Nexus Network Journal (2022) 24:935–952
https://doi.org/10.1007/s00004-022-00623-x

NEXUS NETWORK JOURNAL
Architecture and Mathematics

RESEARCH

Rules of Geometries of Control in Muslim Architecture: Emergence and Conflicts of a Research Field in France (1863–1899)

Francisco Javier Girón Sierra[1]

Accepted: 11 June 2022 / Published online: 4 August 2022

Abstract

In the second half of the nineteenth century, studies and hypotheses on the geometric rules used in the past for setting up buildings experienced a growing momentum, fueled by the demands of a discipline in the making: the history of architecture. One area yet to be studied was the regulating geometric lines of Muslim architecture. This article describes how this research emerged and developed in France, highlighting its protagonists, hypotheses, and conceptual framework. The research was carried out by a small group of architects, engineers, and diplomats tied by professional or personal links: Vogüé, Mauss, Dieulafoy, and Choisy, being all of whom were in some way influenced by Viollet-le-Duc. Also discusses is why their sustained efforts failed to achieve a consistent overall picture. At the end of the nineteenth century, the task of describing the geometric of Muslim architecture and finding its place in the universal history of architecture was still open.

Keywords Geometrical rules · Muslim architecture · Eugène Viollet-le-Duc · Charles-Jean-Melchior de Vogüé · Christophe Edouard Mauss · Marcel Dieulafoy · Auguste Choisy

Introduction

In the second half of the nineteenth century, studies and hypotheses on the geometric regulating lines of architecture gained momentum as they became an integral part of an emerging discipline: the history of architecture. In addition to the hypotheses previously put forward on Roman architecture, historical studies were increasingly popping up: in the seventeenth century (Blondel 1675); those dealing with the possible layouts of Gothic architecture (Kerrich 1821; Wallen 1842; Billings

✉ Francisco Javier Girón Sierra
Franciscojavier.giron@upm.es

[1] School of Architecture, Universidad Politécnica de Madrid, Av. Juan de Herrera 4, 28040 Madrid, Spain

1840; Griffith 1847; Freeman 1848); of the temples of classical Greece (Lloyd 1860). From the middle of the nineteenth century, attempts were made to make a broader history. Essays seeking to discriminate procedures according to different architectures (Cresy 1865); Gwilt 1876) or theories aspiring to find a universal principle applicable to all architecture (Henszlmann 1860) emerged. Some authors even predicted what the geometrical characteristics of future architecture would be (Daly 1869).[1]

However, in the middle of the nineteenth century, a big piece was still missing: the regulatory geometrical lines of a whole cultural domain were yet to be studied: those of Muslim architecture.[2] In this article, we will trace how research on the regulatory layouts of this architecture was born and developed in France and what were its theses and hypotheses.[3]

For the nineteenth-century historian, the study of these layouts was a crucial issue since those diagrams could reveal, at a deeper level than the analysis of forms and styles afforded, were to locate the sources of architectural creation and follow their geographical transmission. This kind of research could question the originality of Muslim architecture among other architectural cultures, and decide whether it had played an active or passive role in the concert of the history of global architecture.

This article covers a time span that begins in 1863, with the publication of the first volume of Viollet-le-Duc's *Entretiens sur l'architecture,* and ends in 1899 with Choisy's *Histoire de l'architecture*, on the threshold of the twentieth century, tracing how this legacy was constructed over a period of three decades. It will show who the protagonists of this research were, their theoretical assumptions, and the discourses that underlay an apparently rational and positive approach.

[1] Another group consists of those who are more "prescribers" than historians, more interested in creating a method of control than in investigating the history of its use in architecture. One particular prolific author in this regard is David Ramsay (1798–1856).

[2] I see that while the two expressions "Islamic" and "Muslim" are found in the current bibliography, the preference seems to go in the sense of "Islamic". But there is also continued use of the term "Muslim", for example, in Dessus-Lamare (1931), Marçais (1954), Degeorge (2002). On the other hand, the authors cited in the article do not use the adjective *islamique* to refer to this architecture. Choisy clearly preferred to speak of Muslim architecture. The extensive chapter XIV (1899: 89) on this architecture is entitled "Architectures musulmanes", and in it, he includes both Persian and Arabic constructions (in addition to that, at the end of it, he has a section on *les écoles de l'architecture musulmane*). Vogüé also often uses the expression "Musulmane" (1864: 83): *c'est la première fois que nous voyons apparaître ce détail, qui joue un grand rôle dans l'architecture musulmane du moyen âge*. Dieulafoy, uses it on a single occasion (1883: 150): *Ces édifices … contenaient le principe de tous les tracés utilisés du III^e^ au VII^e^ siècle, dans les constructions sassanides, et, depuis le VIII^e^, dans l'architecture bysantine (sic) et musulmane*. But he prefers to refer to this architecture as Iranian or Persian. What seems to be at stake here is an important question: whether religion or race imposes a type of architecture. In conclusion, I have decided to maintain the term "Muslim" because it is accepted, and it is the one commonly used by the authors studied.

[3] We refer here to those studies that sought to establish the geometry of control for a whole building. Therefore, we will not deal with the vast field of Muslim decorative geometry, which was begun at that time by authors such as Jules Bourgoin (1879) and Leon Parvillé (1874).

The Question of Muslim Geometries of Control and its Context in the Seminal Hypothesis in Viollet-le-Duc's *Entretiens sur l'architecture*

In 1863, Éugène-Emmanuel Viollet-le-Duc (1814–1879) clearly established in the "Neuvième Entretien" (ninth discourse) of his *Entretiens sur l'architecture* (1863), the field of research in which the problem of the "Muslim geometry" was to be inscribed, and defined its place among the geometric layouts of architecture throughout history. This was an "invisible history" of architecture from which one could expect discoveries about forms of transmission and frontiers between architectural cultures, a field in which the undiscovered procedures of Muslim architecture could occupy a place, not well determined at the time.

For Viollet-le-Duc, there was no doubt that architecture, whether Egyptian, Greek, or Renaissance, had relied on geometric methods to provide its buildings. They all would have used the triangle as a fundamental element of their layouts, with a particular preference for the equilateral and its combinations.

Following these trains of ideas, Viollet-le-Duc begins to explore their possible existence in Muslim architecture, which immediately raises the question of their original focus and their potential dependence on systems generated in another culture. His hypothesis was this: the Nestorians, who in the fifth century had fled Byzantium after being declared heretics, settled in areas dominated by the Persians, later incorporated into Islam. And there, they would have eventually been responsible for the erection of "monuments of an extraordinary elegance, in which the study of proportions is pushed very far" (Viollet-le-Duc 1863: 431). Thus, a system of Greek origin would have been transported to Persia and, after that, to the world. This is an idea that elsewhere Viollet-le-Duc expresses explicitly: "what is agreed to call Arab architecture is only a derivative of the architecture of the Persians modified by the Greeks, that is to say, by the Nestorians" (1863: 431).[4]

Viollet-Le Duc concedes, however, that progressively these geometric procedures of Greek origin would have been taken by the Muslims—by renouncing other forms of expression—to a higher level: "The study of geometry thus became, among the Arabs, the main element, not only of the architectural structure but also of its decoration" (1863: 229).[5]

Confirming these hypotheses required fieldwork, surveys, and well-measured drawings. But for the moment, this was not the case. The regions Viollet-le Duc had in mind were not easily accessible, given the geopolitical circumstances of the time. The scarcity of written sources in French was only compensated by those works dealing with Muslim architecture within reach: the Spanish (such as *The Alhambra* by Owen Jones (Jones and Goury 1842), the *Antiguedades árabes de España* by Lozano y Casela (1780–1804), and the *Monumentos arquitectónicos de España* (Dorregaray 1859–1881). But these were works that provided little in geometric layouts and referred to the period of Umayyad Caliphate and later stages.

[4] This an all translations from the French are by the author.

[5] For a general overview of Viollet-le-Duc's position on Muslim art and architecture, see: (Çelik 2005: 20–37).

Viollet-le-Duc, finally, for the only drawing he presented (1863: 430), had to rely on an old engraving by Pascal Xavier Coste (1837). Here Viollet-le-Duc shows how the Greek builders of the arcades of the Cairo mosque would have used the triangle to define their proportions (Fig. 1).[6]

Thus, the "construction" of a theory of the geometric layout of Muslim architecture depended on the development of fieldwork, and that depended on taking advantage of favorable political or diplomatic circumstances. Viollet-le-Duc's hypothesis indeed called for them and was an invitation to seize the opportunity when it arose. However, the mental framework he had created was imbued with certain inconvenient a priori biases (including a racist perspective, which denied Arab peoples the capacity for original thought).[7] His authority may also have conditioned future research in several ways: it made it difficult to recognize a distinct identity of Muslim architectural procedures; it emphasized the weight of Persia (inhabited by peoples of the Aryan race); it tilted the balance to find some continuity with Greco-Roman designs based on the triangle.

A First Fieldwork: Vogüé's Description and Meaning of the Regulating Lines of the Mosque of Omar in Jerusalem (1864)

A year after the publication of this *Entretien's chapter,* a first fieldwork survey appeared in 1864, which seems to confirm Viollet-le-Duc's hypothesis, although not in Persia, but in Jerusalem. It was found in *Le temple de Jérusalem* by Charles-Jean-Melchior Vogüé (1829–1916), a diplomat turned archaeologist and historian. His work originated in a campaign that took advantage of the opportunity to draw up a precise topography of Jerusalem and explore the possible traces of Egyptian architecture in Jewish architecture. On the express recommendation of Viollet-le-Duc, he was accompanied by a young architect, Edmond Duthoit, who assisted him in this task.[8]

In the course of this work, the Mosque of Omar (Quobbet-es-Sakhra) attracted his attention. As he had done for the Solomon's Temple, he looked for its possible geometrical ordering lines. To have a solid basis for this research, he resorted to the most precise measurements possible: on the one hand, he borrowed those taken in 1833 by Frederick Catherwood, Thomas Arundel, and Joseph Bononi, whose drawings James Fergusson had reproduced (Fergusson 1847: section facing page 104, plan plates at the end) and on the other hand, the surveys of Duthoit (Fig. 2).[9]

[6] Viollet-le-Duc (1873, unnumbered preface) praises Coste, but, at the same time, sees in his work an example of an approach to oriental architecture already surpassed. Bourgoin's work on the rules of the Arabic decorative system is, for him, the promise of the work to be done.

[7] On Viollet-le-Duc's ethnic prejudices, see the chapter devoted to "Instinct and Race" in Bressani (2014: 333–379).

[8] For further research on Vogüé, see the research data platform of the INHA: https://agorha.inha.fr/ark:/54721/591a5db4-d4da-49db-927c-28eb9ce5015e.

[9] Fergusson's interpretations in this book led to a great controversy, as Alexandrina Buchanan has recorded (2013: 139–149). On Catherwood's surveying and drawings of the Mosque, see (von Hagen 1950: 34–7).

Vogüé sets out, in a drawing combining two half-sections, the hypothesis at which he arrives. The geometric layout of the Mosque would be based entirely on the triangle: "By submitting the heights to geometric analysis, I recognized that they had been determined by combining triangles: I found there the two triangles of ancient monuments" (1864: 81). That is to say, the equilateral and Egyptian triangles, the same ones, as Vogúé pointed out, that were for Viollet-le-Duc in his *Entretiens sur l'architecture* "the basis of the design of most Greek and Roman monuments" (1864: 32). (Fig. 3).[10]

These results were even more significant, as they were also the same ones that would define the Temple of Solomon, where, as Vogüé had observed: "by an ingenious concordance, the same points satisfy both the combinations of the two triangles" (1864: 80) (Fig. 3). Therefore, Viollet-le-Duc's thesis of the triangle as the primary figure of any layout seemed to be fulfilled in these architectures outside the Western framework. The supposed Greco-Roman origin was, for Vogüé, ratified: "it is interesting to discover in this building, which is Muslim, but built by the Christians, the maintenance of the architectural traditions of antiquity" (1864: 81).

On the other hand, in a back-and-forth movement, this scheme could have encouraged the use of similar regulatory lines based on triangles in medieval Christian architecture. Vogüé points out that the Crusaders may have taken the Mosque of Omar for the Temple of Solomon, which served as a model of imitation (1864: 81, note 2). This fits in with Viollet-Le Duc's observation that "the equilateral triangle was one of the signs adopted by the Templars" (1868: 16).[11]

Refuting Vogüé's Interpretation: Mauss and the Specificity of Oriental Methods (1869–1888)

Five years later, in 1869, another study of the same Mosque of Omar, conducted by the architect Christophe Edouard Mauss (1829–1914), a student of Constant Dufeux, yielded different results.

Mauss had been sent to Jerusalem (1862–1874) by the French government as an architect attached to the Ministère des Affaires Étrangères with the mission of

[10] It is interesting to note the rapid international diffusion and attention Vogüé's studies deserved. Some of Vogüé's drawings, not yet published, were discussed at the Cambridge architectural society in 1864, in a session where "the Rev. George Williams, of King's College, delivered a lecture on two beautiful coloured drawings of the interior of the Dome of the Rock (…) in his possession for a time, through the kindness of the Count de Vogüé, to whom they belonged" (Anon. 1864: 380).

[11] Unlike other authors, Vogüé's approach to Arab cultures is not based on ethnic considerations, but cultural: "Under the name of Arabs, I do not mean to designate a race, but this whole, more political than ethnographic, of which the Koran was the law, of which Arabic became the language". His vision of his architecture is rather positive; it "rejuvenates" Byzantine art and finally achieves a character of its own (1864: 90–91).

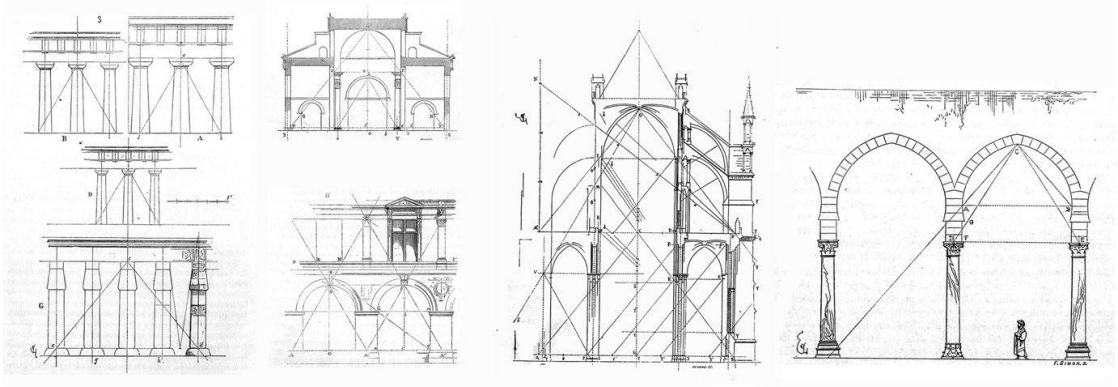

Fig. 1 The steps of research on the regulating lines of Muslim architecture. According to Viollet-le -Duc, the triangle has always been the primary element throughout history. Image composed of examples of Egyptian, Greek, Roman, Renaissance, and Gothic architecture, respectively: (1863: 398, 404, 411, Fig. 10 between 408 and 409). On the right, geometric construction applied over Coste's drawing of the Amrou Mosque in Cairo (1837: 430)

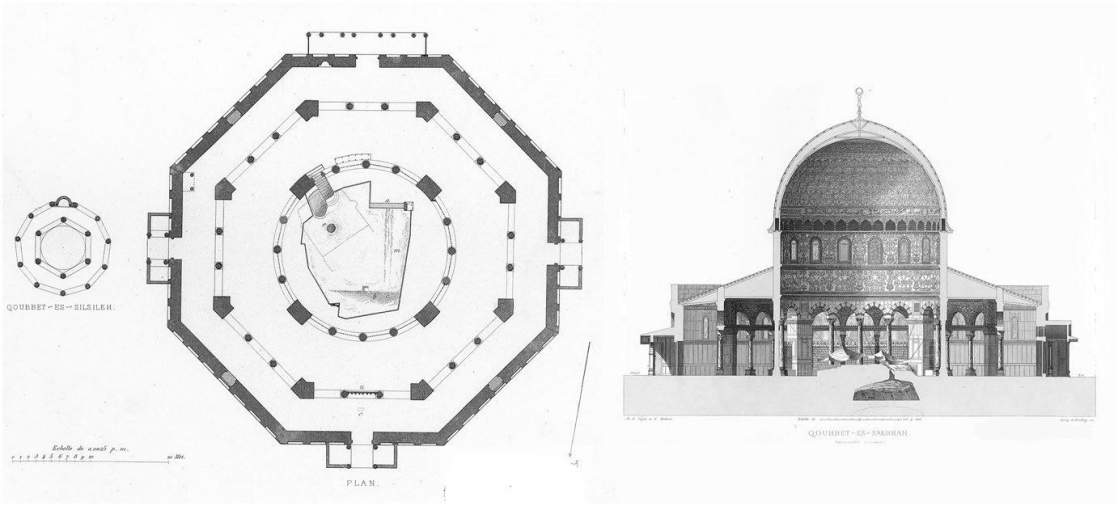

Fig. 2 The section and plan of the Mosque of Omar in Vogüé's *Le temple de Jérusalem* from the surveys of Fergusson and Duthoit. Image: composition of two plates from (Vogüé 1864, Pl. XVIII and XIX)

restoring the church of Saint Anne. In 1866, one of the important works he had in hand was reconstructing the great Dome of the Church of the Holy Sepulcher.[12]

In this context, he decided to carry out a comparative study with the dome of the Mosque of Omar. This investigation led him to discover in the latter, despite their "striking similarity in plan" (1888: 6), an "oriental" principle of design different

[12] Mauss also took part in other expeditions, such as Félicien de Saulcy's exploration of the Holy Land in 1863. Saulcy (1865) offers a vivid description of Mauss's activity. There is an obituary in the *Journal de Rouen* (Anon 1914). For Mauss's biographic references and archival sources see: https://agorha.inha.fr/ark:/54721/4decd5b3-35d3-4356-b3a3-50389091e33a.

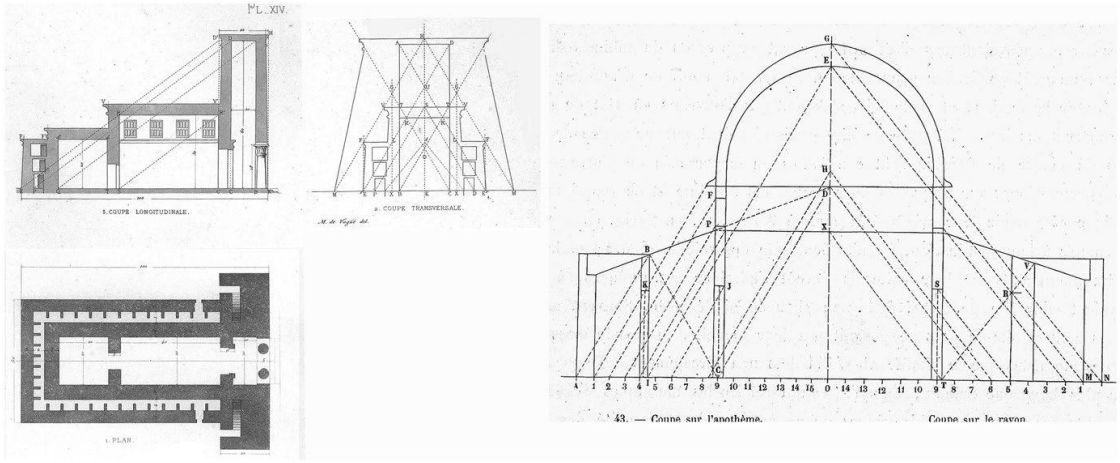

Fig. 3 The similarity of the geometrical layouts based on the triangle of the Temple of Solomon and the Dome of the Rock, according to Vogüé. Image: on the left, a selection of drawings from the Temple of Solomon (1864, pl. XIV); on the right, the Dome of the Rock (1864: 81, Fig. 43)

from that of the West. The results of this research were published in the *Revue Archéologique* (Mauss 1888).[13]

According to his measurements, the geometry of the ground plan of the Holy Sepulcher emerges from "the superposition of two equilateral triangles whose vertices determine the outer circle of the gallery and whose intersections determine the inner circle of the rotunda" (1888: 12–13). This layout would fit in very well with the hypotheses on the design of Templar architecture as described by Viollet-le-Duc in his *Dictionnaire* (1863. IX, 16-17) (Fig. 4).[14]

However, in the mosque of Omar, the geometrical operations take a very different course. In his quest to find the geometric construction that unites the two octagons of the ground plan, Mauss found a solution radically different from that of the Holy Sepulcher: "The plan of this mosque proceeds from the square as that of the rotunda of the Holy Sepulcher proceeds from the equilateral triangle" (1888: 15).

It is a process in which both the basic figures and the process of generation development are radically different from those assumed by Viollet-le-Duc. The construction grows from a center outward, but this growth does not follow a linear direction from the focus: it does not rest on the circle's radii (as, for example, happens with the sequence of the intersection of successive squares and circles shown by Serlio (1551: 1, 3). It is produced on lines that do not touch the center of the construction, launched from the perimeter of inscribed figures (squares) in concentric circles. Their intersections create a sort of stellar design that grows

[13] Mauss (1890: 217–239) provides a detailed picture of the context of power rivalry and religious conflicts that hampered archaeological and conservation work in the Holy Land at the time.

[14] The Rotunda of Paris, a twelfth-century templar building, for example, was supposed to be defined by the interpenetration of two equilateral triangles. Viollet le Duc (1863: IX, v. "temple", 16–17, Fig. 3) draws the scheme and attributes to it numerological and symbolic reasons: the founders of the order of the Temple were nine in number (square of 3); they were not allowed to ordain new brothers until after nine years. The great Rotunda of Paris had six pillars inside and twelve bays outside.

successively. The points of intersection are supported by polygons of increasing size (octagons in this case) (Fig.5).[15]

This procedure regulates more than just the ground plan. Mauss also notes that the square and not the triangle would have been used to determine the height measurements in the section. "Like the plan itself, the cross-section of the Mosque of Omar proceeds from the square, and this feature is reflected in the subdivisions of the height" (1888: 19).[16]

Given these results, he concludes that behind these layouts, one can detect a different spirit from Western architecture. This, he thinks, could not only be seen in the Byzantine buildings but could even be found in all the architecture of antiquity: "perhaps in the use of these methods … lies the charm of ancient compositions" (1888: 18). He believed that his hypothesis would oppose everything that had been established until then about geometries of control. It would be possible when counting with more fieldworks "to demonstrate that all the heights of ancient buildings are derived from their plan and not from a combination of triangles" (1888: 18).

In other words, he proposes a break with Viollet-le-Duc's thesis that imagined a historical "continuity" of regulatory schemes based on the triangle among the different architectural cultures. And for Mauss, all this has a profound significance. This way of concatenating geometric figures could reflect a mentality, another way of thinking and approaching problems in the East, which can also be detected in its construction. When he later describes the wooden dome, he discovers that the elements and their disposition differ amazingly from Western "logic," to the extent that he states that "we still find here the trace of this reverse conception of the things which distinguishes the Occident from the Orient" (1888: 26).

[15] In Mauss's words (1888: 15): "The plan of the Mosque of Omar (designed by the Byzantine architects) is generated by two squares inscribed in the circle of the dome. The prolongation of their sides engenders lines that intersect at points that determine the regular octagon limiting the first side aisle. The sides of this first polygon, extending in turn, determine two other squares to which a circle is circumscribed. Drawing from the center of the construction radii passing through the vertices of the first octagon, we obtain another octagon inscribed in this last circumference which bounds the second side aisle". Amraoui (2015: 71–8) displays the sequence of steps of this geometric construction and discusses recent contributions and other alternatives. Later, Mauss (1889: 195–200) returned to this layout to ratify it from the metrological point of view, seeking to ascertain the system of measurements employed: "the two initial dimensions were 100 and 150 feet exactly, given to the diameters of the two circles that delimit the outer contour of each of these buildings. This double observation does not destroy the idea of the geometrical layout previously stated. It is, on the contrary, the confirmation of the same".

[16] For a review of the hypotheses of the geometrical lines of the mosque, see Creswell (1989: 19–42), section on the Dome of the Rock). For its place and significance among other encircled concentric buildings, see Shalev-Hurvitz (2015).

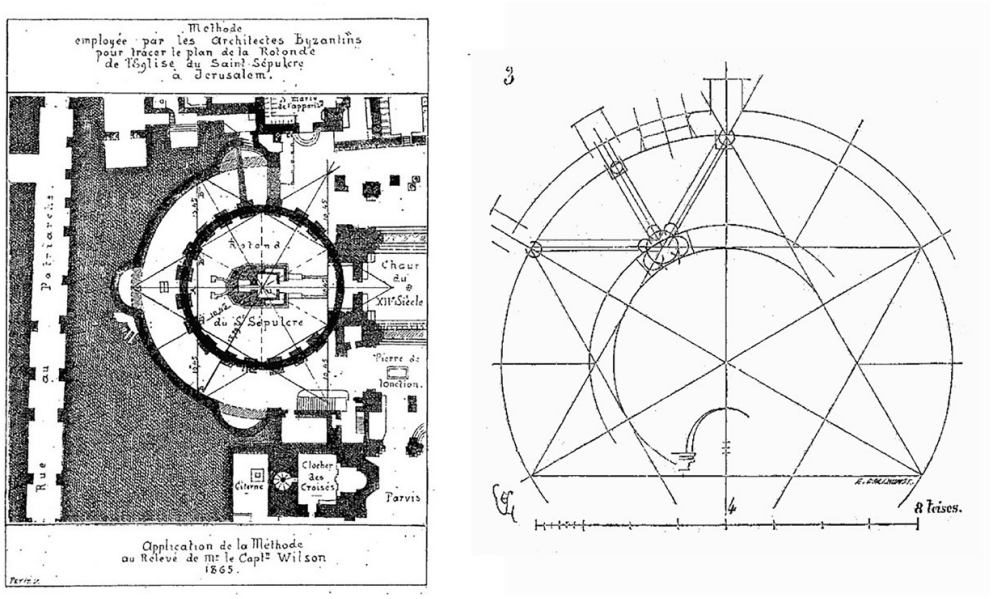

Fig. 4 On the left, the geometry of the plan of the Holy Sepulcher in Mauss. Image: (1888: 13, Fig. 5); on the right, the twelfth-century Rotunda of the Paris Temple, defined in Viollet-le-Duc's *Dictionnaire* by the superposition of two equilateral triangles. Image: Viollet-le-Duc (1863: IX, 16–17, Fig. 3)

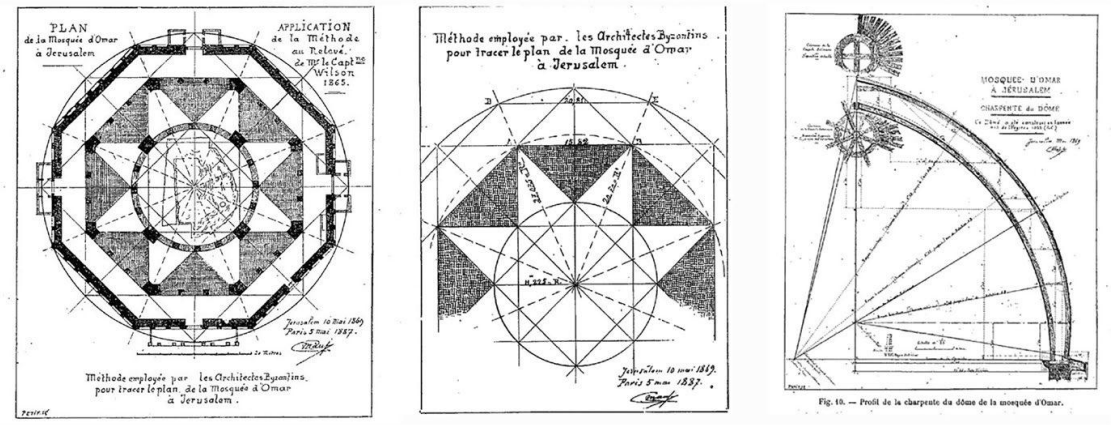

Fig. 5 Geometric and constructive peculiarity of Oriental architecture according to Mauss. On the left: The geometry based on the square (and the successive prolongations of its lines) regulates the plan of the Mosque of the Rock. Image: Mauss (1888): 19. Fig. 7). On the right, drawing of the profile of the carpentry of the Dome. Image: Mauss (1888: 28, Fig. 10)

Geometrical Rules in Muslim Persian Architecture: Dieulafoy's Survey of Cha-Khoda-Bendé Mausoleum (1883)

Almost twenty years after the publication of the *Entretiens* (and five years before Mauss's article appeared), another fieldwork, this time carried out in Persia appeared. It was the subject of a contribution by Marcel Dieulafoy (1844–1920) published in 1883 in the *Revue générale de l'architecture et des travaux publics* (1883: 97–104, 145–151, 193–197, 241–243, pl. 23–24), which did not fully agree with Viollet-le-Duc's theory.

Dieulafoy, an engineer trained at the École nationale des ponts et chaussées de Paris, was posted in Algeria until 1870, where his interest in archaeology was awakened. Later, in the 1880s, encouraged by Viollet-le-Duc, under whom he had worked for four years in the commission of historical monuments, he undertook two expeditions to Persia with his wife Jeanne to study Sassanid and Achaemenid architecture (the first took place between February 1881 and April 1882; the second to excavate in Susa, between February and May 1885).

According to his wife, Marcel was "deeply persuaded that Sasanian Persia had had an overwhelming influence on the origins of Islamic architecture and that it was through the study of the monuments of Ḵosrow and Šāpūr that it would one day be possible to substitute the ingenious theories for ingenious theories reasoning based on solid foundation" (quoted in Amiet 1995).[17] During one of his exploratory trips, he had the opportunity to survey a thirteenth-century Muslim building: the mausoleum of Cha-Khoda-Bendè, on the Kongorolang plateau. This building, which occupies a relevant place in the history of domed buildings, was, for Dieulafoy, "the most vast and remarkable building after the Muslim conquest" (1883: 98) in Persia.[18]

In examining and measuring this monument (1883: 97–104), he found that it was regulated by "very simple lines defining all the building elements" (1883: 101). Its geometric layout operated (as Viollet-le-Duc had asserted happens in Gothic architecture) from inside-out: first, the interior is defined, and then, the external forms. As Dieulafoy shows in his drawings (1883: 101, Figs. 4 and 5, 103, Fig. 6), the system also controls minor elements such as the arcatures (Fig. 6).

For Dieulafoy, the logic of this layout had an important historical significance: its total concatenation was characteristic of certain "superior" cultures: "the Iranians, like the Greeks and the masters of the works of the Middle Ages," (1883: 100) shared the same harmonious spirit. Something that for someone who supported Viollet-le-Duc's ethnic prejudices to a large extent was "a most interesting fact to note" (1883: 101).

But that was as far as the coincidences with his master went. Even though this building did not represent a sample of the first stages of Muslim architecture, Dieulafoy's hypothesis contradicted Viollet-le-Duc's convictions about the Nestorians having inspired its geometrical order.

This thirteenth-century Muslim mausoleum would have used rhythmic forms from a more distant past, "known and used in Persia from the earliest times" (1883: 98). The layout was faithful to the principle followed by the Achaemenid and later Sassanid builders of "linking the main dimensions of buildings to a module" (1883: 100). The geometrical lines regulating the domes of the palace of Sarvistan, which he had described in his *Art Antique de la Perse* (1884: IV, 27–29, Fig. 22–23),

[17] For a summary of Dieulafoy's life and works, see also the "note biographique" in Cagnat (1921). For online searching, explore the extensive collection of Diuelafoy's work in: https://www.persee.fr/authority/246363.

[18] For recent sources and bibliography on this monument, read the document for its inclusion in UNESCO's World Heritage List (UNESCO 2005).

evidenced this relationship. Due to a chronological error, he traced back those domes to the Achaemenid period (sixth to fourth centuries B.C.).[19]

Choisy and the Form and Place of Muslim Geometries of Control in a Global History of Architecture (1899)

At the end of the nineteenth century the Ponts et chaussées engineer Auguste Choisy (1841–1909) published a pioneering and comprehensive *Histoire de l'architecture* (1899) At the beginning of his career, being a promising figure in construction history, Choisy had found the warm support of Viollet-le-Duc. Therefore, it is not surprising that he took up the subject of geometric designs from a global perspective under the lasting influence of his former mentor. A peculiar feature of Choisy's work is that he regularly devoted a section to the geometric procedures followed in each period. Accordingly, there is a brief section dedicated to Muslim systems of proportion.[20]

This was an architecture he knew firsthand. He had encountered it on at least two occasions: in Turkey, when he was preparing his *L'art de bâtir chez les Byzantins* (Choisy 1883), and in Algeria, where in 1881 he led an expedition to map out a possible route for the Trans-Saharan railway.

On the other hand, Choisy and Mauss had known each other for a long time: they were already in contact when he worked on his Byzantine construction. The relationship was still alive in 1899 since Choisy acknowledges that the tracing lines of the Syrian arc (1899: II, 115, Fig. 8) is based on an unpublished drawing, "a document given to me by M. Mauss".[21]It is therefore not surprising that for his section on the rules of Muslim architecture, Choisy offers an axonometric version of the Mosque of Omar,[22] in which Mauss's geometrical regulating lines are shown (1899: II, 96, Fig. 7) (Fig. 7).

[19] Dieulafoy was probably not unaware of Mauss's hypotheses. He maintained cordial ties with him. In *L'Art antique de la Perse* (1885: 100), he said that he owned un unpublished drawings of a small building located at Rabbath-Ammân "to the extreme kindness of M. Mauss, the eminent restorer of the Holy Sepulcher … I beg Mr. Mauss to accept the expression of my gratitude".

[20] Mandoul (2008: 194–200) devotes a section to Choisy's approach to geometrical and modular systems of proportions in his *Histoire de l'architecture*. The activity of the French engineers of the École nationale des ponts et chaussées is striking in this regard: Choisy will resort for other periods to the theories of engineers such as Auguste Aurès (1806–1894) (on Greek metrology and modulation) and Charles Babin (1860–1932) (on Egyptien and Persian Achaemenid rules). The latter was part of Dieulafoy's expedition to Persia.

[21] Choisy had in his *L'Art de bâtir chez les Byzantins* (1883, 27, 148), thanked Mauss for giving him some first-hand notices. He also borrowed from him (1899: I, 74) some discoveries on the pyramids' metrology, and Assyrian measures (1899: I,87).

[22] Choisy (1899: II, 770) labeled this drawing "Mosquée à dôme de charpente: La Sakhra à Jérusalem (Mauss, Mosquée d'Omar: revue archéolog)". This seems to be a common assumed misname, as Vogüé (1864: 2) warned about this mistake: *la célèbre rotonde improprement nommée Mosquée d'Omar et que nous désignerons désormais sous son véritable nom de Qoubbet-es-Sakhrah, ou Coupole de la Roche.* But later on (1864:80) when describing his geometrical layout, he writes: *C'est dans un des angles de ce parvis que s'élève le Qoubbet-es-Sakhrah, vulgairement connu sous le nom de "Mosquée d'Omar".*

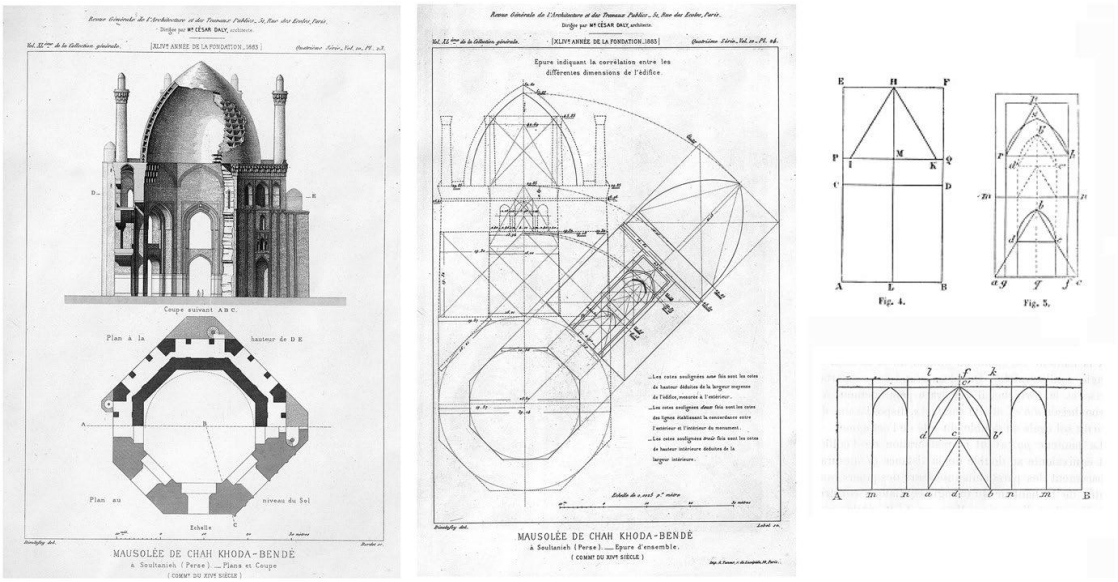

Fig. 6 On the left, the geometrical layout of the mausoleum of Cha-Khoda-Bendè in (sic) (Soltaniyeh is the current transcription) based on the concatenation of triangles and squares. Dieulafoy linked it to those he believed have been used in the Achaemenid Persian architecture. Image: (Dieulafoy 1883: pl. 23–24). On the right, top: the width of the section as the starting point of the construction and rules for the chapels; bottom, lines controlling the outdoor gallery. Images: (1883: 101, Figs. 4 and 5, 103, Fig. 6)

Choisy's conclusions endorsed Mauss's opinions, stating the existence of a distinctive geometrical method in Arabic architecture. It was a geometry that shared some patterns with decorative arts. The layout of the Mosque of Omar reminded him of the arabesques Bourgoin had collected in *Les éléments de l'art arabe* (1879). For him it was evident that:

> "those graphic canvases… extend to the plans of the buildings themselves" (1899: II, 117) (Fig. 7 center).[23]

He also takes up the arguments of Dieulafoy, who was a close friend from his youth.[24]Although he does not reproduce Dieulafoy's drawing, his text underlines how in Sultanieh's scheme, all the measurements, including the vertical ones, "derive from the diameter of the circle inscribed in the polygon of the ground plan" (1899: II, 117). This is a system that, for Choisy, in agreement with his friend's opinion, connects with the ancient Achaemenid geometrical rules. To prove this point, he invites the reader to peruse the chapter on Persia, where he reproduces Dieulafoy's geometrical analysis of Sarvistan (1899: I, 137). As he says elsewhere: "Muslim art

[23] On Choisy's considerations on Arabic planar geometry see also the section "les arabesques" (Choisy 1899: II, 109–110). Bourgoin's interpretations are summarized in Choisy (1899: II, 112–113). For him, the geometrical architectural lines resembled the patterns of textile design: "It seems that, by a habit of race, the sedentary Arabs transferred to their architectural decoration the decorative solution of the hangings of their previous nomadic life" (1899: II, 110).

[24] The intellectual implications of this close relationship between Dieulafoy and Choisy have been explored in Girón (2009: 201–234).

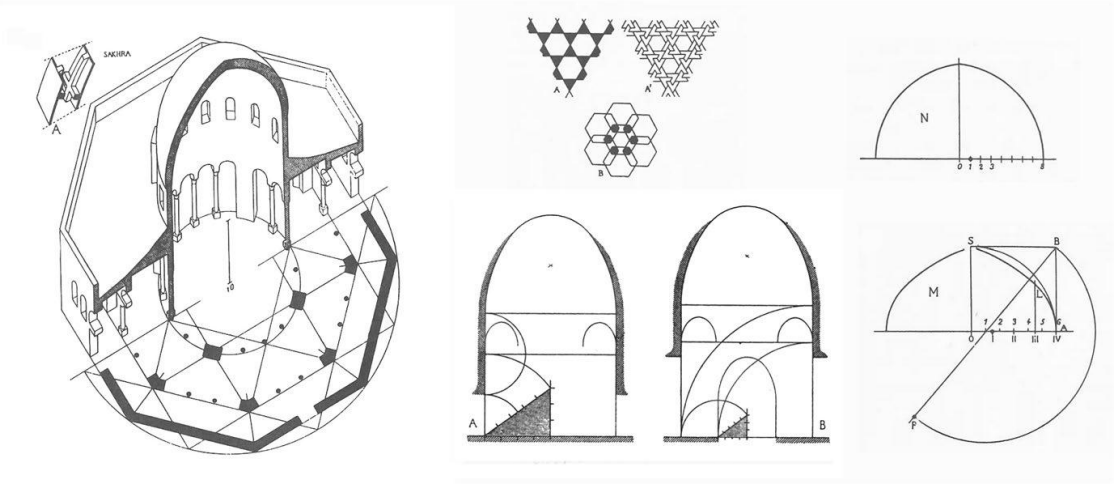

Fig. 7 Choisy's synthesis. On the left, axonometric drawing showing Mauss's hypothesis. Image: (1899: II, 96, Fig. 7). On the center up, his comparison with the geometrical patterns of Arabic flat decoration in Bourgoin (1879) and bottom, with Sarvistan's layout borrowed from Dieulafoy (1884: 22–23) Image: (1899: II,113, Fig. 4) and (1899: I,137) respectively. On the right, top, tracing of Syrian ogive from an unpublished Mauss drawing, and bottom, Persian arch after Dieulafoy. Image: (Choisy 1899: II, 115, Fig. 8) and (Choisy, 2: 116, Fig. 9) respectively

will only be the continuation and development of the vaulted architecture of Firouz Abbad and Sarvistan" (1899: I, 152) (Fig. 7, center).[25]

In his synthesis, Choisy diplomatically avoids pointing out the conflict between these two geometrical explanations and Viollet-le-Duc's assumptions. He also seems deliberately silent about Vogüé's diagrams with which he probably disagreed.[26]

Choisy sees no contradiction in asserting both the originality of Arab geometry and the ancestral antiquity of the Persian patterns that inspire it. He wisely overcomes this obstacle by suggesting a link: the star-shaped geometric patterns of the floor plans of Arab buildings could derive from Persian ornamental motifs. Mauss's plan reminds him of "a star, a widespread design in Persian decorations, the vertices of which mark the corners of the perimeter and the position of the interior pillars" (1899: II, 117).

But when did this cultural transfer between Persian and Arab cultures take place? Choisy does not say explicitly, although from what he says elsewhere, one can conclude that it would probably have been at the beginning of the Arab domination since, for him, the emergence of original and creative local schools in the Arab world could only have taken place during a short period, one which could have lasted "at least a century" (1899: I, 136). It is striking that his hypothesis is based simply on ethnic prejudice. What is original in Arab architecture belongs to:

[25] Dieulafoy in the 4 vol. of his *L'art antique de la Perse* (1884: 27–29, Fig. 22–23) describes and traces the Sarvistan diagrams to which Choisy alluded.

[26] Although Choisy clearly appreciated Vogüé's scholarship, he evoked his work on Solomon's temple when dealing with the constructive features of the Dome of the Rock (Choisy 1883: 147). Years later Choisy (1899, 1: 221–22) again cited Vogüé's interpretation of Solomon Temple and his Egyptian triangles hypothesis. Choisy also relies on him in his discussion of the relationships between Syria and Occident (1899: II, 56, 58, 73, 179). On his own side, Vogüé (1865–1877: 21) praised Choisy's "excellent" 1873 book on Roman construction.

> …the works of a population of half-breeds combining with the aspirations of the Arab race a sense of art and, to a certain extent, an inventive spirit which the pure Arab does not possess in any degree. The flowering was short: the mixed races have superior qualities, but they cannot be transmitted (Choisy: II, 136).

Therefore, it is a fusion – a "combination of blood", if I may use the expression and not the simple influence of foreign actors or forms that would have given rise to the uniqueness of Arab architecture. Choisy thought that too much weight had been given to those influences: "We are too much inclined, I believe, to look at the Arab buildings as exclusively executed by architects called from outside" (1899: II, 135). Persian Byzantines and Copts may have had, but a nuanced role, "similar to the Italians called in France to build our Renaissance monuments" (1899: II, 135). Although the movement from Persia is not "a simple transmission of the mother architecture—as each province imparts a character of its own to the art" (1899: II, 135), all Muslim architecture shared "the same spirit that prevails in the geometrical solutions" (1899: II, 135). Choisy concluded eventually that "these seemingly capricious architectures are, in fact, a constructed geometry; only a simple law could establish order in the complexity of their designs" (1899: II, 117).

Conclusions and Further Research

This first examination of the theories on Muslim geometric rules in the second half of the nineteenth century may be completed with future research. We have mentioned the problems of surveying them in situ. But France had easy access as a colonial power to parts of the Maghreb in the studied period. It was a suitable place for further investigation. Proof of this is Dieulafoy's (1922) studies in the last stage of his life on the proportional system of the Hassan Mosque in Morocco, which he thought corroborated his earlier hypotheses.[27]

The French government sent scientific missions in which architects and engineers could participate. We mentioned earlier how the architect Edmond Duthoit (1837–1889), encouraged by Viollet-le-Duc, had assisted Vogüé as a surveyor and draughtsman. This architect was commissioned in 1872 by the Ministry of Public Instruction and Beaux-Arts to undertake a scientific mission to Algeria. (Duthoit 1873: 305–326) From then on, every year, he spent several months documenting and restoring the local architecture, maintaining an interest in revealing the geometric patterns of its decoration (Anon 1890; Duthoit 1873: 28). His radius of action would

[27] Dieulafoy "asked in 1914 to be reappointed and was sent to Morocco, under Governor-General orders, General Lyautey. In Rabat, Marcel Dieulafoy submitted a proposition for an archaeological exploration of the site of the Hassan Mosque".
(https://heritage.bnf.fr/bibliothequesorient/en/jane-dieulafoy-art). According to Dieulafoy (1922: 313–314), the architects of Yakub el Mansour "remained faithful to the Chaldean-Persian traditions, represented by the graphic combination of the equilateral triangle". The Halicarnassus' Mausoleum ("a Greek adaptation of the Chaldean ziggurat or tower") and the inscriptions related to the Temple of Bel Marduk in Babylon would be the proof of such an origin.

even cover a vast region. He would later say, "From Constantinople to Spain along the Mediterranean, I have drawn an incalculable number of Arab buildings origin or deriving from this art" (Duthoit 1936: 65). The result of all this activity must have been findings and theories in the field of Arab geometry, which Viollet-le-Duc echoes in the preface to Léon Parvillée's book (1874: II): "as for most of the (Arab) monuments, both Mr. Parvillée and Mr. Duthoit agreed on using certain triangles to obtain satisfactory proportions".[28] We also know that other official missions to the region, such as those of Henri Saladin (1851–1923) in Tunisia, investigated the geometric rules of the monuments of different cultures.[29]

In the documents collected during of these journeys to North Africa, would we find new lines of interpretation hitherto ignored? Fortunately, some scholars, such as Nabila Oulebsir (1994) and Miryam Bacha (2009: 159–178), have focused on these missions, bringing valuable new sources to light. Future research on the archival material preserved may help to complete the story of the discovery of the regulatory lines of Muslim architecture in the nineteenth century.

It is worth noticing, as we have seen, that the different authors we have discussed here gave different answers to the existence and form of the geometric layouts of Muslim architecture, moving in a cultural context of sources and references, generally French, that were familiar to them. In future inquiries, it would be interesting to address what was raised in this regard in other circles, especially the English, and their eventually influence. Relations at the scholarly level were fluid on both sides of the channel, and the authors cited here were followed with interest, as evidenced by the fact that Viollet-le-Duc (in 1864), the Marquis de Vogüe (in 1879), and Choisy (in 1904) were awarded the RIBA Royal Gold Medal.

Funding Open Access funding provided thanks to the CRUE-CSIC agreement with Springer Nature.

[28] Viollet-le-Duc (1874: II), in his preface to Léon Parvillée's *Architecture et décoration Turques au XVe siècle* commented on Duthoit's work, saying, "I had made on the monuments of the Middle Ages similar observations. Therefore, we can admit that at the time of the crusades, in the East, as in the West, there were applicated certain geometrical formulas in the construction of buildings".

[29] See the proportions and regulating lines of the Punic mausoleum of Dougga in Saladin (1893: 483–485).

References

Amiet, Pierre. 1995. Dieulafoy, Marcel-Auguste. *Enciclopaedia Iranica*, Vol. VII, Fasc. 4, pp. 399–401. Online : https://iranicaonline.org/articles/dieulafoy-2. Accessed 22 May 2022.

Amraoui, Bellavès. 2015. Le tracé du Dôme du Rocher à Jerusalem. *Architectonics, Mind, Land and Society*. Universitàt Politècnica de Catalunya. 27: 71-82

Anon. 1864. Cambridge architectural society (record of sessions). *The Ecclesiologist* XXV(CLXV): 375–384.

Anon. 1890. *Edmond Duthoit, Architecte, 1837–1889*. Amiens: Yver et Tellier.

Anon. 1914. Christophe Edouard Mauss, architecte français 1829–1914. Nécrologie. *Le Journal de Rouen et des départements de la Seine-Inférieure, et de l'Eure*, n. 357, 23 décembre 1914. https://www.archivesdepartementales76.net/

Bacha, Myriam. 2009. La constitution d'une notion patrimoniale en Tunisie, XIX-XX siècle ; émergence et apport des disciplines de l'archéologie et de l'architecture. In Baduel, Pierre-Robert, Ma'had al-Buḥūth al-Maghāribīyah al-Mu'āṣirah. Chantiers et défis de la recherche sur le Maghreb contemporain, 159–178. Paris: éditions Khartala, Tunis : Institut de recherche sur le Maghreb contemporain.

Blondel, François. 1675. *Cours d'architecture enseignée dans l'Académie royale d'architecture*. Première partie. Paris: Lambert Rouilland.

Billings, Robert William. 1840. *An attempt to define the geometric proportions of Gothic architecture: As Illustrated by the cathedrals of Carlisle and Worcester*. London: T. and W. Boone.

Bourgoin, Jules. 1879. *Les éléments de l'art arabe: les traits des entrelacs*. Paris: Librairie de Firmin-Didot et Cie.

Bressani, Martin. 2014. *Architecture and the Historical Imagination. Eugène-Emmanuel Viollet-le-Duc, 1814–1879*. Surrey: Ashgate.

Buchanan, Alexandrina. 2013. *Robert Willis (1800-1875) and the Foundation of Architectural History*. Woodbridge, Suffolk: Boydell Press in association with Cambridge University Library.

Cagnat, René Louis Victor. 1921. Notice sur la vie et les travaux de M. Marcel Dieulafoy, *Académie des Inscriptions et Belles-Lettres*. Paris: Publications de l'Institut de France, n.27.

Çelik, Zeynep. 2005. *Commemorating the Empire: From Algiers to Damascus. Edges of Empire: Orientalism and Visual Culture*, Edited by Jocelyn Hackforth-Jones, Mary Roberts. Oxford: Blackwell Publishing. 20–37.

Choisy, Auguste. 1899. *Histoire de l'architecture*, 2 vols. Paris: Gauthier-Villars.

Choisy, Auguste. 1883. *L'art de bâtir chez les Byzantins*. Paris: Librairie de la Société Anonyme de Publications Périodiques.

Coste, Pascal-Xavier. 1837. *Architecture arabe, ou Monuments du Kaire, mesurés et dessinés, de 1818 à 1826*. Paris: Firmin Didot.

Creswell, Keppel Archibald Cameron. 1989. *A short account of Early Muslim Architecture, Revised and supplemented by James W. Allen*. Aldershot: Gower Publishing.

Cresy, Edward, 1865. *Encyclopaedia of civil engineering, Historical, Theoretical, and Practical*, Chap. XXXI, pp. 1579–1636. London: Longmans, Green, and Co.

Daly, César. 1869. De l'architecture de l'avenir. A propos de la Renaissance française. *Revue générale de l'architecture et des travaux publics* 27: col 10–71.

Degeorge, Gérard and Yves Porter. 2002. *The Art of the Islamic Tile*. Paris: Flammarion.

Dessus-Lamare, Alfred. 1931. *Notes sur la terminologie de l'architecture musulmane*. s.n.

Dieulafoy, Marcel. 1883. Mausolée Chah-Khoda-Bendè. *Revue générale de l'architecture et des travaux publics*, 40 : 97–104, 145–151, 193–197, 241–243.

Dieulafoy, Marcel. 1884. *L'art antique de la Perse. Achéménides, Parthes, Sassanides. Partie* 4. Paris. Ve A. Morel.

Dieulafoy, Marcel, 1885. *L'art antique de la Perse. Achéménides, Parthes, Sassanides. Partie* 5. Paris: Librairie des imprimeries réunies.

Dieulafoy, Marcel. 1922. La Mosquée d'Hassân [article] *Mémoires de l'Institut de France*, 42 : 167–321.

Dorregaray, José Gil, ed. 1859–1881. *Monumentos arquitectónicos de España. / Publicados á expensas del Estado, bajo la dirección de una Comisión especial creada por el Ministerio de Fomento*. Madrid, Impr. y calcografía nacional.

Duthoit, Edmond. 1873. Rapport sur une mission scientifique en Algérie. *Archives des missions scientifiques et littéraires,* 3e série, vol. 1 : 305–326.

Duthoit, Edmond. 1936. *Un Amiénois en Orient, Edmond Duthoit, architecte, 1837–1889*, *Conférence faite à la séance des Rosati Picards le 21 Juin 1935.* Fontenay-le Comte : Imprimerie Moderne.

Fergusson, James. 1847. *An essay on the ancient topography of Jerusalem, with restored plans of the temple, &c., and plans, sections, and details of the church built by Constantine the Great over the Holy Sepulchre, now known as the mosque of Omar*. London: J. Weale.

Freeman, Philip. 1848. *Proportions in Gothic architecture.* Cambridge: Cambridge Architectural Society.

Girón, F. Javier. 2009. Persia, Dieulafoy y Choisy: el debate sobre la influencia persa en la arquitectura occidental. In *Auguste Choisy (1841–1909). L'architecture et l'art de bâtir. Actas del Simposio Internacional celebrado en Madrid,19–20 de noviembre de 2009,* eds. Francisco Javier Girón, and Santiago Huerta, 201–233. Madrid: Instituto Juan de Herrera.

Griffith, William Pettit. 1847. *Ancient Gothic Churches, Their Proportions and Chromatics*. London: Gilbert and Rivington.

Gwilt. Joseph. 1876. Principles of proportion, in *An encyclopaedia of architecture.... revised with alterations and considerable additions by Wyatt Papworth*. 898 -1023. London: Longmans Green and Co.

Henszlmann, Imre.1860. *Théorie des proportions appliquées dans l'architecture depuis la XIIe dynastie des rois égyptiens jusqu'au XVIe siècle*. Atlas. Paris: A. Bertrand.

Jones, Owen and Jules Goury. 1842–1845. *Plans, Elevations, Sections, and Details of the Alhambra.* London: Owen Jones.

Kerrich, Thomas. 1821. Observations on the Use of the Mysterious Figure, called Vesica Piscis, in the Architecture of the Middle Ages, and in Gothic. *Archaeologia* 19 : 353-368.

Lloyd, William Watkiss. 1860. A Memoir on the Proportions. In: Charles Robert Cockerell, *The Temples of Jupiter Panhellenius At Ægina, And of Apollo Epicurius At Bassæ Near Phigaleia In Arcadia. To which Is added a memoir of the systems of proportion employed in the original design of these structures. By William Watkiss Lloyd*, pp. 61ff. London: John Weale.

Lozano y Casela, Pablo. 1780–1804. *Antiguedades árabes de España.* Madrid: Real Academia de San Fernando.

Mandoul, Thierry. 2008. *Entre raison et utopie : l'Histoire de l'architecture d'Auguste Choisy*. Wavre : Mardaga.

Marçais, Georges. 1954. *L'architecture musulmane d'Occident: Tunissie, Algérie, Maroc, Espagne et Sicilie.* Paris: Arts et Métiers graphiques.

Mauss, Charles Edouard. 1888. Note sur la méthode employée pour tracer le plan de la mosquée d'Omar et de la rotonde du Saint-Sépulcre à Jérusalem. *Revue Archéologique.* Troisième Série. T.12 (Juillet-Décembre 1888) : 1–31, pl. XVII-XIX.

Mauss, Charles Edouard. 1889. Note pour faire suite au tracé du plan de la Mosquée d'Omar. *Revue Archéologique*, Troisième série, T.14. Juillet-Décembre 1899 : 195-200.

Mauss, Charles Edouard. 1890. Note sur une ancienne chapelle contigüe a la grand' salle des patriarches à la rotonde du Saint-Sépulcre à Jérusalem. *Revue Archéologique*, janvier. Troisième série, T.15 (Janvier-Juin) : 217–239.

Oulebsir, Nabila. 1994. La découverte des monuments de l'Algérie. Les missions d'Amable Ravoisié et d'Edmond Duthoit (1840–1880)] *Remmm. Revue des mondes musulmans et de la Méditerranée*, N°73–7. *Figures de l'orientalisme en architecture.* 57–76. Online at https://www.persee.fr/doc/remmm_0997-1327_1994_num_73_1_1667.

Parvillée, Léon. 1874. *Architecture et décoration turques au XVe siècle*. Paris: Ve A. Morel et Cie.

Saladin, Henry. 1839. Rapport sur la mission accomplie en Tunisie en octobre-novembre 1885. In : *Nouvelles Archives des missions scientifiques et littéraires*, vol. 2. 377–561. Paris : Ernest Leroux

Saulcy, Félicien de. 1865. *Voyage en Terre Sainte*, 2 vols. Paris : Didier.

Serlio, Sebastiano. 1551. *Il primo (secondo) libro d'architettura*. Venice: Cornelio de Nicolini da Sabbio.

Shalev-Hurvitz, Vered. 2015. *Holy Sites Encircled: The Early Byzantine Concentric*. Oxford Studies in Byzantium, xviii. Oxford: Oxford University Press.

UNESCO. 2005. Soltaniyeh date of inscription: 15th July 2005. *The dome of Soltaniyeh; the pasture which became the capital city of an empire*. UNESCO. World Heritage Convention. Nomination of Properties for Inclusion on The World Heritage List: 53–56. https://whc.unesco.org/uploads/nominations/1188.pdf.

Viollet-le-Duc, Eugène. 1863. Neuvième Entretien. Sur des principes et des connaissances nécessaires aux architectes. *Entretiens sur l'architecture*, vol. 1, 385–448. Paris: A. Morel.

Viollet-Le-Duc, Eugène. 1864. Proportion. In *Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle*, Tome VII, 532–560. Paris: A. Morel.

Viollet-le-Duc, Eugène. 1868. Temple. In *Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle*, Tome IX, 12–20. Paris : A. Morel.

Viollet-le-Duc, Eugène. 1873. Préface. In: Jules Bourgoin, *Les Arts arabes, architecture, menuiserie, bronzes, plafonds, revêtements, marbres, pavements, vitraux, etc., avec un texte descriptif et explicatif et le trait général de l'art arabe*, not numbered page, Paris: Vve. A. Morel.

Vogüé, Charles-Jean-Melchior (Comte de). 1864. *Le temple de Jérusalem. Monographie du Haram-Ech-Chérif suivie d'un essai de la Topographie de la Ville-Sainte*. Paris: Noblet & Baudry.

Von Hagen, Victor Wolfgang. 1950. *Frederick Catherwood Arch(t.)* Introduction by Aldous Huxley. New York: Oxford University Press.

Wallen, William. 1839–1842. An elucidation of the Geometrical Principles of Gothic architecture. *Proceedings of geological and polytechnic society of West Riding of Yorkshire*, I: 296–314, 352–381.

Francisco Javier Girón Sierra Is an architect; he holds a Ph.D. from the Universidad Politécnica de Madrid (U.P.M) and is a Professor at its School of Architecture: Escuela Técnica Superior de Arquitectura of Madrid (ETSAM). He belongs to the Ideation Graphical Department teaching architectural drawing. His main research domain is drawing's role in the XIX century emerging disciplines of History of Architecture and Construction History. His activity (journals articles, book chapter's, international conferences proceedings, translations and editions, symposiums organization) has focused on the contributions of pioneering figures such as A. Choisy, R. Willis, E. Viollet -le Duc or Rondelet- and less studied ones such as Goodyear, M. Diuelafoy, A. Caumont, Ch. Chipiez, or Th. Rickman- on issues covering: the appearance of parallels, analytical construction drawings, surveying techniques, architectural cartography, architectural anatomies, and representation systems. He is currently Academic Secretary of the Doctorate Program in Architecture and Urbanism and Dean of Research of Madrid School of Architecture.