a modern star vault from the *Premier Tome*, in which an eighth segment of a vault is projected to define the shape of its surface. Typically in such operations, the coordinate the surface can be determined by projecting the profile of the plan in two directions. Illustrations of Delorme's procedures and further explanations can be found in, *The Projective Cast: Architecture and Its Three Geometries*, pp. xxxii, 222, 223.
[32] *The Projective Cast*, 229-231.
[33] Ibid, p. 229.
[34] Ibid, p. 228.

points of intersection. This meant that every surface within the single block of the boss stone had to be molded to a different curvature, which was determined by the next successive piece. Focusing on the design of connective stones within the fan vault at east end of Peterborough Cathedral, Robert Willis's analysis reveals the geometric ingenuity that was involved in the construction of Late Gothic vaults. It is enough to review his exposition of the geometric operations necessary for outlining the profiles of one of these elements to show the amazing dexterity of the masons.[35] Figure 19 illustrates the plan of the stones and their projections. An axonometric view of the inverse side of the vault demonstrates the interlocking of the stones and can be studied along with the plan (fig. 20). Every surface in his construction has to be projected at least two times to determine its geometric relationship to the next surface with which it is in contact.

It is not necessary to repeat the lengthy geometric procedures through which Willis illustrates the calculation of the curvature within each surface of the stone. It is sufficient to note that the construction of the six-sided figure at the top-most of the drawings, has to accommodate the profiles of four arch joints (indicated in the drawing as *gt, tw, wx, dy*) and two radial joints (indicated as *gd, yz*), while its top surface is shaped by the curve of the ridge rib GBH. Placed at the junction of two ribs AB and FB, and of the ridge rib GBH, this stone resembles a boss. In order for each of these surfaces to have been calculated the craftsman would have had to undergo a lengthy process of geometric exercises, possibly through trial and error. The complexity of such procedures is revealed in Willis's analysis and attests to the advanced knowledge of geometry of the English masons. Evans is right to ask whether the English masons were indeed versed in projective geometry. Surely the complexities involved in the design of a single connective stone such as the six-pointed connector in Peterborough vault demonstrates that advanced geometry was required.

[35] For the full discussion of the geometric processes involved in this design, see Willis's article in *RIBA Transactions*, vol. 1, pp. 46-50.

Conclusion

While an examination of Late Gothic and medieval Islamic drawings confirm the two-dimensional logic of their constructions, differences between them emerge as the procedures for projections of vaults and their resultant forms are analyzed. The construction of muqarnas begins with, and is defined by the composition of its plan. Once the plan is devised, the next step, that of projection, is done through one basic procedure in which one module (as Kashi's text emphasizes) is applied to the equally spaced tiers of the vault. The vertical module remains consistent throughout. The repetition of the single module emphasizes the dominance of the plan, while highlighting the minimal amount of geometry that is necessary for calculating the three-dimensional extension of the pattern.

Late Gothic drawings and architecture attest to uses of geometry and methods of construction that cannot be paralleled by Islamic examples. As the construction of the muqarnas is based on the delineation of its horizontal contours, its conceptual character fundamentally differs from the Gothic rib. The vault plan in the Gothic tradition is projected in order to determine the arc of the principle rib. The continuity of the rib and coordination of ribs at various locations in space accounted for the difficulties which confronted the masons. Late Gothic English vaults provide further evidence for assessing the geometric knowledge of the masons and the complex character of their vaults. Robert Willis's analysis of the construction of vaults at Peterborough Cathedral provides undeniable proof that stereometry had reached a truly formidable level of complexity in architecture of Late Gothic England. Whether it is the ribbed vaults of Late Gothic German buildings or the "continuous" vault surfaces of English buildings, the order by which the Gothic masons approached the technical and geometric difficulties of their designs emphasizes the differences between Gothic traditions and the ways in which muqarnas were imagined, drawn and then projected into three-dimensional vaults.

The progression from the simple order of the muqarnas in 11th century Seljuq buildings (c. 1050-1200), in which these elements are primarily structural and only employ a handful of variations, to the geometrically complex fan-shaped muqarnas types of Timurid buildings took approximately four centuries. The earliest remaining representation of the muqarnas dates to the 13th century. Discovered during the excavations at Takht-i Suleimon, this piece is a drawing of a muqarnas that is etched at full-scale on a plaster slab (fig. 21 and 22). The orthogonal composition of the Ilkhanid drawing characterizes the simple geometries of early muqarnas constructions. Its design which only employs a geometric grid of ninety and forty-five degree relationships is only the beginning point in the formation of fan-shaped Timurid muqarnas, in which radial compositions present the opportunity for infinite variations.

The strictly orthogonal character of early muqarnas patterns can be connected to Kashi's definition of the first three types of muqarnas, which he includes as the last section in his treatise on practical arithmetic. Kashi isolates the fourth type of muqarnas identified as *Shirazi*, for its extreme flexibility. A variation on the curved type, *Shirazi* is different for where "the measures of the bases of the facets of the cells of the curved muqarnas do not exceed the four measure mentioned … for the *Shirazi*, their measures are innumerable."[36] This produces a distinctly more elaborate muqarnas form, examples of which can be seen in the Topkapi and Tashkent scrolls.

The gradual development of the muqarnas marks the domination of crafts within medieval Islamic building practices, in which change occurs at a slow rate and the will to experiment is as much subdued as possible. Notkin's observations of the work of a contemporary Uzbek craftsman and the study of partially damaged medieval muqarnas prove the construction of muqarnas as a living art. As muqarnas remained tied to craft practices, innovations within its formal types remained conceptually unchanged. It is strongly suggested that drawings allowed the designers of muqarnas to develop more complex variations than what they previously had been able to produce. While this may have been, it was only the two-dimensional structure of their plans that gained in complexity.

When Islamic builders were still primarily concerned with manipulations of two-dimensional patterns, Late Gothic masons in contrast had already begun to experiment with the potentials of drawings. The procedures for flattening the length of the arch and finding the principal arch of the rib were to lead the way to combine drawing and geometry in ways that surpassed a strictly two-dimensional Euclidean geometry, which was essentially devised for constructing shapes on a flat plane. While the design of

[36] *Centaurus*, vol. 35, p. 226.

Gothic vaults, which began as purely two-dimensional exercises, quickly advanced to an exploration of three-dimensional forms, their Islamic counterparts continued to use their traditional design methods.

Chapter Two

Practice of Architecture in Timurid Central Asia

Medieval Islamic Craftsmen and Architects

Timurid sources suggest that the boundaries between the tasks of various workers in the field of architecture were not as concretely established as contemporary models imply and, that the participation of a large group of individuals including craftsmen, patrons and even official superintendents were often integrated in the processes of design. This evidence questions the role of architects as the sole and principle designers within the practice of architecture. While hierarchies surely existed, when it came to design, everyone had a say. Consequently, our understanding of the medieval Islamic building practices is hampered by scholarly efforts which have tried to fit the medieval designer into the mould of what today characterizes the role of architects. In this chapter, the search for the identity of the Timurid architect will set the ground for delving into what may have been the nature of Timurid architectural practice.

The two remaining scrolls from Timurid Central Asia (the Topkapi and Tashkent drawings) provide us with additional sources for investigating the role and responsibilities of designers. In order to understand both the similarities and the differences between Gothic and Islamic architectural practices, early medieval drawings from Gothic Europe will also be referred to. As Islamic builders and craftsmen did not leave textual evidence of their design methods, this essay stresses the importance of architectural drawings and historical texts as valuable sources through which speculations about the thinking and the professional responsibilities of designers can be made.

The Timurid Architect

The craft of building in medieval Islamic Central Asia was an extremely complex affair. The construction of a large, lavishly decorated commission such as the Friday Mosque of Timur in Samarqand required the orchestrated effort of a large group of skilled craftsmen and builders. A miniature from the 15th century produced by the court painter Bihzad depicts just this event.[37] Illustrated in this painting are the varieties of building tasks as they were performed by craftsmen belonging to different trades, their tools and the materials of construction (fig. 23). In this conglomeration, one conspicuous figure in the upper left hand corner is holding up a staff, ready to punish anyone acting in a lackadaisical manner. With a dagger hung at his side, this individual is most probably a royal guard whose role was to ensure an orderly and rapid progression of the work. What is absent from this illustration is the figure of an architect: an individual who supervises the progress of the work and when needed advices on design decisions.

Arzadasht, a unique 15th century document, attests to the complexity of building programs and the careful supervision of builders' tasks within Timurid architectural practices.[38] The three parts of this document are composed as a progress report on the work of the scribes, calligraphers and artisans employed at Baysunghur's (d. 1433) royal library.[39] The second part reports on the construction of buildings and gardens. Due to their elaborate design schemes and the scale of the project, this construction could only have been a royal commission. The court, the Old Palace, the atelier for the painters, the new Garden, and the courtyard garden are some of the spaces and rooms which need to be completed before the entire building complex can be inhabited. In this report, the names of the principle rooms and spaces are placed at the head of paragraphs, which are followed by a description of what parts of design are completed and what still requires work. Aside from distinguishing between the various stages of construction, the document also differentiates between distinct architectural components within the spaces. For example, the vestibule to the new garden is identified as *dalan*, while the forecourt to the complex is a *dargah*.

While some artistic license may be granted to the illustration of Timur's mosque construction, the library report has to be taken as factual evidence that attests to the existence of complex methods for documenting and monitoring building activities in the Timurid period. Both documents strongly suggest that architectural practice in Timurid

[37] This is a double page miniature on fol. 359b and 360a, attributed to Bihzad which appears in the *Zafarnama* (Book of Victories) of Sharaf al-Din 'Ali Yazdi. This book was copied by Shir 'Ali in 872/1467 and illustrated possibly some years after. It is today preserved in the Milton S. Eisenhower library of the John Hopkins University.
[38] For the full document see, *A Century of Princess,* pp. 323-327.
[39] Although the document contains no name of its author or recipient, internal evidence suggests that it was composed by the head of Baysunghur's artistic establishment, Ja'far Tabrizi.

Central Asia could not be reduced to chaotic gatherings of artisans and builders, whose intuitive powers enabled them to proceed without requiring the advice of a principle designer. Their wok had to be coordinated and planned if a building with such lavish decorations and monumental scale as Timur's mosque in Samarqand were to be erected.

Our contemporary settings have conditioned us to believe that important architectural projects cannot be conducted without the services of a head designer, or an architect who supervises the work of builders. When we are faced with a tradition in which this individual is difficult to identify, some explaining needs to account for the great monuments that remain as legacies of cultures without architects. The practice of architecture during the Timurid age is one example in which an individual acting as the principle designer cannot be spotted. Whether in fact such an individual with the duties we often ascribe to architects, as for example in Renaissance Italy, existed is questioned by the scarcity of sources in which the clear role and responsibilities of architects have been outlined. With the absence of architectural treatises, the historians of Islamic art have had to undergo painstaking examination of literary and epigraphic sources in which the names, and sometimes clues about the role of designers are mentioned in often chaotic and unsystematic ways.

The identity of the medieval Islamic architect and his precise role within the practice of architecture has for long intrigued the scholars of Islamic architecture. The pioneering work is L. A. Mayer's *Islamic Architects and Their Works*, which was published in 1954. Mayor's "Roll of architects" in which the names of about 350 architects from the entire history of Islamic architecture and from all Islamic lands are collected, highlights the difficulties which have hitherto faced the scholars of Islamic architecture. While defining the criteria according to which the individuals in the Roll are chosen, Mayer does not distinguish between masons and craftsmen working within various disciplines. He explains that he has included in his Roll, "all men known to have been architects, engineers and master masons, no matter whether such of their works as have survived actually belong to the field of architecture and engineering or not." His conclusions emphasize the close connections that exist between the training and the artistic productions of architects and artisans in medieval Islam. As Mayer discovers, some architects were "also stone-cutters or sculptors in plaster or makers of fayence tiles."[40]

The writings of three scholars, Bernard O'Kane, Lisa Golombek and Donald Wilber, can be recognized as the most significant contributions to the study of Timurid architects and craftsmen. Employing similar methods, Golombek and Wilber's survey *The Timurid Architecture of Iran and Turan* (1988) and O'Kane's *Timurid Architecture in Khurasan* (1987) trace the identity of architects and designers through the inscriptions on monuments and relevant historical texts. Striving for methods through which a greater degree of precision can be brought into identifying the work of individual designers, Golombek and Wilber interpret stylistic and architectural differences between designated monuments as signs of the intervention of distinguished architects. Their efforts emphasize the existence of a principle designer within Timurid architectural practice. The career of Qawam al-Din Shirazi is highlighted and a portrait close to that of a contemporary architect is painted for him. The findings of these scholars distinguish the Timurid period as one in which an inclusion of a greater number of signed works attest to improved conditions for the craftsmen.[41]

However, even with such evidence the Timurid architect is rendered indistinguishable from his ally craftsmen. This essay will begin with a discussion of the terminological difficulties which have limited our understanding of the identity and professional responsibilities of Timurid designers. The designation of an architect as the principle designer is complicated by considering the role of the clerk of the projects, and also through historical sources that recognize patrons as architects.

Literary sources from the Timurid age seldom, if ever, mention the names of architects. In the instances when this information is provided, a variety of terms are used to designate these individuals. This is proven by considering the large array of qualifying terms (*nisbah*) within both epigraphic and literary sources that can be translated to mean

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[40] *The Islamic Architects and Their Works*, p. 12.

[41] This is confirmed by both surveys. O'Kane states: "Looking over the list of craftsmen and calligraphers as a whole, one is struck first of all by the great increase in signed work. In Wilber's list which covers the years from 1000-1400, gives approximately 80 masons (whether brick, tile or plaster), 8 calligraphers and 8 carpenters. There are no more Timurid buildings surviving than there are Mongol ones, and much less than Seljuq and Mongol combined, so this increase almost certainly reflects the growing prestige of the craftsmen and calligraphers." *Timurid Architecture in Khurasan,* p. 41.

architects.[42] Sometimes called *Ustad*s, architects were also recognized as *mi'mar*, *muhandis*, and sometimes the general word *banna* (builder) sufficed to mention an architect. Another factor that accentuates the problems of using historical texts as the principle sources for identifying medieval designers is that, the introduction of one individual as an architect in one source does not always match their description as such in another source. Qawam al-Din Shirazi, perhaps the most famous medieval Islamic architect, is identified on the dedicatory inscription at the mosque of Gawhar Shad as a stucco-worker,[43] while in Khwandamir's *Tarikh-i habib al-Siyar* he is both an architect (*mi'mar*) and an engineer (*muhandis*).[44] Consequently, the terminological inconsistencies by which architects are identified in Timurid literary sources renders their use as insufficient means to fully understand the professional rank and responsibilities of the architects.

Enforcing the receptivity of Timurid craftsmen to the work of each other is that the general term *banna*, which literally means builder, is the most common term that can be found in a survey of Timurid craftsmen and designers. While the appearance of new qualifiers such as tile-worker (*kashi-kar*), stone-cutter (*hajjar*), etc. in late Timurid epigraphic sources has been noted by some authors to signal the extended divisions, and by implication a clarification of the work of craftsmen, this information sheds no new light on the role of the principle designer and their rank within the personnel responsible for the erection of buildings.[45]

The art of building was only one, and not the principle specialty of the Timurid architect who was destined for fame. While it was possible for medieval designers and builders to gain a social standing that was comparable to the highly regarded ranks of bureaucrats and scribes, it took a great deal of effort. The career of Qawam al-Din Shirazi can be cited to confirm the challenges with which an ambitious Islamic architect

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[42] The reading of an architect's name from such sources is made possible through the translation of the word that follows the name of the individual and what usually marks his professional rank. These words are referred to as *nisbahs*.

[43] The inscription reads: amal al-'abd al-zaif al-faqir al-muhtaj bi-inayat al-mulk al-rahman Qavam al-Din ibn Zain al-Din Shirazi al-taiyan. This appears on the mosque of Gawhar Shad in Mashhad.

[44] *Tarikh-i habib al-siyar*, vol. 4, p. iv. The etymology of the word *muhandis* is difficult to resolve. There is evidence that this could mean both an engineer and a geometrician. I have taken this word to refer to an engineer which is its most common association.

[45] *The Timurid Architecture of Iran and Turan*, p. 66.

was faced in his quest for popularity. Qawam al-Din was not only an extraordinary designer, but he was also skilled in the higher knowledge of geometry – a fact that surely accounts for his redemption from the large pool of otherwise unknown architects and designers who existed during his lifetime. That he was an exceptional case is attested by Dawlatshah who wrote that, "among the four unparalleled artists at the court of Shah Rukh was Master (*ustad*) Qawam al-Din, who excelled in engineering (*muhandasi*), drawing (*tarh*), and architecture (*mi'mari*)."[46] Recognizing Qawam al-Din as the greatest architect of the age, Khwandamir relates a "well known and oft-mentioned" story, in which Qawam al-Din is presented as both an architect and an expert in astronomy. It was Qawam al-Din's knowledge of astronomy which ultimately helped him regain his patron's support:

> Once the emperor was angry with Ustad Qawamuddin over a building and for one year refused him permission to enter court. Since the master was an expert at astronomy, he produced an ephemeris. When he was again permitted at the court, he presented it as a gift to the emperor, who smiled and recited this line of poetry: 'You did the work of the earth so well that you took up the heavens too.'[47]

The structure of medieval Islamic societies attributed architects with modest designations. In his analysis of the careers of four Mamluk architects, Nasser Rabbat has demonstrated that the professions of architects, practicing in Mamluk Cairo and Syria, conditioned them to the same hardships that architects in Timurid Central Asia had to endure. In order for a Mamluk architect to be recognized by historical biographies, he either had to possess the intellectual abilities of a polymath, with expertise in a variety of disciplines, or, engage in politics, and if neither of these, he needed to perform miraculous acts that dazzled his audiences. For example, Aydaghdi al-Rukni, who was a blind master-builder, was able to use his cane as a yardstick to detect a mistake in the measurement of a hall that his clear-sighted engineers (*muhandisin*) and assistants had missed.[48] Explaining the occasional mention of scribes and calligraphers in Mamluk sources as a sign of their high social rank, Rabbat notes the few times that the names of architects and craftsmen are recorded. Belonging to a low social class,

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[46] *The Timurid Architecture of Iran and Turan*, p. 189.
[47] *A Century of Princes*, p. 159.
[48] *Journal of Architectural Education*, vol. 52, pp. 30-37.

> Artists and architects had to transform themselves intellectually and socially to move beyond the confines of small-time artisanal limitations. They had, in fact, to become something else, in addition to being artists and builders.[49]

This "something else" which an architect had to become in order to be recognized for his work, however, entailed that he leans an entirely new discipline.

In Timurid Central Asia, artisans and craftsmen (and especially talented ones) were often recruited by powerful patrons to engage in the construction of important royal and religious monuments. The classic example of such an occurrence is that of Timur who, after conquering most of Central Asia, Iran and some of the Jibal, transported all the local architects and craftsmen to his new capital at Samarqand.[50] While Timur's motivation for relocating architects and craftsmen to his court can be explained by considering his intentions to found an impressive capital, his actions also explain the formal and decorative homogeneities that unite the architecture of monuments as remotely located as the cities of Samarqand and Baghdad.

Literary sources that mention important constructions often verify the habit of patrons to demand the services of the best of craftsmen, regardless of how far these individuals had to travel to arrive at the court of the patron. Characteristic of the ways in which architects and craftsmen are identified in these sources is the intimate relationship which binds the imported individuals and their crafts to the regions whence they come. Calvijo, an Italian ambassador on his visit to Transoxiana and the court of Timur, relates that while Timur was preparing for his grand feast, he first, "commanded that the Egyptian and Syrian builders should raise a royal palace in the mist of the garden that had been made to the south of the Shimal Garden." Praising the skills and workmanship of Syrian and Egyptian builders who were imported to decorate the gardens of Timur, Clavijo elaborates:

> In Syria architectural decoration is of marble, running water in the buildings and houses of that region is common, and the builders of that country are expert at stonecutting, faience work, and the invention of flowing fountains. The delicate, intricate work that inlayers do in ebony and ivory, etc., they execute on the walls and floors of buildings in multicolored stone. Consequently, inside that marvelous

[49] Ibid, p. 36.

[50] For a list of the primary sources in which this event is described see, *The Timurid Architecture of Iran and Turan*, pp. 35-36.

> palace they produced graceful works of marble and displayed their consummate skill and mastery. By making many fountains they added to the pleasantness and freshness of the place.[51]

The construction of the mosque of Samarqand was similarly supported through the work of craftsmen imported from abroad. While the masters (*ustadan*) from Baghdad and Basra were responsible for the construction of the maqsura and (stone) platforms, the lay workers (*Amale*) from the regions of Fars and Kerman stretched the silken carpets to the measure of every corner in each of the rooms.[52] The tendencies of medieval literary sources to associate the skills of architects and craftsmen with their places of origin obscure the individuality of the workers. Not only are their names forfeited for names of their cities of birth, such descriptions tend to emphasize the crafts, which are generally local traits.

A good grasp of the theories of geometry could have been the mark of distinction that the medieval Islamic architect needed to elevate him from the ranks of the lay craftsmen and builders. Yet, the medieval branch of geometry that specifically addressed the needs of designers posed no intellectual challenge to protect its codes from the everyday craftsmen. The principal means through which masons and craftsmen of the Timurid age acquired their knowledge of geometry consisted of manuals on practical geometry, in which instructions on how to construct basic geometric shapes were described.[53] These texts were strictly practical in nature and mastery of them did not require their audience to be conversant in the theoretical language of mathematics, or for that matter require a high level of literacy.

Exemplifying the ways in which medieval texts on practical geometry instructed the artisans is a 14th century treatise entitled, *Fi tadakhul al-ashkal al-mutashabiha aw al-mutawafiqa* (On interlocking similar or congruent figures).[54] Composed of sixty four problems, this treatise written by an anonymous author contains evidence that the

[51] *A Century of princes*, p. 90.
[52] *Zafarnama* (Shami), vol. 2, p. 197.
[53] See note 7, for the debates in the scholarship of this topic.
[54] It is noteworthy that these texts do not directly instruct on the construction of the muqarnas, which perhaps involves the most intricate geometries of Timurid architecture. Kashi's text that discusses the muqarnas is an arithmetic text, and only conveys the technique for measuring the vertical module of these vault forms. His text does not address the two dimensional organization of the muqarnas that is the most difficult part of its arrangement.

medieval mason could easily have approached complex geometric problems, based on simple instructions and the use of basic drafting tools which included the compass, the straightedge and the triangle. Problem forty one in this text illustrates a geometric construction which bears some resemblance to one of the decorative patterns in the Topkapi Scroll (figs. 24, 25 and 26):

> Problem 41: The way of drawing and the ratio of proportion of this construction are as follows: Angle BAJ represents an added sum of three parts of a right angle that is divided into seven parts. We divide in half the line of AJ at the point D. Then the length BH is marked to be the same length as AJ. And, we draw the line of HR parallel to AJ. From point T, which is on the middle of that line (HR), we draw TY parallel to BJ. We divide TH in half at H' and we mark TY to be equal to the length of TH'. Then, we draw the line HY, and continue it until it intersects the line AB at point K. Then, we draw the line KL parallel to BH, and with the center at R and radius of RK, we draw the arc LMQ in a way that KM is equal to MQ. Now, we draw the line LQ and continue it until it intersects the line AF at the point C. This point is the center of an equal heptagon and the rest of the design becomes easy.[55]

In this exercise, the descriptive text only supplements the diagram. It is not a mathematical proof of the geometric operation that is illustrated. Once the author of the anonymous text has laid out the intricate part of the geometry, the artisan can understand the remainder of the design through the illustration. Both in their simple descriptive language and ample illustrations that demonstrated the construction of shapes in a step by step manner, these texts could easily be understood by any mason. Thus, the ephemeris that the 15th century architect Qawam al-Din invented in order to impress the Sultan, implying that he was an expert geometer, is best explained as the product of an imaginative mind who aimed to glorify the "greatest architect of the age."

The terminology through which medieval practical geometries address their audience does not discriminate between their users. In the content of the manuals on practical geometry, much like the historical texts, a combination of terms including "artisans," "craftsmen" or "masons," and even "geometer" can be found.[56] Entitled *'A'mal al-handasa* (geometry in practice), Abul al-Wafa al-Buzjani's practical geometry

[55] *Handasa-i Irani: Karbord-i Handasa dar Amal*, p. 86. This text is a translation of al-Buzjani and the anonymous texts into modern Persian. English translation is mine.

[56] Only two examples of these texts survive. That the practical geometries had a more scientific aim than the histories, one could imagine that they would adhere to a more strict terminology than the latter.

was especially designed for artisans as is suggested by its title. On more than one occasion, al-Buzjani refers to his audience as *sunna* which is the general term for artisans. Chastising the 'artisan' who approximates the shapes of his construction, al-Buzjani, in the introduction to his text states:

> I know that artisans (*sunna'*) construct figures in round forms unmethodically ... In order to create fine works, the artisan has to quit working by the eye-measure. Instead, he must determine the dimensions of sides of the pentagon, hexagon, decagon, or other figures as we explain in this book.[57]

In the same manuscript, Buzjani describes that he was present at a gathering which was held "among a group of artisans (*sunna*) and engineers (*muhandisin*)." He uses the word *muhandisin* which could also translate as geometricians. Similarly in Kashi's measurement of the muqarnas, he begins his instruction on the construction of the vertical module by urging the "masons" to begin by drawing a rectangle.[58]

In order to maximize efficiency and order in the process of construction, patrons often employed the services of an administrator.[59] The principle duties of this individual included financial supervision of the work of builders, timely completion of buildings and the calculation of the quantity of materials that was needed for a project. The responsibilities of the clerks and the distinctions between their mathematical training and the designers' are discussed by Gulru Necipoglu. She believes that it was only through knowledge of arithmetic that the clerks were able to fulfill their purely administrative duties, which consisted of "making correct estimates of building costs and wages ... (as well as) their expertise in land surveying and in the digging of irrigation channels."[60] The division between the knowledge and the professional duties of an architect and those of a clerk was a function of their education. Necipoglu argues: "practical manuals on arithmetic seem to have been more useful to the concerns of building supervisors than for

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[57] Originally written in the 10th century, this text was copied and reworked in later centuries. The copy from which the quotation above is extracted is today preserved at Istanbul. It was presented to Ulugh Beg, the Timurid Prince, in Samarqand and was probably made an earlier Persian translation. The citation above is from page 21 of the Istanbul copy.

[58] See note 26.

[59] A variety of terms can be found in medieval sources to designate the superintendent of the project. *Shadd* is the primary word in Mamluk sources, while in Persian Timurid texts, these individuals are commonly recognized as *sarkaran* or *sarkarha*.

[60] *Topkapi Scroll*, p. 157.

architects whose design methods primarily relied on geometry."[61] It is perhaps due to such distinctions that historical sources sometimes distinguish between architects and craftsmen, who are responsible for design tasks, and superintendents, who manage financial and bureaucratic matters. For example, according to Abd al-Razzaq, a historian from the Timurid period describing the construction of Bagh-i Jahan Aray in Herat: "The architects (*mi'maran*) and builders (*banayyan*) set the designs for the foundations; and the master-craftsmen (*Ustadan*) proceeded in the work of building; (while) the work of computation and bureaucracy was left up to the skills of the superintendents (*sarkarha*)."[62]

As building tasks increased in complexity and as patrons raised their expectations from their employees, clerks were also forced to expand their knowledge and skills beyond a mere mastery of administrative and financial duties. Ibn Qutayba (825-889), a ninth century scholar, elaborates on the skills of a perfect clerk. In addition to the knowledge of how to make correct estimates of a building, a well-rounded clerk (*katib* in this case) was also expected to:

> (be) knowledgeable about diverting water channels, digging out courses for irrigation streams, and blocking up disused well-shafts; about the changes in the length of the days as they increase and decrease, the revolution of the sun, the rising places of the stars and the state of the new moon as it begins to wax, and its subsequent phases; about the various weights in use; about the measurement of triangles, four sided figures and polygons; about the construction of bridges and aqueducts, irrigation machines and water wheels; and about the materials used by various artisans, and the fine points of financial accounting"[63]

Raising the level of knowledge required from a clerk to that of a polymath, this early source surely describes the most ideal of cases. While exaggerating the abilities of its subject, this account confirms Rabbat's conclusions that in order for individuals in the building trades to gain any kind of reputation in medieval Islamic cultures, they would first have to acquire mastery of a vast knowledge in diverse fields.

Perhaps the coordination of a sophisticated project such as the royal commission for Bagh-i Jahan Aray, mentioned above, absolutely necessitated the administrative

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[61] Ibid.
[62] *Matla a-sa' dain va majma' al-bahrain*, pp. 1374-5.
[63] *Isis* 54, pp. 98, 99. Also mentioned in *Topkapi Scroll*, p. 157.

specialties of a clerk. We can assume, however, that more modest projects did not necessarily require the help of such individuals, and that the tasks of clerks were handled by others including the craftsmen. Surveying, for example, which according to Necipoglu and Ibn Qutayba's description was one of the responsibilities of clerks, was in some cases conducted by a mason, as one passage from a 15th century source describes. In a letter to his father, the astronomer and mathematician Jamshid Ghiyath al-Din al-Kashi (d. 1429) records the construction of a new observatory commissioned by the Sultan at Samarqand.[64] As this building was under construction at the time Kashi was there, his letter contains first-hand documentation of the building processes as they were undertaken in 15th century Central Asia. Kashi writes: "One day when the ground was being leveled for the determination of the meridian, at the site of the observatory," in order to test whether the surface was truly plane or not,

> By way of a gauge, the masons who were smoothing the surface were relying, for the observatory, on a triangle which they had made, of which each leg was four Hashimi cubits.[65]

Kashi's letter has not received the attention that it truly deserves. However, it certainly contains enough evidence to convey that the boundaries between the tasks and expertise of a craftsman and those of a clerk were not clearly defined.

By the same token, the interpretation of the responsibilities of a clerk as restricted to administrative duties is challenged by existing evidence. When Timur realized that the entrance portal to the Bibi Khanum Mosque was not tall or wide enough, it was the clerk, Khvaju Mahmud Daud, and not the architect who was punished.[66] As the designer of this monument has remained anonymous, it is noteworthy that what ultimately was a design fault was projected onto the clerk, which consequently adds to the ambiguities that cloud the specific role of medieval Islamic architects.

One way through which the medieval Muslim architect could gain a prominent position was by securing the support of a powerful patron. Consequently, the will and intentions of patrons had a significant role in the conception of buildings and are often

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[64] Kashi, the Timurid mathematician was residing at the court of Sultan Ulugh Beg, and was employed by the Sultan for his knowledge of astronomy.
[65] *Orientalis* XXIX (1960), p. 198.
[66] *Timurid Architecture in Khurasan*, p. 40. That Khvaju was the superintendent is O'Kane's interpretation. The original citation is from Yazdi's *Zafarnama*, vol. 2, p.421.

expressed in the architecture and inscriptions found within their monuments. While the monumentality of Timurid buildings, exemplified in the Aq Saray palace of Timur in Samarqand, reflects the grandeur of the patron's sovereignty, in this case the Sultan himself, it is also the patron's name that is most frequently and prominently displayed on the surfaces of his buildings. A line from a poem composed by a 15th century Timurid writer Mir Ali Shir Nava'i designates the portal of a building as the ideal location for the name of its patron:

> When any ruler builds a building impregnable or raises a portico high, he has his own name and titles inscribed on the arch in order that, as long as the arch remains, his name may remain therein.[67]

The control of the design of projects and their construction by the medieval patron was to a large extent a product of his material wealth. In the same text, the above mentioned poet goes on to emphasize the insignificance of builders and architects as their roles are compared with the job of the Sultan who covers the expenses. Not only does the "exalted palace" of the Sultan emerge in his poem as the ultimate goal of design, the financial strength of the Sultan dissolves the hierarchies that might have distinguished a lay mason from an expert architect:

> Whether laborer or expert architect; when a thousand wages were paid,
> When the kings gilded palace is finished; what have they to do with the palace?
> If Abraham made the Ka'ba flourish; is it known for certain what master built it?
> The dam that Alexander made famous; who can say who labored upon it?
> In the effort of construction; the building will be known by the name of whoever pays the gold.[68]

While a patron's longing for his everlasting recognition as a powerful ruler initiated the design of buildings, his urge to interfere in the design process sometimes exceeded his political motives. In such cases, he himself became the designer. The capacity of the patron to participate in the process of design is best proven by his ability to compose architectural drawings. In these cases, the patron fulfills both his role as the financial source for a project, as well as the role of a designer by producing design drawings. In an

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[67] *A Century of Princes*, p. 371. This appears in his preface to the poet's first Turkish Divan, Gharayib al-sighar.

[68] Ibid, p. 371.

early source, the author of an important history of Central Asia, Bayhaqi relates that, when he visited the court of Masud,

> One year when (he) went there, the vestibules of the portal and the shops were all changed. It was done by order of the king without the help from engineers ... He (Amir Masud) himself drew this (the plan for the changes) in his own writing, the fine palace and the houses and the mosque which are there now.[69]

Bringing the sources closer to the timeframe that concerns us in this paper, a passage from a 14th century *vaqfnameh* supports the hypothesis that patrons were in some cases intimately involved with the process of design and construction. In this document, the Ilkhanid vizier Rashid al-Din plans out the tasks of workers, while describing the various types of buildings which he wishes to include in his new library complex at Tabriz. In a nostalgic tone, Rashid al-Din in one passage of his *vaqfnameh* reminiscences about his life as he was still a youth:

> In the prime of my youth, at the time of my study of the sciences and features of buildings, it happened that I became preoccupied in the service of the Shah and other notables, and only rarely had I time to erect buildings. Such time as I had, I spent with the workmen in discussion and explanation, or I would draw a sketch or a plan of the buildings on paper and show them too.[70]

As Rashid al-Din devotes the little time he has left from his official duties as a minister to the construction of buildings, he divides it between conversing with the workmen and making drawings to communicate his ideas; a surprisingly close match for what according to contemporary standards define the role of architects. We will conclude this section of the essay on the influence of the patron by quoting another passage from the Divan of Mir Ali Shir Nava'i, in which both the architects and gardeners are ultimately recognized as extensions of the imagination of the patron:

> Since the architect that is His Majesty's delicate nature has constructed an exalted castile that is like the celestial dome, and since the gardener that is His Highness's noble imagination has designed a world-adorning garden that like heavenly paradise, what wonder is it if his regal titles are inscribed on the foundation arch of this castle or on the arcades of this garden palace?[71]

[69] *Akten des VII. Internationalen Kongress fur Iranische Kunst und Archaologie, Munchen* 7-10, p 612.
[70] *Vaqfnameh-ey Rab'i-e Rashidi*, p. 21
[71] *A Century of Princes*, p. 371.

Drawings

Two 15th century scrolls (Topkapi and Tashkent), containing drawings for vaults and decorations provide us with additional sources through which we may investigate the role of architects and designers within Timurid architectural practices. As a large portion of these drawings depict muqarnas vaults in their two-dimensional plan views, it can be assumed that they were produced by individuals whose familiarity with conventions of architectural representation and their ability to visualize complex forms qualified them as skilled craftsmen and designers. The four building plans which exist as part of the Tashkent collection of drawings are specially tantalizing sources. As these drawings represent buildings in their entirety, they could not have been made by craftsmen who only focused on isolated parts of buildings. The Tashkent plans are also remarkable for their use of modular grids and architectural conventions that distinguishes their graphic language and geometry from the muqarnas drawings in which radial grids dictate the patterns.

The rise of architects to fame in Gothic and Renaissance Europe is associated with their ability to produce architectural drawings:

> Only through this kind of formation (ways to represent three-dimensional space) and an improvement of the strictly graphic methods of design could the figure of an architect in the modern sense evolve during the first half of the thirteenth century, where projects to be transmitted to the builder-craftsmen existed independently of the finished building.[72]

While it is difficult to squarely compare the innovations which characterize architectural representations as they were made by Gothic and Renaissance architects to anything that happened in the Islamic East, it is plausible to assert that Islamic drawings had also arrived at high levels of complexity. Proof for this claim is found within the drawings of both Tashkent and Topkapi scrolls, in which techniques for representing complex spatial features as scaled two-dimensional projections and the use of conventions to clarify spatial relationships within the drawings, had not been seen before. What is puzzling, however, is why such innovations in representational and graphic techniques did not result in elevating the role of their authors, who were supposedly skilled designers.

[72] *The Renaissance from Brunelleschi to Michelangelo The Representation of Architecture*, p. 101.

Islamic architects left no trace of their individuality within their drawings. While we may be able to find examples of 15th century muqarnas and decorative drawings that exist independently of the finished buildings – thereby fulfilling Frommel's criterion for the famous architect – making any attempt to identify signature styles which could highlight the career of any particular designer is asking for disappointment. Aside from the fact that Islamic designers did not sign their drawings with their names, the graphic techniques and the character of their drawings contribute to the difficulties for identifying individuals responsible for their creation. While the personalized sketches of High Renaissance architects, such as those of Antonio da Sangallo, can be used to trace the professional development of their authors, the starkly geometric and impersonal style of muqarnas drawings yield no information about the idiosyncrasies of their designers and their approach to drawing.[73]

Timurid historical sources in which drawings are mentioned are also of little help in revealing the identities of the draftsmen. Often confusing and inconsistent terminologies, not dissimilar to examples of architects and their *nisbahs*, introduce drawings as the work of different groups of practitioners. For the construction of Bagh-i Shumal in Samarqand, both architects (*mi'maran*) and engineers (*muhandisin*) gathered to draw the design on tablets.[74] In another instance, the plan (*tarh*) of the Masjid-i Jami Samarqand first necessitated the drawing of its plans which was done through a collaborative effort between Masters (*Ustadan*), builders versed in engineering (*banayyan-i muhandis*).[75] While no individuals are mentioned in these references, it is noteworthy that the recurrence of *muhandis* (engineer) in both cases confirms the technical character of drawings.

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[73] Further complicating the task of isolating the work of one designer through their style of drawings is that much of what remains as the corpus of architectural representations from 15th and 16th century Central Asia (primarily the Topkapi and Tashkent drawings) is not even the work of their original designers. As the two extant medieval scrolls are essentially conceived as collections of design fragments for vaults and other decorative elements within buildings, they most likely represent the work of a group of artists, and not one individual. This hypothesis is further emphasized through the varying sizes of the drawings, which despite their consistent subject matter and graphic language create a heterogeneous spectrum of works. It is highly possible that the drawings preserved within the two extant collections were copies made from originals, both for educational and archival purposes. For further explanation of this topic, see: Renata Holod in *Theories and Principles of Design in the architecture of Islamic Societies*.

[74] *Zafarnama* I, p. 571.

[75] *Zafarnama* (Shami), p. 212.

As architectural drawings are often conceived as vehicles through which ideas about design are communicated, it is also possible to imagine them as filling a lacuna between two distinct categories of individuals within the building process: A privileged group of designers responsible for the production of ideas, and the masses of lay workers who, with no input in the design process, translate ideas into built-form. We can investigate the existence of hierarchies within the profession of architecture by considering the design of templates by Gothic master masons.

The importance of templates in Gothic building processes has been discussed by Lon Shelby: "As drawings in the medieval period were less detailed and lacked the specificities and dimensions of contemporary drawings, templates played a significant role in conveying technical information regarding the construction of details."[76] Templates in Gothic architecture were used to delineate the profiles of window mullions and tracery, vault ribs, bases and capitals of pillars, moldings for gables, pinnacles and finally buttresses. Most medieval templates were constructed from wood. Other materials such as parchment and canvas could also be used.

The sketchbook of Villard de Honnecourt can be noted as an early example in which templates are used for communicating information between two stages of design, and possibly two groups of workers. On one page, Villard displays an interior and exterior elevation of one bay of the nave of Reims Cathedral, followed on the next page with drawings of fifteen templates which illustrate details of profiles and moldings in the bay (figs. 27 and 28). Specifying the location of each profile, a caption below the template reads: "Here are the templates of the chapels of the former page, of the tracery, and of the window lights, of the diagonal ribs, and also the transverse ribs, and the super-arches above them."[77] The identifying marks which correlate the templates with the elevation in the previous page facilitate the use of drawings in construction. While the extensive use of templates by Gothic masons can simply be dismissed as a practical solution for registering design details prior to construction, the procedures through which designs for profiles were translated to full-scale copies in wood or parchment, highlight the strictly controlled and hierarchical character of Gothic design and practice. The

[76] *Journal of the Society of Architectural Historians*, vol. 30, p. 143.
[77] Ibid.

rigidity with which the design of profiles was preserved, as they were passed from the hands of designer to lay workers, took away the latter's right to intervene in the process of design.

The assertion that drawings function as communicative devices between professional designers and undistinguished lay workers assumes a minimum amount of intervention in the process of design by the latter. Architects are in such cases expected to act as the sole designers of a project, leaving no room for craftsmen to interpret their work. The considerable input that the medieval Islamic craftsmen had in the design process negates the centrality of one principal designer within the design and construction of buildings. This is attested by considering the ways in which muqarnas were designed and built.[78] The large degree of approximation in the muqarnas drawings of the Tashkent collection also testifies to the craft-based tradition of architectural practices in medieval Central Asia. The disparities between the craft-based practices of Islamic builders and the systematic processes of Gothic design are also evidenced in Gothic vault plans in which the notations on the plan, as in templates in Villard's sketchbook, established concrete relationships between designs as they were conceived on paper and their translation into three-dimensional form. By encouraging greater complexity in the design of buildings and through developing techniques for more efficient ways of communicating their ideas, Gothic masons were able to distinguish themselves from the masses of lay workers.

The overlaps between the skills and the education of Islamic artisans, practicing in various media, and architects and designers of buildings are evidenced in their works. As medieval Islamic architects, almost without exception, were in their careers first trained as craftsmen, it should not come as a surprise that their works carry the influence of their early specialties. The intersections between the crafts can be seen in the formal similarities which unite the drawing methods and the graphic character of Timurid architectural representations with designs in other media. The square grid, for example, which organizes the composition of buildings plans in four of the Tashkent drawings, was a useful medium for composing page layouts as it was utilized by Timurid calligraphers and book illustrators (fig. 29). The application of the grid to compose the design for an

[78] For details, see previous chapter within this thesis on vaults, pp. 12-13.

inscription can be seen in the vestibule leading from the large avian to the 14th century mosque of Safid at Turbat-i Jam (fig. 30). As the painter has not completed his work, this example reveals the procedures through which he prepared the groundwork for his design. In this work, a modular grid at the top acts as the appropriate guideline for the strictly linear letters of a Kufic inscription and geometric designs; the spirals below are more suited for arranging the cursive characters of a Naskhi inscription.

The visual connections between Timurid architectural representations and works in other media obscure the divisions between the identity of their makers and their areas of specialty. The Tashkent scroll contains designs for Kufic inscriptions that are juxtaposed with drawings for vaults and building plans. These designs also use the same modular vocabulary that characterizes the design of buildings. One historical source containing transactions of a Timurid Royal Library suggests that original designs for decorations of buildings were produced in that establishment: "Khvaja 'Abd al-Rahim is engaged with designs (*turuh*) for bookbinders, illuminators, tent makers and tile-mosaicists (*kashi-tarashan*)."[79] Bernard O'Kane refers to the last group of craftsmen who are mentioned in this sentence to indicate that some of the designs which were provided for the construction workers were made by book illuminators and calligraphers.

It is tempting to postulate that the drawings of the Tashkent scroll were in fact made by craftsmen or a series of scribes or calligraphers working in the Royal Library who possibly had no knowledge about construction. Certainly the formal connections between the geometric designs for book illuminations and the decorative patterns imply that similar geometric techniques were used in both cases to compose the designs. However, the spatial complexity of the drawings which depict muqarnas projections may have required powers of visualization which went beyond the abilities of a book illustrator. The plan drawings superimposed on the grids form a separate category, both in their formal language and mode of representation. They differ fundamentally from the muqarnas drawings in their use of conventions to delineate spatial boundaries and wall divisions, as well as in their overall layout.

The use of similar grids by the Central Asian craftsmen in their designs for both decorative patterns and entire layouts of buildings were according to Bulatov – a Russian

[79] *Timurid Architecture in Khurasan,* p. 41.

scholar practicing in the 1950s – methods by which they established proportional harmony in their architecture.[80] Aside from this aesthetic function, grids also fulfill the purely practical criteria of facilitating the task of costing a building. A document, written by a 19th century traveler C. Purdon Clark who visited the masons of Persia, shows the use of grids to make cost estimates of buildings. As the Persian masons used grid papers to lay out their buildings, Clark learns that this practice allowed them to quantify the materials of construction. The formula is simple: each module of the grid on paper represented either one or four bricks. In this way, the masons were able to count the number of bricks which were necessary to lay out the building at the height of one brick course. This quantity was then multiplied by the number of bricks used in the height of the structure. Clark emphasizes the precision of this method:

> Error is not possible, as the squares confine the sizes to brick dimensions, and as only one system of bond is used the number of bricks required for the intended structure is easily computed by counting the squares and multiplying by the height after deducing the openings.[81]

The orthogonal grid of the Tashkent plans (fig. 29) shares one main connection with the radial grids which organize the muqarnas. They both quantify their subjects. However, as the modular grids were particularly useful for calculating the cost of a structure, they fundamentally differ from the radial grids used in muqarnas drawings, in which considerations of cost are less stressed than the formal complexities which characterize these features. We already noted that in medieval building practices a category of workers identified as clerks were in charge of administering the cost factor within constructions. The training of these individuals in arithmetic was also considered by Necipoglu, and recognized to distinguish them from the designers, who were more adept at practical geometry. The plans also utilize a representational language that is different from the muqarnas and pattern drawings. Not only do they depict buildings in their entirety, the convention of hatching is used within the plans to define the spatial limits of the walls. Muqarnas drawings in contrast employ an entirely abstract language of representation from which architectural features are excluded. The plans also convey

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[80] *Geometricheskaia garmonizatsiia v arkhitekture Srednei Azii IX-XV VV.* [Geometric harmonization in the architecture of Central Asia from the ninth to the fifteenth century.] I am using an interpretation of Bulatov's writing as made by Necipoglu. *Topkapi Scroll: Geometry and Ornament*, p. 9.

[81] *Transactions of the Lodge Quatuor Coronati, No. 2076,* pp. 100-101.

an application of geometry that is not based on constructive geometry. This suggests the possibility that they were executed by individuals other than the designers of muqarnas.

Conclusion

Medieval Islamic architects could not have constituted a distinct body of professionals whose social status and design expertise distinguished them from the mass of lay workers and craftsmen. Historical sources from the Timurid age lack the evidence to support strong divisions within the professional practice of architecture. Often the terms that designate an architect are difficult to translate, and interchangeable expressions for architect and craftsman highlight the close connections which united the education and responsibilities of these individuals. The sources also demonstrate that the knowledge of geometry as it was taught in medieval manuals was not strictly limited to the domain of architects. Kashi's mason who was able to make a survey illustrates that masons were able to function in roles which traditionally were not seen as a part of their training. An analysis of the historical sources also highlights the instrumental role that patrons had in both the conception and execution of architectural designs. While references to a few famous architects exist, they are only exceptional cases.

As the conclusions of this paper de-emphasize the role of architects within Timurid architectural practice, one fundamental question remains to be answered. If architects as they are conceived according to contemporary definitions were not found in Timurid building practices, how can we explain the complex building activities and the formal and stylistic innovations which characterize the architecture of the age? A few generalizations about the architecture of the Timurid age will suffice to illustrate its major formal and stylistic features while allowing us to speculate whether architects were necessary for the innovations that distinguish the architecture of the period.

Timurid architecture is marked by many innovations in form and decorative content. Characterized by their harmoniously proportioned features and novel structural solutions, Timurid buildings emphatically announce the emergence of a new architectural style. The invention of intersecting arches, the high double domes of royal constructions, and increasingly complex muqarnas vaults can be mentioned as some of the features which differentiate the design of Timurid buildings from the architecture of previous dynasties. Perhaps the best representation of consolidated Timurid architecture design can be found within one monument identified as the Madrasa al-Ghiyassiya, located at Khargird in contemporary Iran. Built in 1444, this free-standing building, which was to serve as a school, can be identified as a point of climax within the development of Timurid Imperial style of architecture.[82] In this building, both an emphasis on the composition of the façade and the harmony of its interior highly suggest the presence of a master-mind behind its design.

While the desire to erect buildings as free-standing monuments may not have been the decision of architects and can more appropriately be connected with the patron's desire to emphasize monumentality as a symbol of his sovereignty, this new trend in Timurid architecture resulted in concentrated attention on the design of facades and exterior features of buildings. In the madrasa at Khargird, the new concept of a visible façade results in a close consideration of the placement and size of the exterior features with an emphasis on their final visual effect. With two low towers in the corners that frame the central units of three niches and a central iwan (portal), the façade at Ghiyasiyya establishes a carefully measured visual crescendo that rises towards the centre (fig. 31). The rhythm that is created by the iwan opening in the centre and the flanking niches convey sensitivities to exterior compositions.

The true subtleties of this design, however, can only be understood by considering the attention to details. While the central iwan accents the point of entry, as it is both the widest and highest element of the facade, the flanking triple niches are composed as separate units in which the central niche is the widest. The play with the planar composition of the façade is reflected in the depth of the niches in which the two niches closest to the central iwan are also the deepest ones. This design move can be seen in the plan where the two outermost niches are shallowest of a series of three indentations in the façade (fig. 32). The effect of light on this façade and the shadows that are cast by the niches emphasize the visual effect of this design. While the intricate decoration that is applied to the surface of the façade can be attributed as the work of craftsmen, it is difficult to imagine that the composition of niches and the subtle variations in their spans was not directed by a sensitive designer.

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[82] *Iran*, vol. XIV (1976), pp. 79-93.

One of the significant contributions of Timurid building technology was the introduction of the intersecting arch. As a novel means to bridge the gap between a square chamber and a dome, the combination of intersecting arches with intricate muqarnas fillers reaches a high degree of refinement in Timurid architecture. Previously in Seljuq architecture, the transition between the brick chamber and dome – a problem which had also preoccupied pre-Islamic Sasanid builders – was achieved through a simple transition zone, consisting of four squinches in the corners which created an octagonal zone. The octagon was then surmounted by a sixteen-sided zone, on top of which the dome was placed. The predominance of surface in the combination of wall and squinches, however, created a massive spatial effect. The use of intersecting arches in Timurid buildings replaced the massive and heavy character of Seljuq designs with one that was based on slender ribs and dissolving surfaces. The spatial effect of the intersecting arches to form a lighter definition of space can be seen in the lecture hall to the south of the entrance at Madrasa al-Ghiyasiyya (fig 33). In this space, the ribs highlight the structural features of the building, while the stalactite muqarnas shells dissolve the surfaces in between.

The emphasis on the visual effect produced by the façade and the introduction of intersecting arches to function both as structural and aesthetic components within Timurid buildings are only two of the traits by which the architecture of this age is characterized. What remains a puzzle is, considering the nature of these innovations, it is difficult to imagine that they were introduced into the architectural palette of the period without the intervention of a principle designer. As isolated features, both the intersecting arches within the lecture hall and the niches on the façade at Khargird madrasa can be noted to identify a new style of architecture. Space, however, is not defined unless these isolated features are brought together to form closed and self-contained entities, which we understand to be buildings. How then, were these subtleties in design conceived and worked into completed buildings?

As the names of only a few and exceptional "architects" have survived from the Timurid period, the responsibilities and skills of a head designer had to be shared between a groups of craftsmen who were also the builders. A few possibilities can be considered to explain the mode of practice and the presentation of architectural ideas in this time period. Assuming a completely democratic environment, designs may have been worked out in the presence of a comity of designers, whose members consisted of the same craftsmen and builders who were responsible for the erection of buildings. Another possibility is that craftsmen, who had gained enough experience and proven their excellence, took on the lead role and acted as the principle designers of buildings. Less likely is the probability that the designers were the patrons or officials, who also had duties outside the realm of construction. Of course, the nature of the projects also determined the ways in which they were organized and conducted. As royal commissions required a large work force, made up of various groups of decorators and artisans, their management differed from small projects in which no such administrative or legal complications were involved.

If in fact designs were conducted in the presence of a comity and with inputs from a large group of individuals, the ways in which ideas were communicated needs to be addressed. As works on paper, drawings allowed easy transference and could be presented to workers on the site of construction. Drawings could also be used at a comity of craftsmen and builders to facilitate final decisions about designs. This would entail that all craftsmen were versed in the technical language of drawings and could also produce them. This possibility cannot be ruled out since, as was shown in this essay, there are no particular authors attached to medieval Islamic drawings and the techniques for transferring decorative details into built form find close reflections in the methods by which the craftsmen prepared their designs. As communicative devices between a large group of practitioners, drawings could only use a very controlled set of conventions.

If drawings and their conventions had in fact developed in direct response to practical requirements, the primacy of crafts in medieval Islamic building traditions inhibited their users from developing personal styles or introducing novel modes of representation. While elaborations on previously developed features were made possible through drawings, this did not result in experimentations with ideas that would transform the character of architecture. Decorations flourished, evolving through amazing conglomerations of colorful patterns and intricate muqarnas vaults were developed, but the austere harmony of Timurid buildings emphasized their connection to older monuments and the articulation of forms at large scales remained obstinately unaffected.

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Illustrations

Figures appear in:
Cover I: *The Topkapi Scroll*
Cover II: *Die gotischen Planrisse.*
1. *The Topkapi Scroll.*
2. *The Topkapi Scroll.*
3. *Die gotischen Planrisse.*
4. *Die gotischen Planrisse.*
5. *The Timurid architecture of Iran and Turan.*
6. *Die gotischen Planrisse.*
7. *The Topkapi Scroll.*
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16. *International Congress of the History of Art: Acts.*
17. *International Congress of the History of Art: Acts.*
18. *The Projective Cast.*
19. *RIBA Transactions* 1.
20. *RIBA Transactions* 1.
21. *Ilkhanidische Stalaktitengewolbe.*
22. *Ilkhanidische Stalaktitengewolbe.*
23. *The Timurid architecture of Iran and Turan.*
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30. *Timurid Architecture in Khurasan.*
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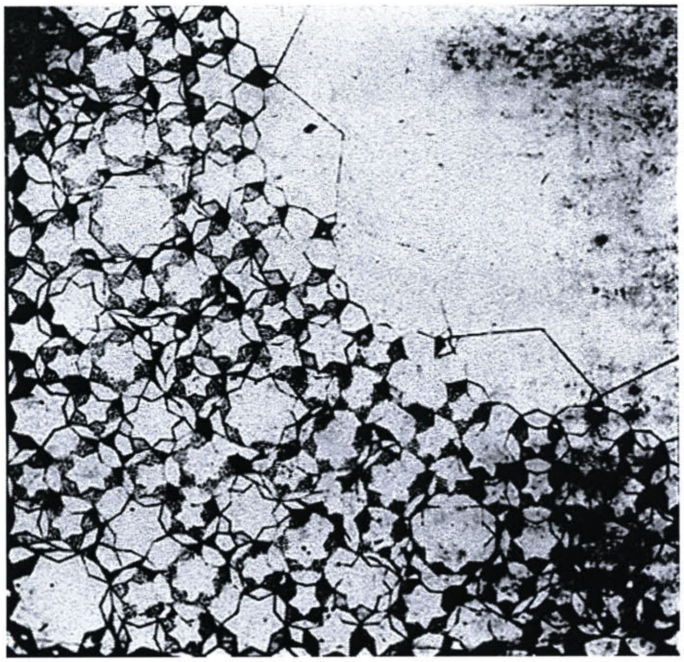


Fig. 1. Complex muqarnas plan from the Tashkent collection.

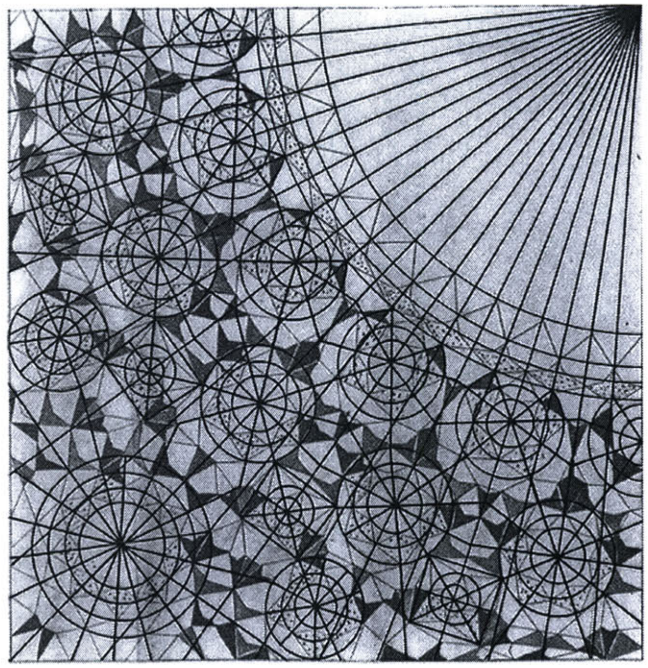


Fig. 2. Fan-shaped muqarnas showing geometric order.

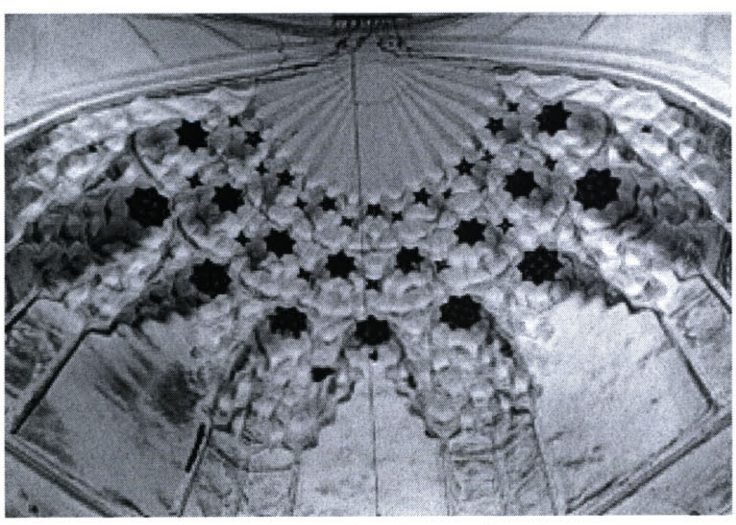


Fig. 5. Shrine of Taqi al-Din Dada, an example of muqarnas with an intricate arrangement of stars and polygons.

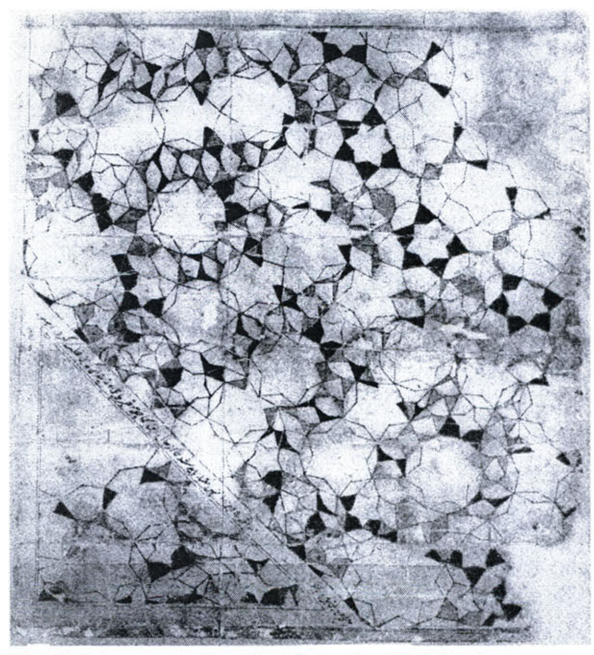


Fig. 7. Muqarnas drawing from the Tashkent collection with inscription.

Fig. 6. Rider's Stair at Prague cathedral.

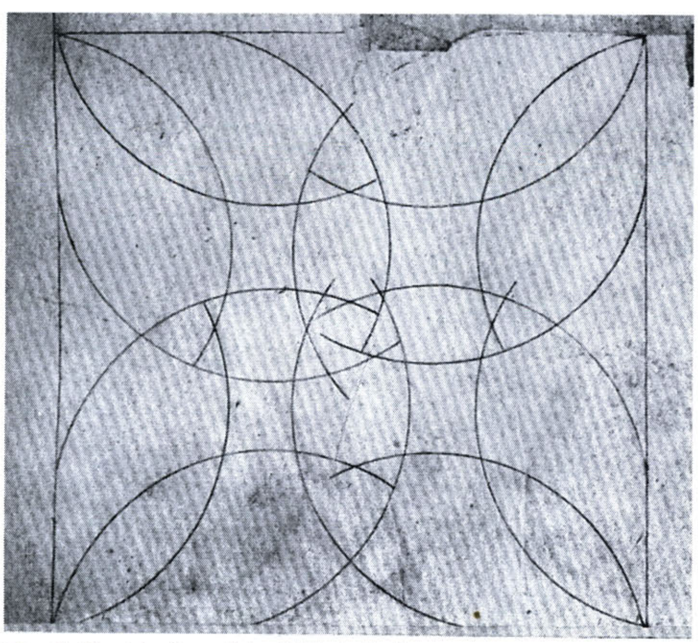


Fig. 3. Sketch plan of the Rider's Stair.

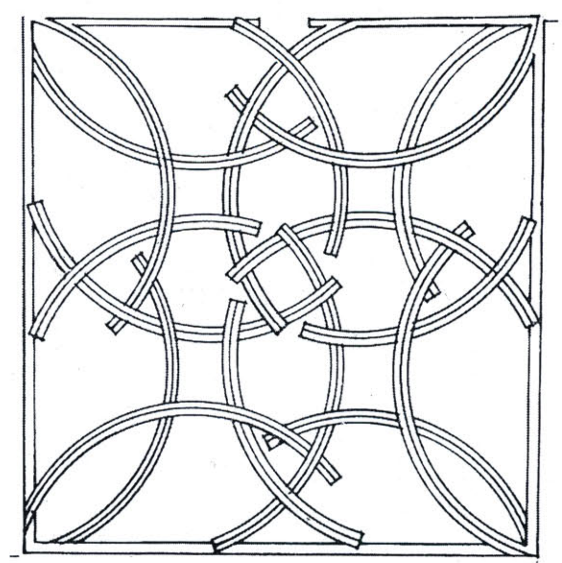


Fig. 4.Reconstruction of the vault plan based on the sketch drawing.

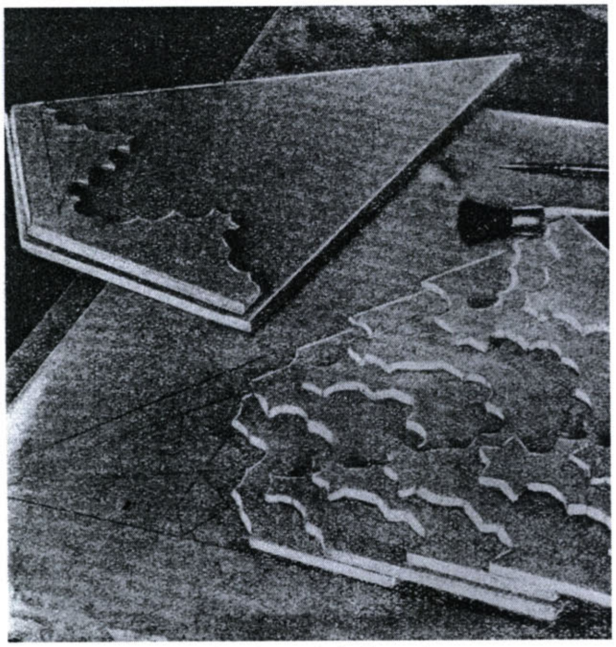


Fig. 8. The cut-out horizontal shelves that support the muqarnas tiers.

Fig. 10. The craftsman filling in the vertical modules of muqarnas.

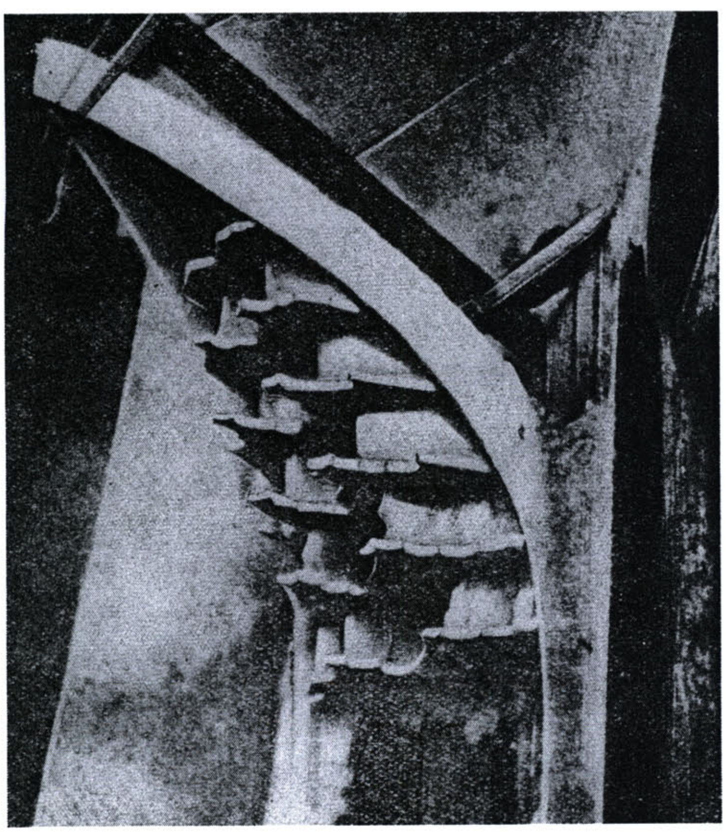


Fig. 9. The supporting shelves attached to the squinch. Note the difference between the horizontal layout of the muqarnas and vertical continuity of the Gothic rib as seen in figure 17.

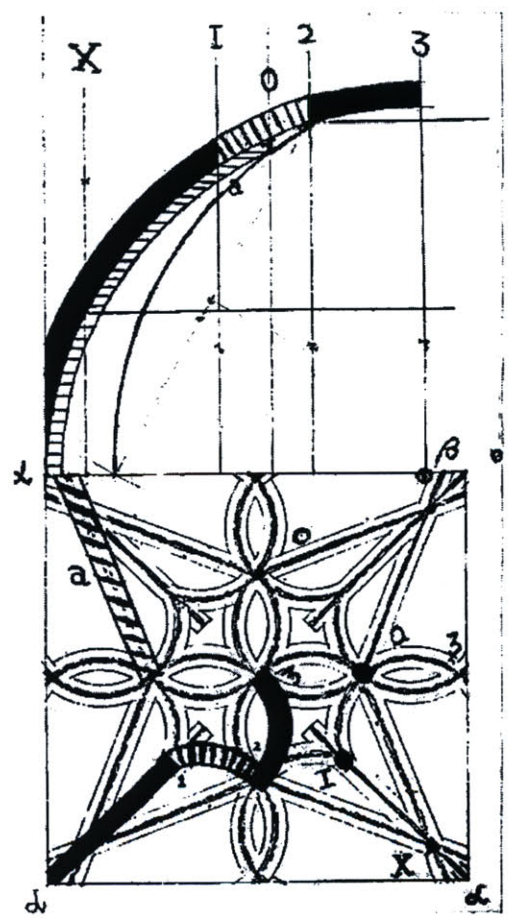


Fig. 17. Plan and vertical projection of a Gothic vault from the Dresden Sketchbook.

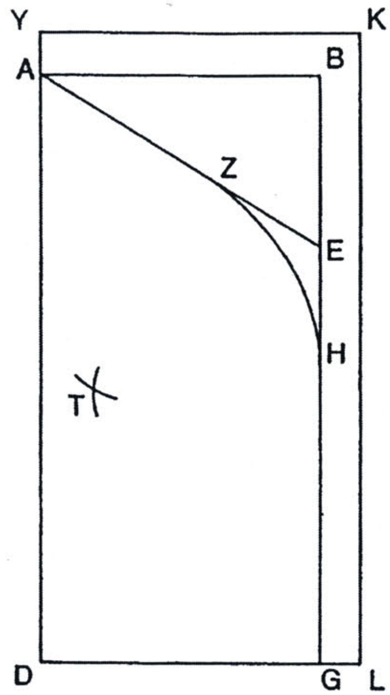


Fig. 11. (above) Madrasa of Saray Mulk Khanum, muqarnas suspended from brick structure.
Fig. 14. (right) Profile of the module of muqarnas based on Kashi's description.

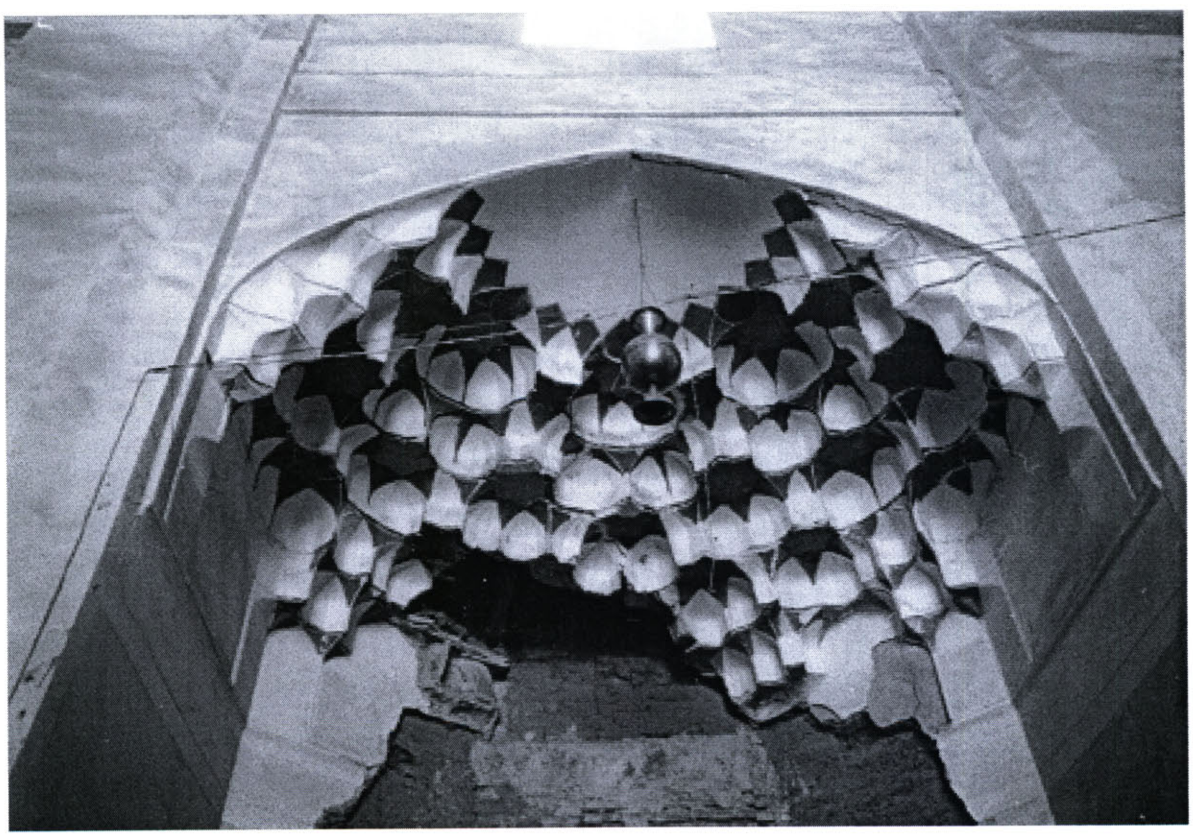


Fig. 12. Masjid-i Jami Ardakan, partly damaged muqarnas. Note the remains of horizontal supports on the left.

Fig. 13. Partial elevation from Strasbourg Cathedral

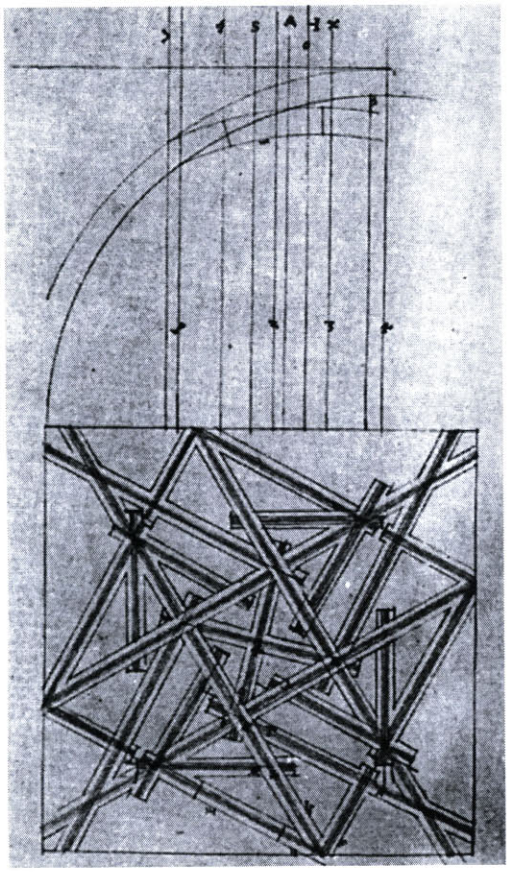


Fig. 16. Complex vault plan, the Dresden Sketchbook.

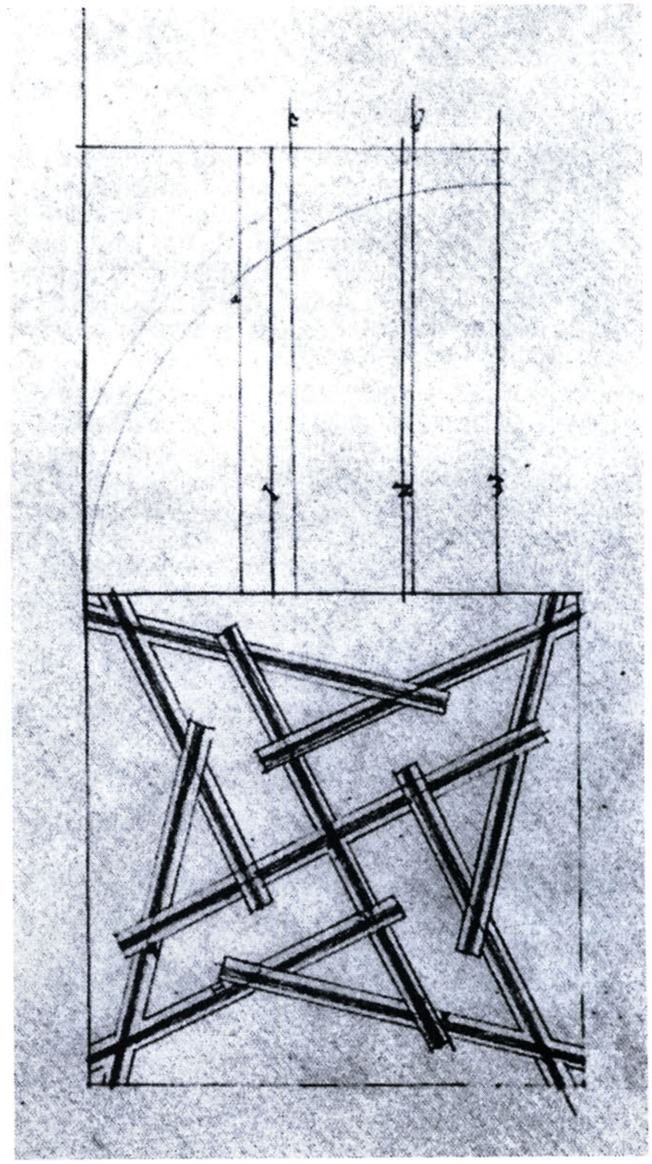


Fig. 15. Plan of vault with the principle arc drawn above, the Dresden Sketchbook .

Fig. 18. The cloisters at Gloucester Cathedral showing the intersecting fan vaults .

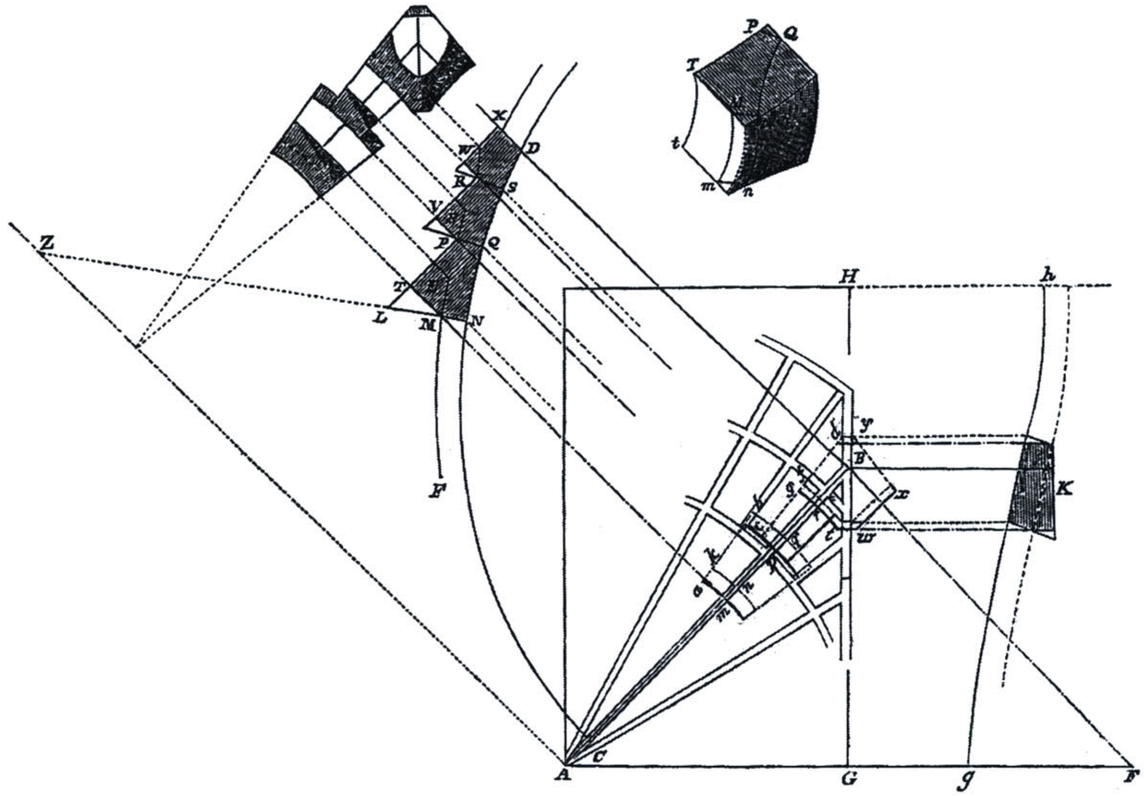
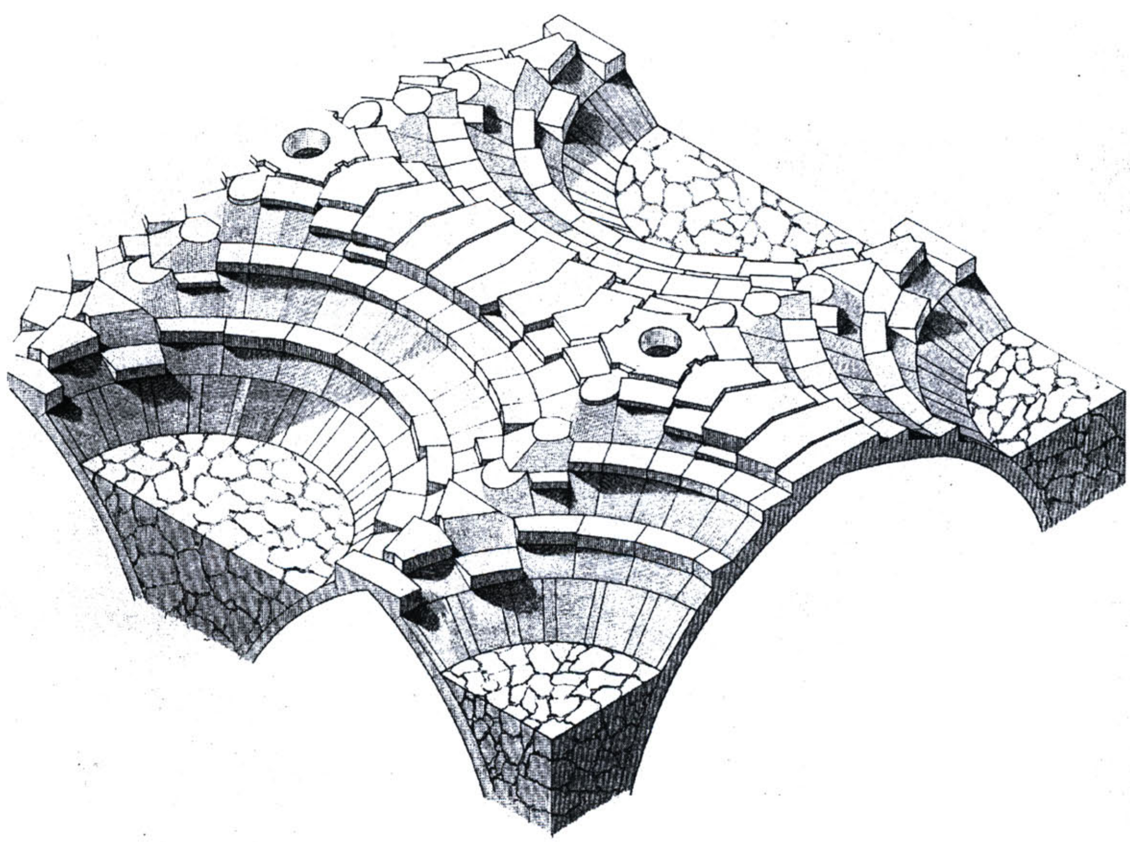


Fig. 19. Detail of interlocking stones within the fan vault at Peterborough Cathedral.
Fig. 20. Axonometric drawing showing the inverse side of the fan vault at Peterborough Cathedral.



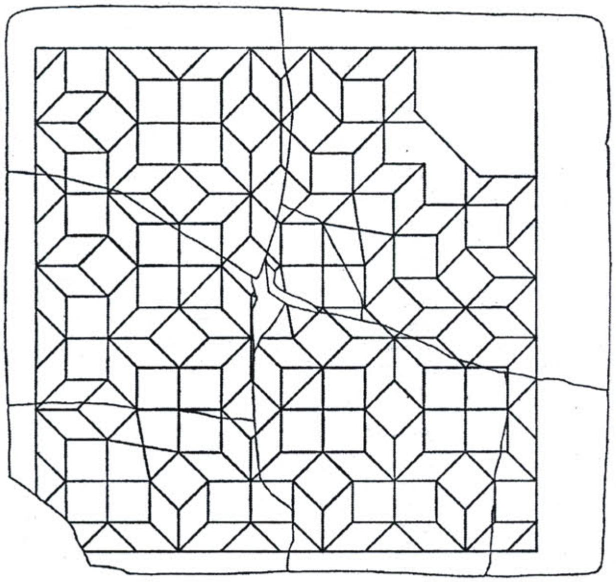


Fig. 21. Reconstruction of the muqarnas from Takhti Suleimon.

Fig. 22. The earliest example of a full-scale muqarnas drawing etched on a plaster slab.

Fig. 23. Construction of the Masjid-i Jami Samarqand.

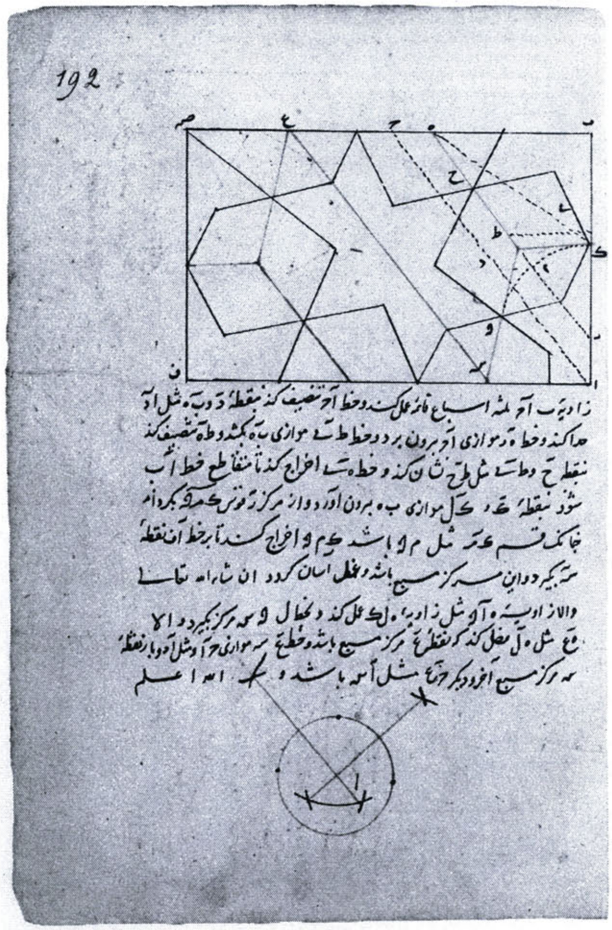


Fig. 24. Page from the anonymous treatise, "On interlocking similar or congruent figures," showing a geometric exercise with descirption.

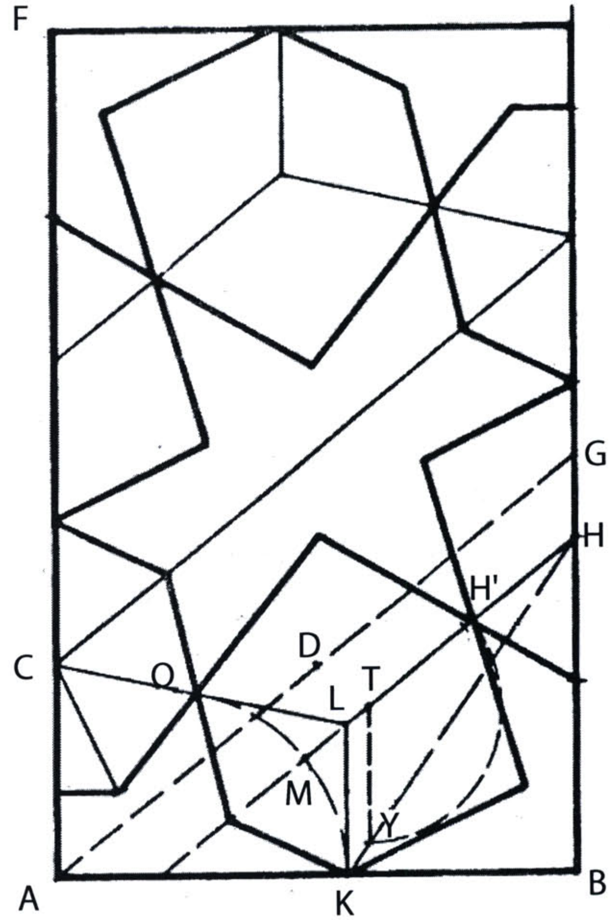


Fig. 25. The geometric exercise from figure 24.

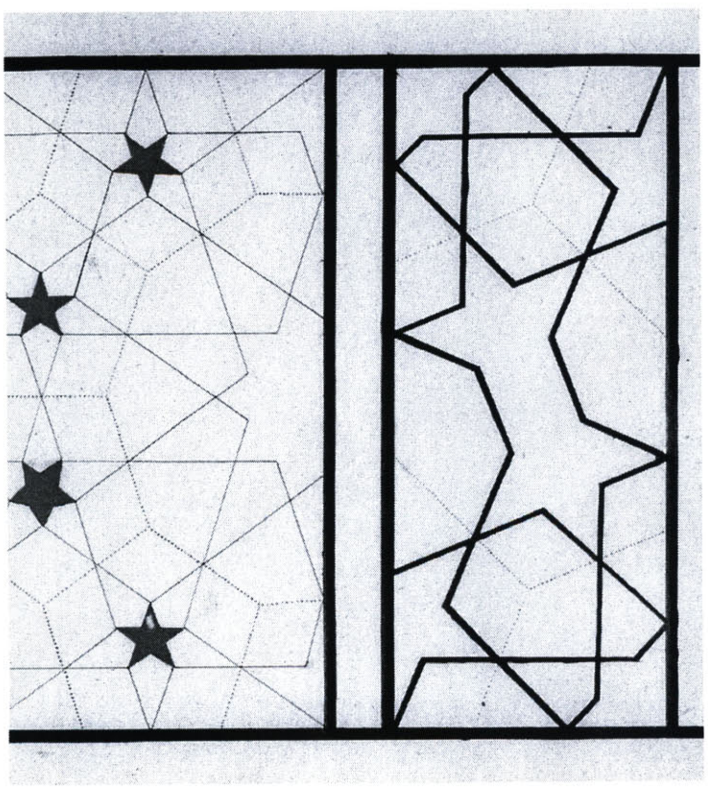


Fig. 26. Pattern from the Topkapi Scroll (dwg. 57).

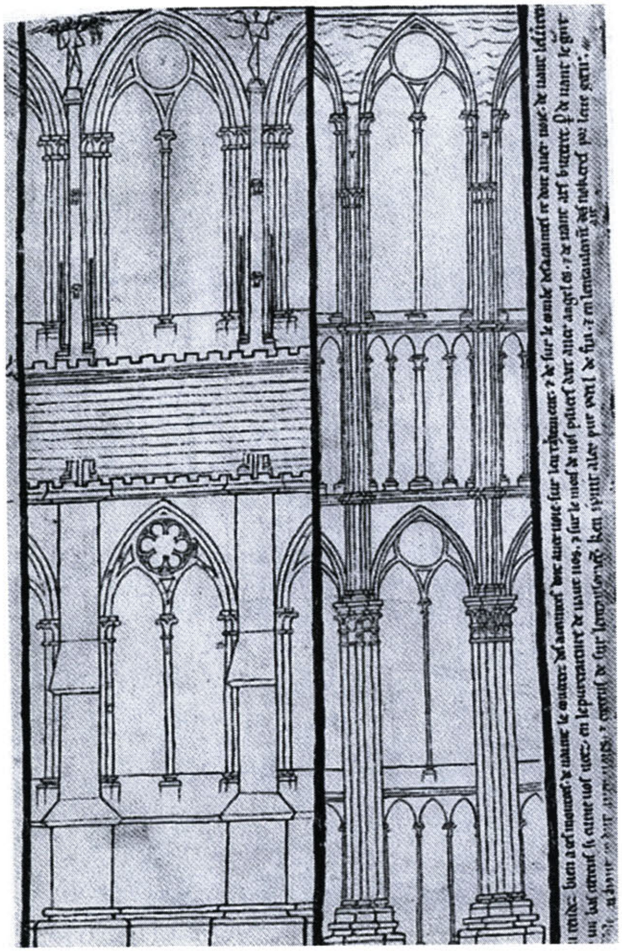


Fig. 28. Exterior/interior view of Reims Cathedral, Sketchbook of Villard de Honnecourt.

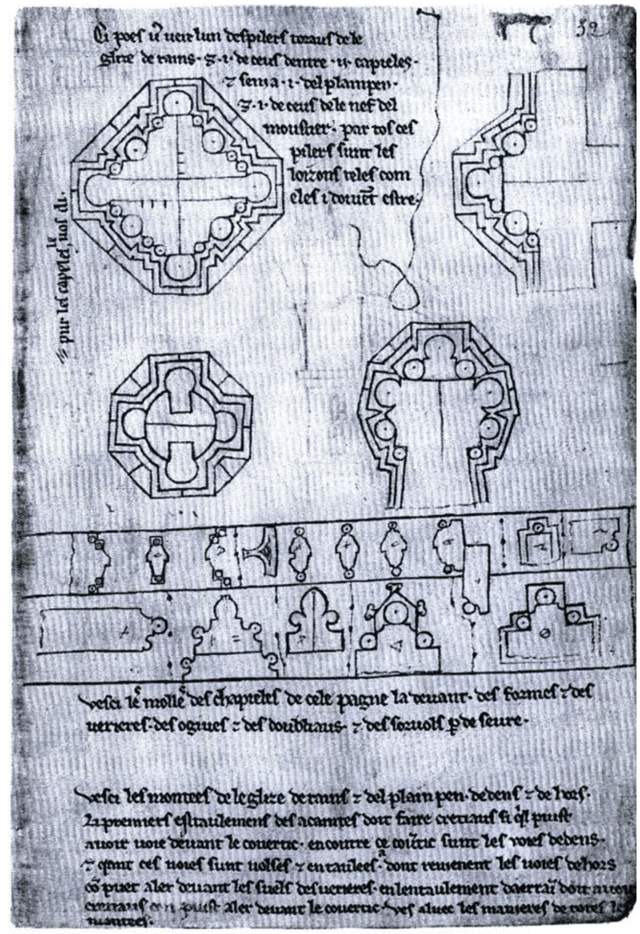
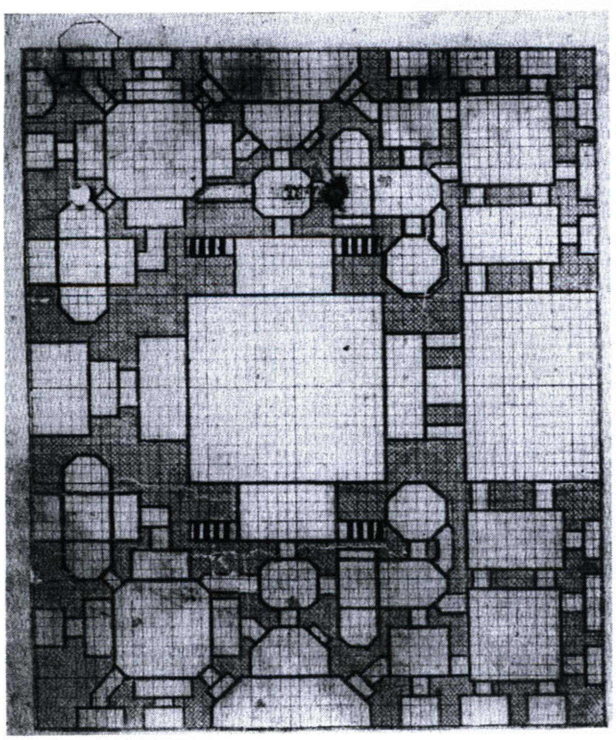


Fig. 27. Template profiles from interior of Reims Cathedra
Sketchbook of Villard de Honnecourt.



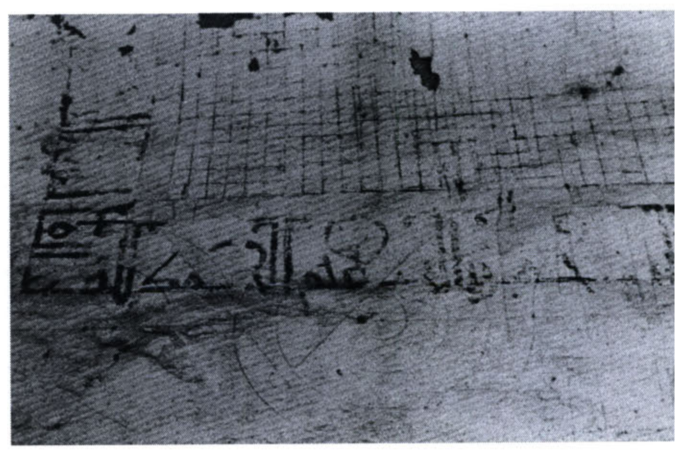


Fig. 30. (above) Masjid-i Safid, Detail of unfinished scheme for an inscription and painting.
Fig. 29. (left) Plan of an unknown building from the Tashkent scroll.

Fig. 31. Madrasa al-Ghiyasiyya, view of facade.

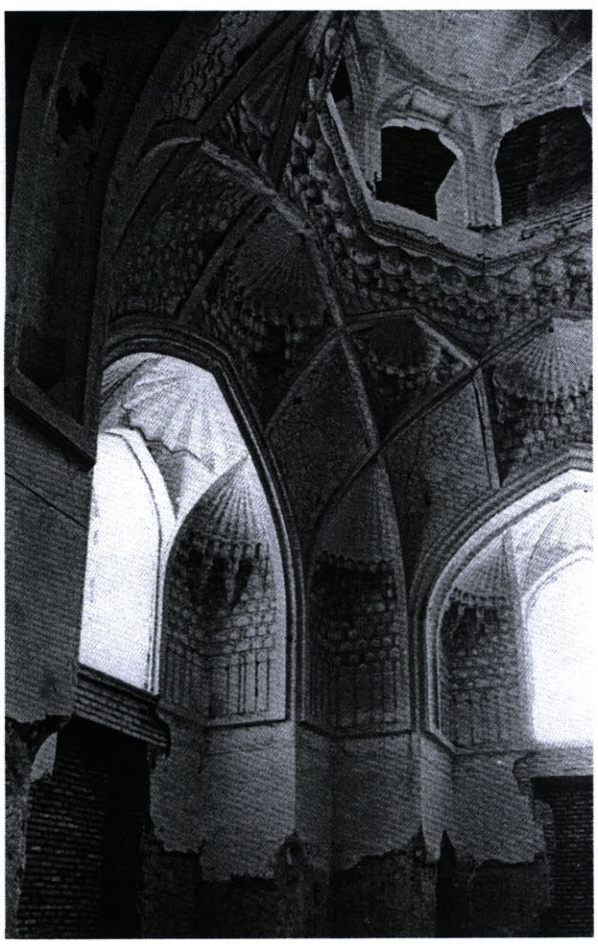


Fig. 33, Madrasa al-Ghiyasiyya, lecture hall.

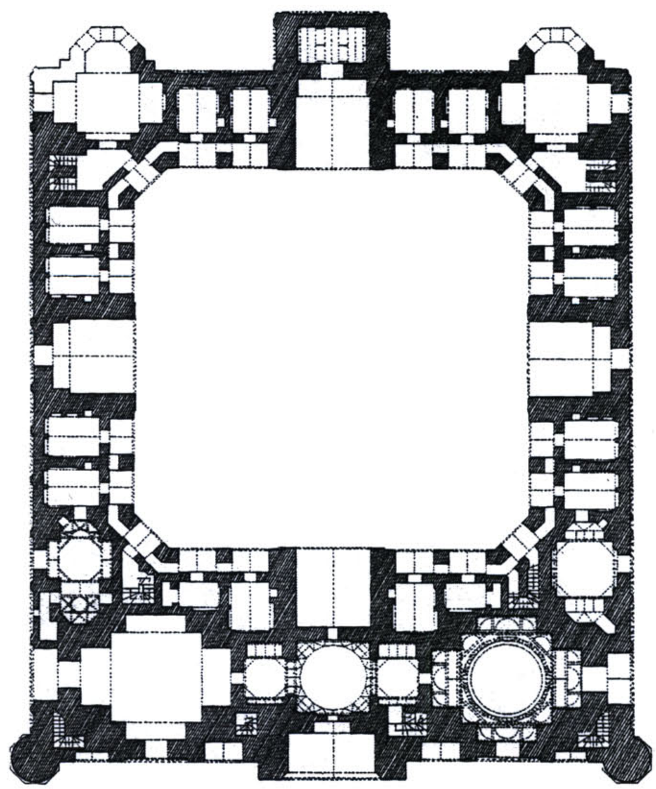


Fig. 32, Madrasa al-Ghiyasiyya, plan of second floor.