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Artistic Transfers from Islamic to Christian Art: A Study with Geographic Information Systems (GIS)

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Abstract: The aim of this article is to present the main aspects of the methodology employed in my research concerning artistic transfers in the late medieval Mediterranean from Islamic to Christian art, with a special focus on the Iberian Peninsula. The starting point of the research was the selection of certain artistic elements incorporated into western Islamic art during the Almoravid period (in particular, the *muqarnaṣ* and the pointed-horseshoe arches), to analyse their spread in western Islamic art and beyond. A Geographic Information System (GIS) was applied to create two databases and assess the distribution of these elements in the Mediterranean framework between the 12th and 15th centuries. As a result, different analyses and cartographic material developed with the GIS are thus included in this work. The GIS made it possible to analyse not only geographic aspects of the distribution of these elements but also other complex phenomena related to the *muqarnaṣ* and the pointed-horseshoe arches in a quantitative way, which allowed me to raise some preliminary hypotheses concerning the use and distribution of both elements in the Mediterranean framework.

Keywords: artistic transfer; Al-Andalus; Christian kingdoms; late medieval Mediterranean; *muqarnaṣ*; pointed-horseshoe arches; Geographic Information Systems (GIS)

1. Introduction: Artistic Transfer in the Late Medieval Mediterranean

The aim of this article is to present the main aspects of the methodology employed in our research concerning artistic transfers in the late medieval Mediterranean from Islamic to Christian art, with a special focus on the Iberian Peninsula.[1] Exchanges between Al-Andalus and the Christian Kingdoms were frequent in all spheres in this area, including art and architecture.[2] The presence of Andalusi objects in Castilian, Aragonese, or Navarrese courts was very common, due to the high quality of these sumptuary objects and the admiration that they provoked in the Christian elites. Islamic architectural influences led to the formation of the so-called Mudejar art during the late Middle Ages.[3] This art is characterised by the use of a hybrid language where Romanesque and Gothic forms coexist with Andalusi-rooted ornamentation, and new spatial conceptions that were highly developed in Islamic architecture, such as the *qubba*.[4]

These exchanges and influences were present in the western Mediterranean from the Umayyad period, and they continued until the Nasrid times. Within this vast context, the chronological framework of this study extends from the Almoravid period (second half of 11th century–first half of the 12th century) to the first decades of the 16th century (until the end of the Mamluk sultanate). The starting point of the research was thus the selection of certain artistic elements incorporated into western Islamic art during the Almoravid period. Al-Andalus and West and North Africa formed a political unity at this time. This political context brought with it multiple relationships in all spheres between both shores of the Strait of Gibraltar, including social, economic, cultural and artistic.

Mutual influences in the artistic field from Al-Andalus towards the Maghreb and vice versa contributed significantly to the development of western Islamic art (Marcos Cobaleda 2018a). Several artistic elements that seem to be unknown in Al-Andalus until this

point were assimilated by the Almoravids into their artistic language, with an outstanding territorial spread during the following centuries. Artistic manifestations that developed within the Abbasid Caliphate of Bagdad were incorporated into western Islamic art during the first half of the 12th century,[5] such as the cursive epigraphy with monumental character, or the systematic use of *muqarnaṣ*[6] (Marcos Cobaleda 2018b).

The artistic manifestations selected for this study are characterised by their subsequent impact on the Mediterranean basin. In the framework of the *ArtMedGIS Project*, three artistic elements were studied: the *muqarnaṣ*, the pointed-horseshoe arches and the *Masājid al-Janā'iz*,[7] also known as "mosques of the dead" (Terrasse 1968) or "oratories for funerals" (Leonetti 2014). Due to the specificity of this type of oratories, however, only the two first artistic elements (the *muqarnaṣ* and the pointed-horseshoe arches) are included in the present study. The methodological aspects of the study are described below, followed by the results obtained from applying Geographic Information Systems (GIS) to this research. The different analyses developed and the cartographical materials obtained have been also included, accompanied by a discussion of the results and some preliminary conclusions.

2. Methodological Aspects of the Study of the Artistic Transfer

After selecting the *muqarnaṣ* and the pointed-horseshoe arches, the HBDS (Hypergraphe Based Data Structure) method[8] was applied to create a Conceptual Data Model (CDM) (Pirot and Saintgérard 2005; Pirot 2012). It includes all the aspects of consideration for the study of both elements, as well as the relational phenomena between them (Pirot 2010): the buildings where they were used, their location, their decoration, chronology, materials, the Mediterranean empire that built them, their credo, and the sumptuary arts (where present)[9] (Figure 1).
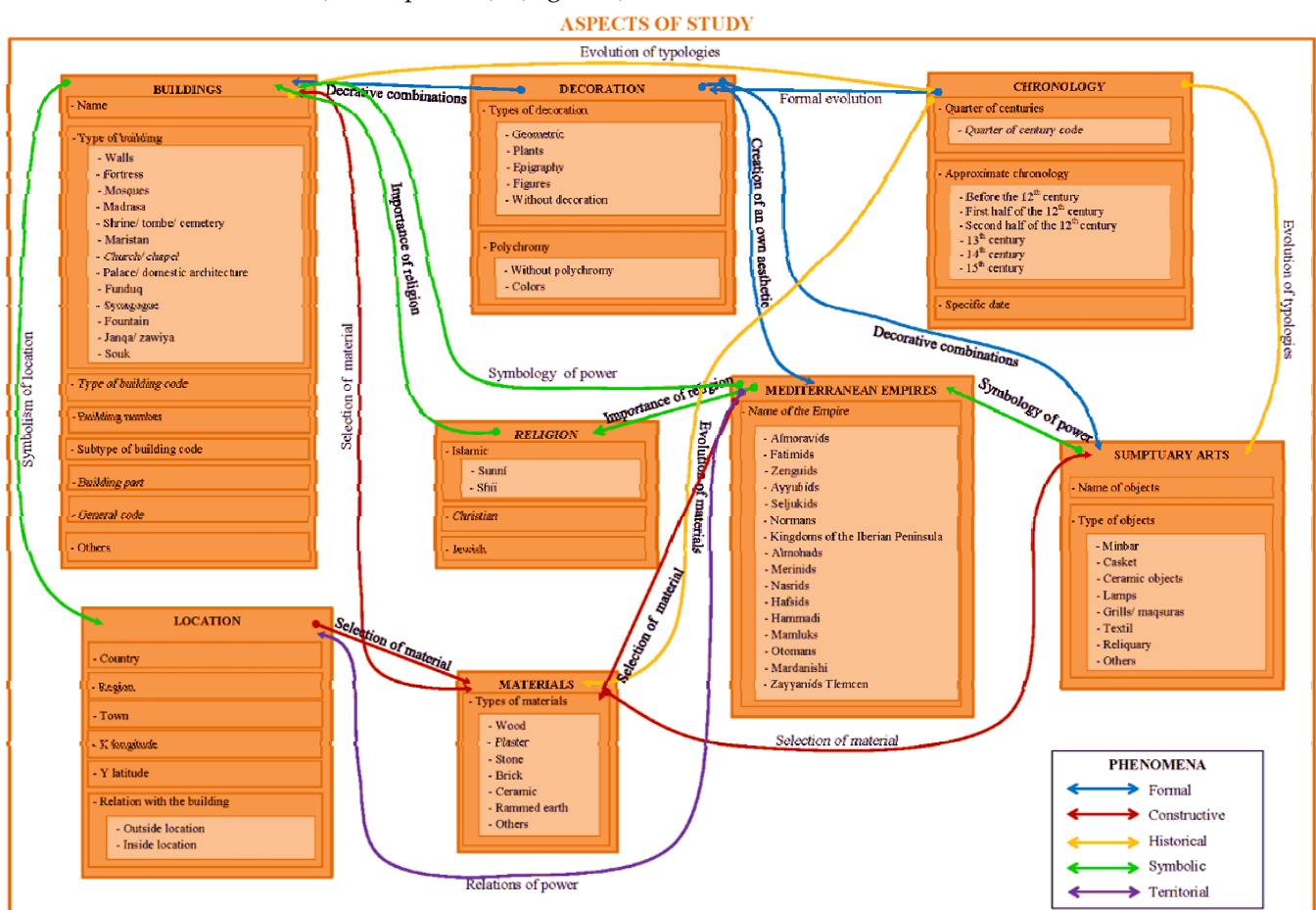
Figure 1. Conceptual Data Model (CDM) for analysing *muqarnaṣ* and pointed-horseshoe arches.

Information in the CDM is organised on levels (Tolaba et al. 2013), from the most global (known in the HBDS method as "hyperclasses" and "classes") to the most specific (known as "attributes"), including the different phenomena that relate to them. The objects of study in this organisation are not the buildings themselves, but each ensemble of *muqarnaṣ* or pointed-horseshoe arches contained within them. The selection of these objects of study instead of the buildings themselves has been determined because, in some cases, the specific location of these elements inside the building was chosen so that they would stand out as the most important parts of the construction, as is the case with the use of *muqarnaṣ* domes and vaults inside the Friday mosques, in the area of the axial nave, the *maqṣūra* or the *miḥrāb* (Marcos Cobaleda and Pirot 2016). This distinction means it is possible to undertake a specific analysis of these outstanding locations with the GIS, in order to determine whether these elements are mostly employed for the categorisation of spaces.

The CDM comprises the structure of the databases to analyse each pre-selected element. These databases were created with a GIS[10] (Pirot 2010; Tolaba et al. 2013; Ciski et al. 2019). Once the databases were created, they were implemented with all the information collected during the research process from different libraries, archives, museums and open databases. The geolocation of the ensembles of *muqarnaṣ* and pointed-horseshoe arches was recorded using the GIS, using the images from the Google Satellite as a background map (Figure 2).
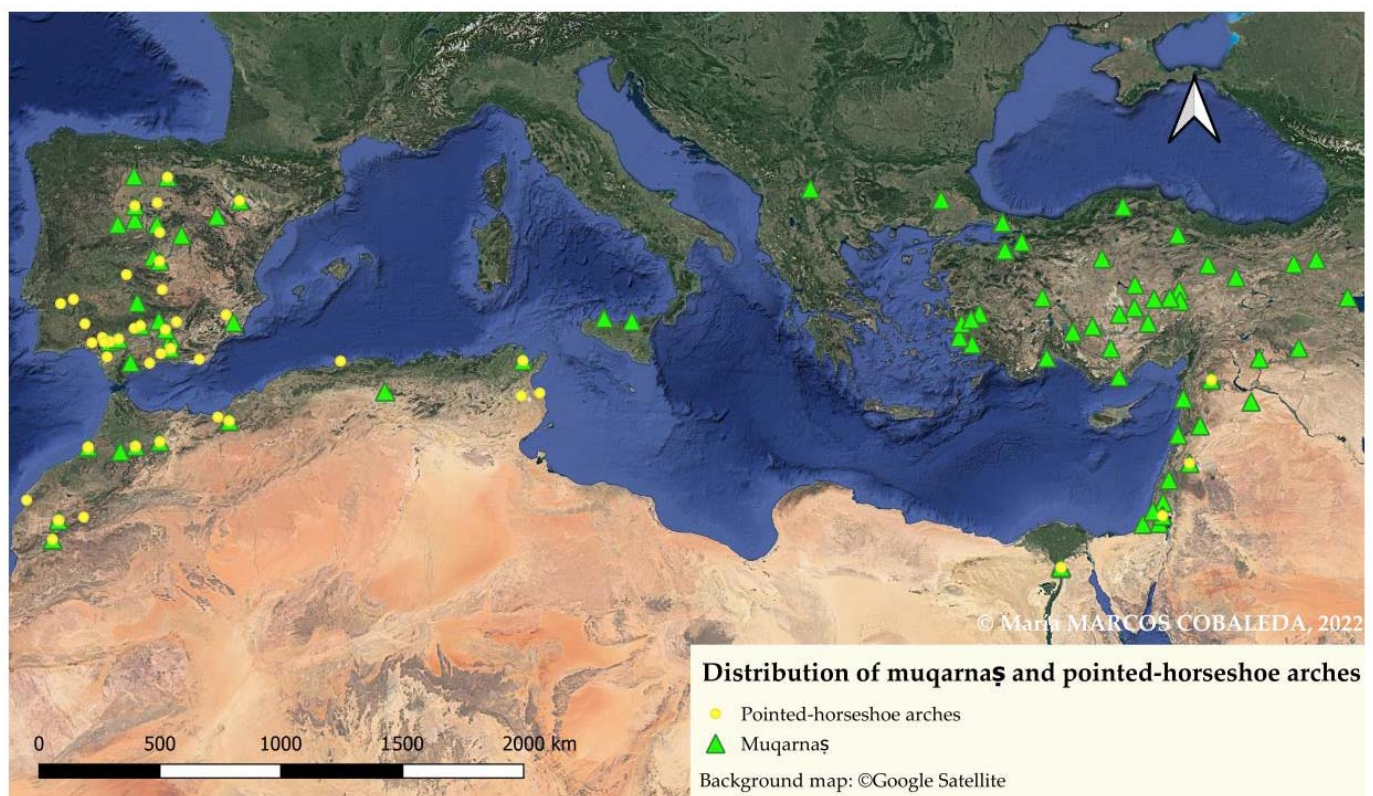
Figure 2. Map of distribution of *muqarnaṣ* and pointed-horseshoe arches in the Mediterranean basin between the 12th and 15th centuries.

There were some problems when using the image from the satellite with several territories in the eastern Mediterranean, where the maps are pixelated (due, above all, to security and military reasons). This makes the geolocation of the buildings from those territories not as precise as it might be, and only relative geolocation has been possible, through a comparison of the image from the satellite with detailed maps of the towns in the affected territories.[11] In addition to this problem, it was sometimes not possible to identify some of the buildings where these elements are present, according to the written sources or the historiography. In those cases, a random point in the middle of the town was chosen, by convention, to enable geolocating the ensembles of *muqarnaṣ*. Neither issue is relevant for the purpose of this research, however, because an approximate geolocation is adequate to assess the distribution of elements in the Mediterranean framework.

Once the objects of study were georeferenced and their characteristics added to the databases, it is possible to develop different analyses with the GIS (ESRI 2013; Mitchell 2001; Mitchell 2005; Mitchell 2012), addressing the phenomena included in the CDM. The GIS tools enable a categorised analysis (Ioannides et al. 2013), addressing, for instance, the types of buildings where *muqarnaṣ* and pointed-horseshoe arches can be found, the Mediterranean empires that built them, and their credo, in addition to other types of analysis, such as chronological.

3. Distribution of *Muqarnaṣ* and Pointed-Horseshoe Arches throughout the Mediterranean Basin

A total of 771 ensembles of muqarnaṣ have been documented throughout the Mediterranean basin, of which 154 are located in the Iberian Peninsula (almost 20%). These ensembles are spread over a total of 308 different buildings. The most ancient examples in western Islamic art are those of the Qal'a of the Banū Ḥammād, in Algeria.[12] The systematised employment of this element did not begin until the Almoravid period, when it was used in all preserved Almoravid Friday mosques.[13] The most ancient examples are those of the Qubbat al-Bārūdiyyīn, in Marrakech, built in 1125 (Marcos Cobaleda 2015). In this case, the muqarnaṣ are present in the four squinches and the central ring of the dome under the small central cupola. These muqarnaṣ are still relatively undeveloped, but the Almoravid muqarnaṣ acquired a great deal of development in just over ten years, as can be seen in the outstanding ensemble of muqarnaṣ domes and the vault in the axial nave and the miḥrāb of the Qarawiyyīn Mosque in Fez (Figure 3), as well as in the dome of its Masjid al-Janā'iz.[14] The Almoravid muqarnaṣ achieved their highest development in this mosque, which can be considered a clear antecedent of the Nasrid muqarnaṣ domes.

Figure 3. Example of *muqarnaṣ* vault (**a**) and dome (**b**) at the Qarawiyyīn Mosque in Fez. Courtesy of Mounir Akasbi.

Concerning the pointed-horseshoe arches, the limited duration of the project means that only 142 ensembles have been included in the database, 58 of which are located in the Iberian Peninsula (almost 41%).[15] These ensembles are spread over a total of 100 buildings. The most ancient examples are dated to the second half of the 11th century in Tlemcen and Algiers, in the context of the Friday mosques built by the emir Yūsuf Ibn Tāshufīn in the eastern territories of the Almoravid Empire.[16] This type of arch was common in religious and military architecture during the first half of the 12th century (Figure 4), and spread to Almohad architecture and later periods of western Islamic art, with only a few examples in the eastern Mediterranean, all built after the Almoravid arches.[17]

Figure 4. Pointed-horseshoe arches of the Qubbat al-Bārūdiyyīn in Marrakech.

As mentioned in the previous section, the distribution of muqarnaṣ and pointed-horseshoe arches across the Mediterranean between the 12th and 15th centuries was analysed using GIS, in order to assess their transfer to other Islamic and Christian societies. Different phenomena have been addressed, including the types of buildings where these elements are found, the credo of the empires who built these constructions, and their chronological distribution.

3.1. Types of Buildings Where Muqarnaṣ and Pointed-Horseshoe Arches Are Found

Analysis shows that the muqarnaṣ are distributed in mosques; madrasa-s; palaces; shrines/mausoleums/cemeteries; churches/monasteries/chapels; fountains/ḥammām-s (i.e., hydraulic constructions); khanqa-s/zawiya-s; māristān-s; walls; funduq-s/caravansar-s; sūq-s and synagogues. Most of these ensembles are found in buildings related to religion: mosques (226 ensembles in 95 buildings, i.e., 29.31%) and madrasa-s (203 ensembles in 78 buildings, i.e., 26.33%). This distribution is followed by buildings related to power elites: palaces (159 ensembles in 49 buildings, i.e., 20.62%) and mausoleums (76 ensembles in 45 buildings, i.e., 9.86%). The presence of muqarnaṣ in the other types of buildings is significantly lower:

- 26 in a total of 18 churches or Christian chapels (3.38%);
- 16 ensembles in 12 hydraulic constructions (2.08%);
- 21 in a total of 9 *khanqa*-s or *zawiya*-s (2.72%);
- 14 ensembles are located in 7 *māristān*-s (1.82%);
- 11 ensembles in 7 walls (1.43%);
- 13 ensembles in a total of 7 *funduq*-s (1.69%);
- 4 in a total of 3 *sūq*-s (0.52%);
- 2 ensembles in a total of 2 synagogues (0.26%) (Chart 1).
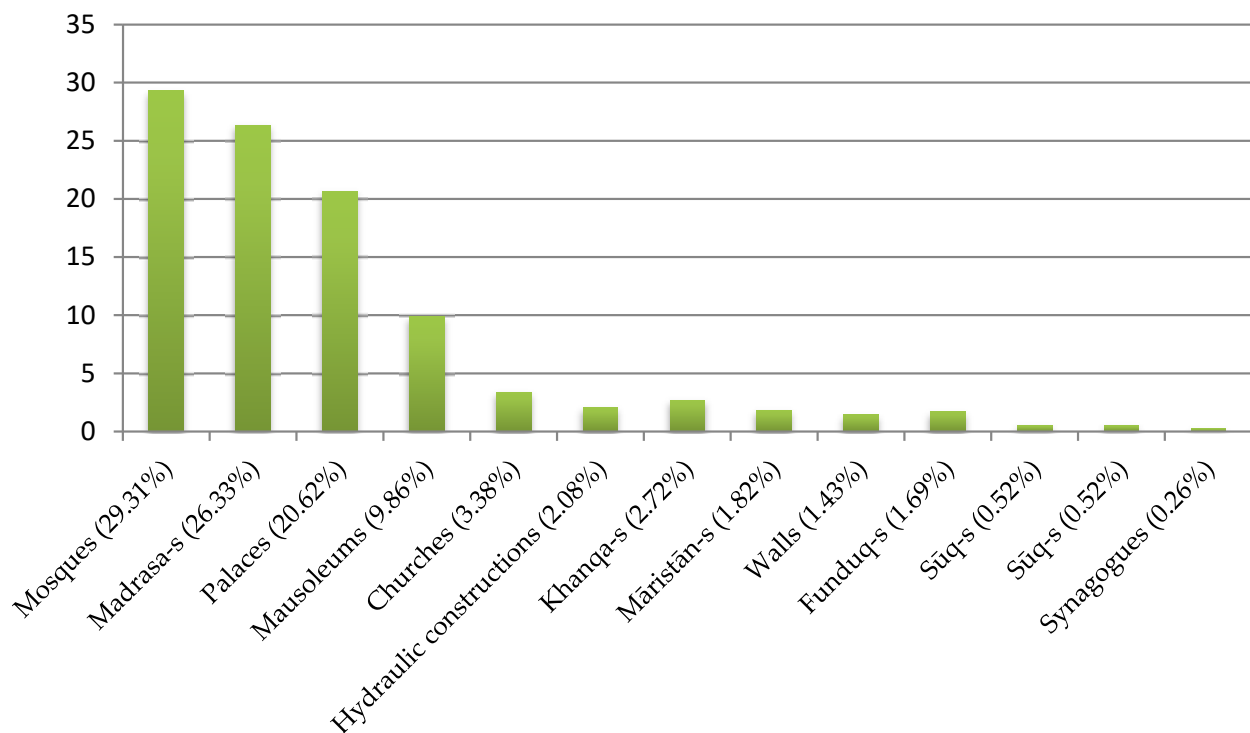
Percentage of types of buildings
for the *muqarnaṣ*

Chart 1. Percentage distribution of *muqarnaṣ* according to the different types of buildings.

As with the muqarnaṣ, a categorised analysis of the pointed-horseshoe arches according to the types of buildings where they are found was undertaken (Figure 5). Although the results achieved are preliminary, due to the limited duration of the ArtMedGIS Project, this sample is representative enough to raise some preliminary hypotheses, as analysed in the following section.
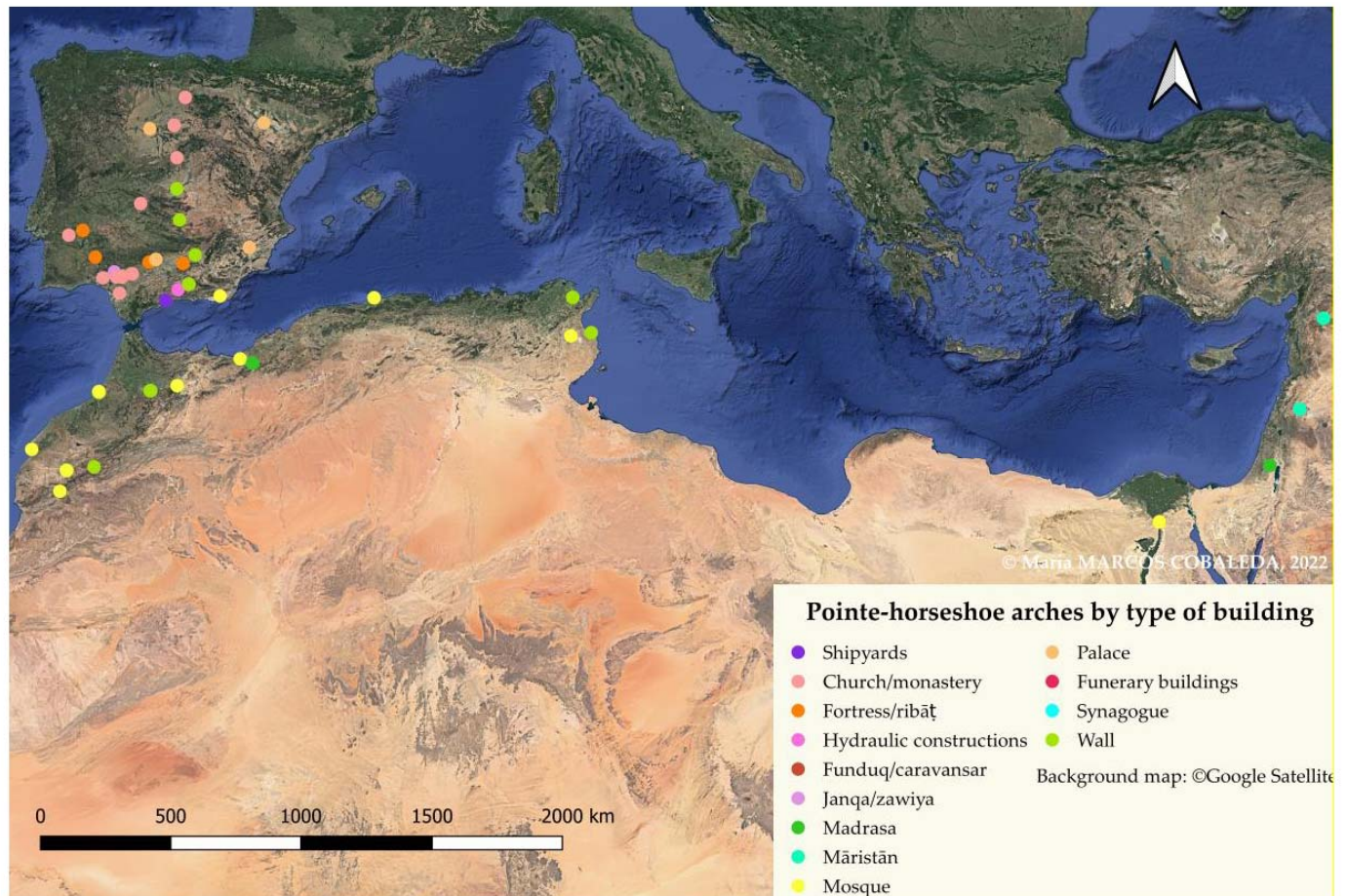
Figure 5. Distribution of pointed-horseshoe arches in the Mediterranean basin according to the different types of buildings.
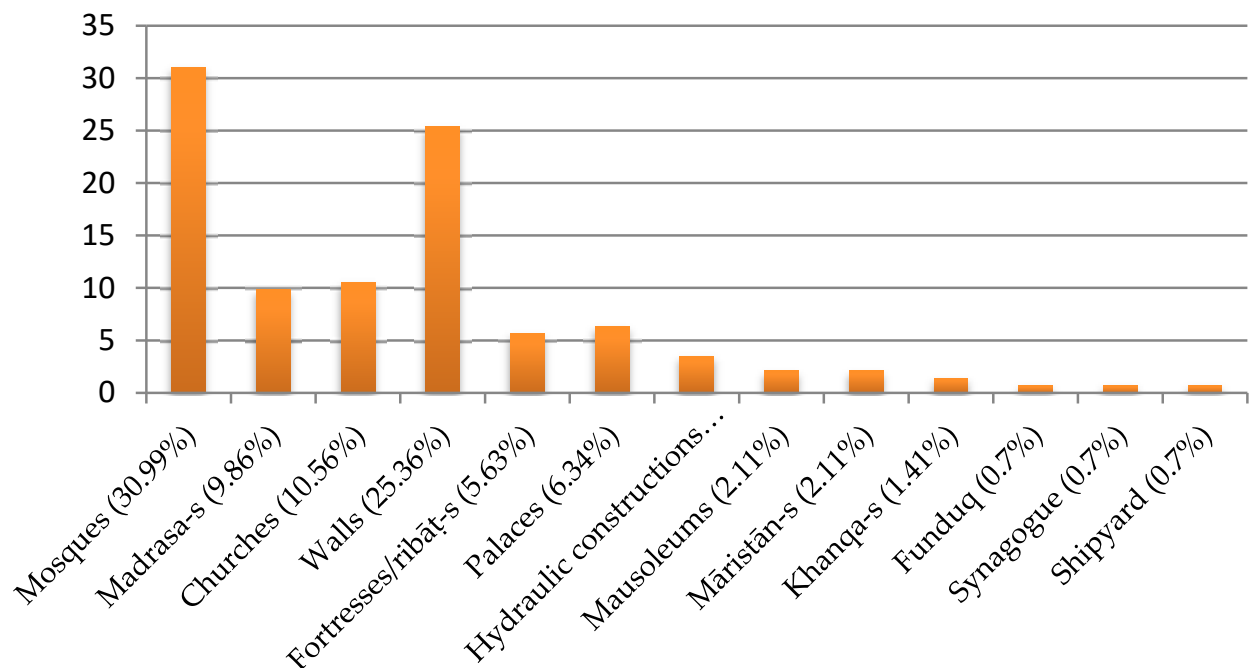
The types of buildings where pointed-horseshoe arches are present are distributed in the same pattern as those for the ensembles of muqarnaṣ (except for the sūq-s). To these buildings must be added, on one hand, the fortresses or ribāṭ-s, and on the other hand, the shipyards. In all these types of buildings, however, the pointed-horseshoe arches are present above all in religious constructions (44 ensembles in 24 mosques (30.99%), 14 ensembles in the same number of madrasa-s (9.86%), and 15 ensembles in 13 churches, chapels or monasteries (10.56%), among 100 different buildings included in the database). This distribution is followed by buildings related to military architecture, where 36 ensembles are located on a total of 17 walls (25.36%) and 8 ensembles in 7 fortresses or ribāṭ-s (5.63%). As in the muqarnaṣ, the presence of pointed-horseshoe arches in the other types of buildings is significantly lower, as detailed below:

- 9 ensembles in 9 palaces (6.34%);
- 5 in 5 hydraulic constructions (3.52%);
- 3 ensembles in 3 funerary architectures (2.11%);
- 3 ensembles in 3 *māristān*-s (2.11%);
- 2 in 2 *khanqa*-s or *zawiya*-s (1.41%);
- 1 ensemble in 1 *funduq*-s (0.7%);

- 1 ensemble in 1 synagogue (0.7%)
- 1 ensemble in 1 shipyard (0.7%) (Chart 2).

# Percentage of types of buildings for the pointed-horseshoe arches

Chart 2. Percentage distribution of pointed-horseshoe arches according to the different types of buildings.

3.2. Results of Analysing the Credos of the Empires That Built These Constructions

We used GIS to analyse the credos of the empires that built the different muqarnaṣ ensembles spread across the Mediterranean (Figure 6). No significant difference was observed for the pointed-horseshoe arches, so the factor of the credo has not been included in the study.
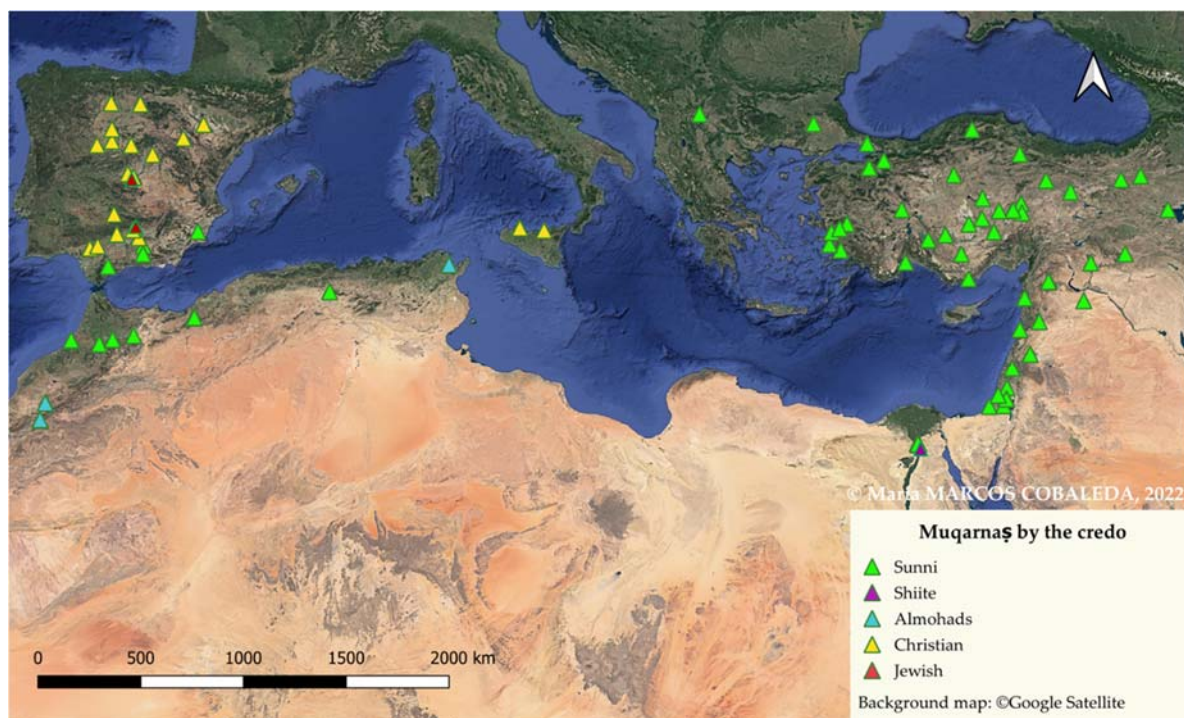
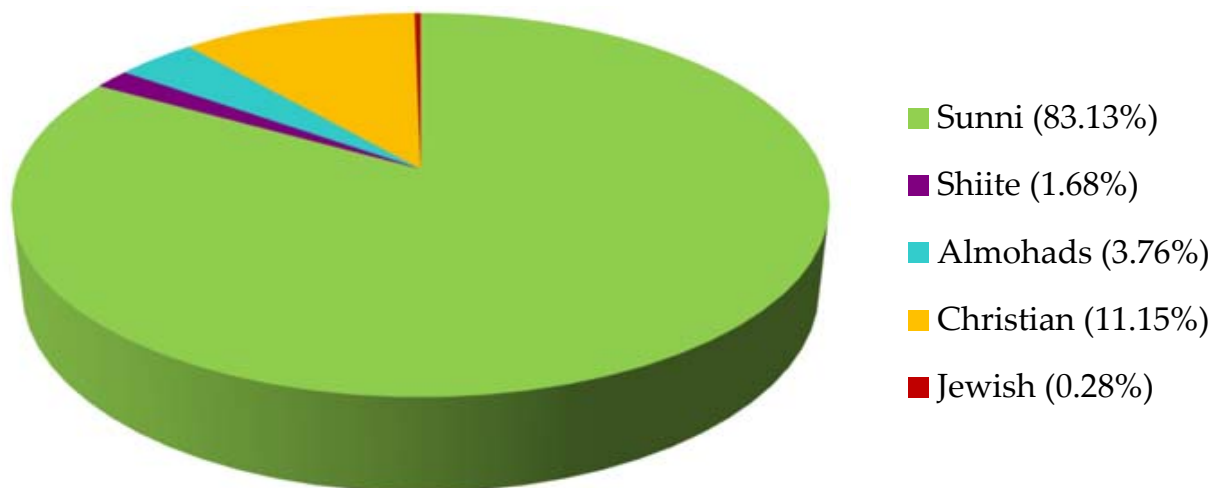**Figure 6.** Distribution of *muqarnaṣ* according to credos.

The results of the analysis for the muqarnaṣ shows that a total of 641 ensembles, distributed in 260 different constructions, were built by Sunni societies (83.13%). Of these ensembles, a total of 65 are located in al-Andalus (10.14% of the total Sunni muqarnaṣ). Conversely, we only documented 42 ensembles of muqarnaṣ in Shiite societies, distributed among 17 different buildings (5.45%). It has to be taken into account that some of these ensembles were built by the Almohad dynasty, however, and it is important to note that the Almohads are not Shiite per se,[18] so this further decreases the number of Shiite ensembles of muqarnaṣ to 13, it is to say, 1.68% of the total of Mediterranean muqarnaṣ ensembles.

Moreover, there are 86 Christian examples spread throughout the Mediterranean context (11.15%), of which 78 are located in the Christian kingdoms of the Iberian Peninsula (90.7% of the Christian muqarnaṣ). There are only 2 ensembles of muqarnaṣ in 2 different Jewish synagogues on the Iberian Peninsula, which is 0.28% of the total Mediterranean muqarnaṣ ensembles.

In summary, the results concerning credos are as follows:

- 641 ensembles built by Sunni societies (83.13%);
- 13 ensembles of *muqarnaṣ* built by Shiite societies (1.68%);
- 29 ensembles of *muqarnaṣ* built by the Almohads (3.76%);
- 86 ensembles built by Christian societies (11.15%);
- 2 ensembles built by Jewish societies (0.28%) (Chart 3).

Percentage of the credo
for the *muqarnaṣ*

Chart 3. Percentage distribution of muqarnaṣ according to credos.

3.3. Results of the Chronological Distribution of Muqarnaṣ and Pointed-Horseshoe Arches

Chronological analyses were also developed using GIS. We included different chronological information in the databases. We indicated the foundation dates for the different constructions (where we have this information). Where we did not have this information, we included an approximate chronology, which varies from a chronological interval delimited by two specific dates, ranging a quarter or half century when the ensembles were built.

We included, for all cases, two columns in the table of attributes: the first ("start_date") includes the half century when the construction was built;[19] and the second ("end_date") includes the first day of the year 1500[20] (Figure 7).

Figure 7. Detail of the "start_date" and "end_date" columns of the table of attributes for the pointed-horseshoe arches.

Mid-centuries were selected as a range because this chronological framework is precise enough for this research: the most important artistic changes involved in the ArtMedGIS Project can be framed by half centuries. These columns ("start_date" and "end_date") enabled us to use the "Time Manager" tool of the GIS to represent the chronological spread of muqarnaṣ and pointed-horseshoe arches in the Mediterranean framework (Figure 8).
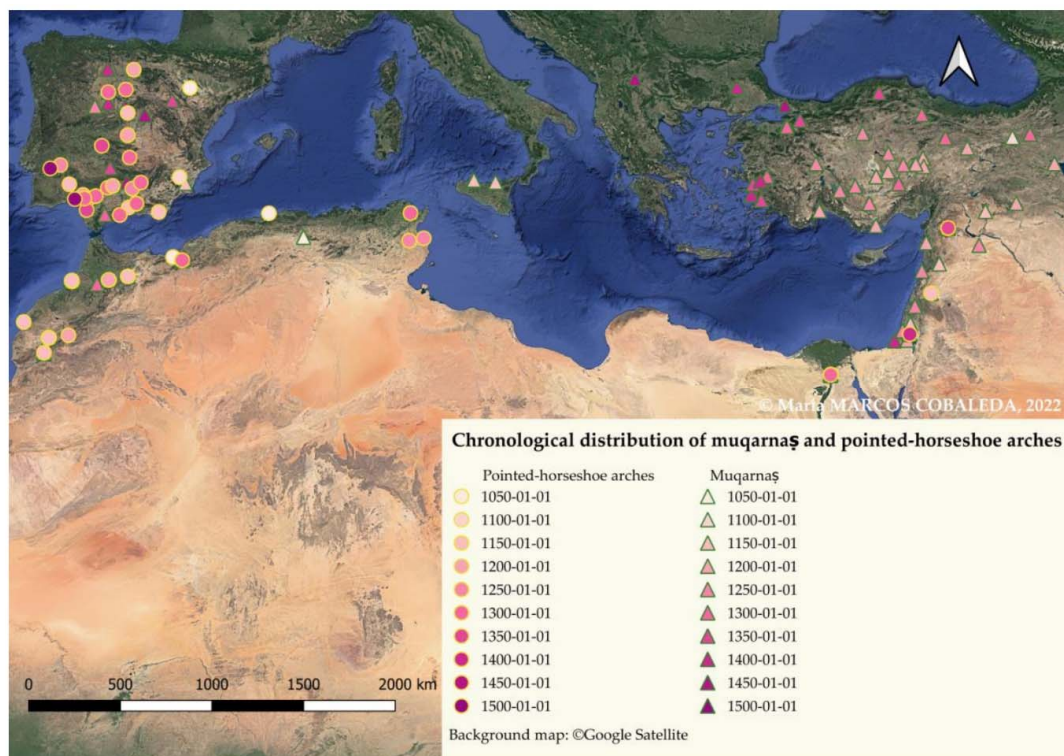
Figure 8. Chronological distribution of *muqarnaṣ* and pointed-horseshoe arches in the Mediterranean framework.

4. Discussion

Several hypotheses can be suggested on the basis of the GIS analysis results, concerning the type of buildings where muqarnaṣ and pointed-horseshoe arches are located. In both cases, the highest proportion of these elements was found in religious constructions, with 59.02% of muqarnaṣ and 51.41%[21] of pointed-horseshoe arches. These results are significant, especially for the pointed-horseshoe arches, because there was a widespread traditional idea that this type of arch was characteristic of military architecture (Marcos Cobaleda 2021). Despite the predominance of these arches in religious architecture, their use in military architecture is also common, with 30.99% of the total.

These results imply that the concentration of muqarnaṣ in religious and palatial architecture (30.48% of all ensembles) can be identified with symbolic meanings determined by religious or political factors. They can be linked, in the political sphere, with the ideas of supremacy, propaganda and legitimacy, and, in the religious context, with the Sunni revival that took place in the Mediterranean framework during the 12th century and onwards.

The use of muqarnaṣ can be directly linked to the Sunni revival, as explained by Y. Tabbaa (2001) and J.C. Ruiz Souza (2000). These authors both propose that the construction of muqarnaṣ domes and vaults can be explained according to the theory of Occasionalism, and directly linked to the Sunni revival.[22] According to the results of this study, in the Mediterranean framework, the use of muqarnaṣ is directly linked to Sunni societies (83.13% of muqarnaṣ ensembles), so the hypotheses of both authors can be corroborated.

The most ancient muqarnaṣ domes and vaults in the Mediterranean basin are those of the Qarawiyyīn Mosque in Fez, built when the mosque was enlarged in 1136–1137, under the rule of the Almoravid emir 'Alī Ibn Yūsuf (Terrasse 1968). As mentioned before, however, muqarnaṣ have been used in Almoravid architecture since the construction of the Qubbat al-Bārūdiyyīn in 1125, and they were used in all the main Almoravid buildings preserved. The use of muqarnaṣ in the Almoravid context can thus be interpreted as a way of legitimating and reaffirming Sunni aesthetic principles by the Almoravid emir, due, on one hand, to the relationship between the Almoravids and the 'Abbāsī Caliphate of Bagdad (De Felipe 2014), and on the other hand, to their confrontation with the nascent movement of the Almohads (Marcos Cobaleda 2018b). This relationship with the 'Abbāsī Caliphate would explain the Almoravid introduction of Oriental forms into western Islamic art, such as muqarnaṣ, or cursive epigraphy with a monumental character, as a way of showing their otherness facing the Almohads, and reinforcing their exaltation of Sunni Islam.

In the case of Al-Andalus, the most ancient documented muqarnaṣ dome is that from the Dār al-Ṣugrà, built in Murcia during the government of the king Ibn Mardanīsh in the second half of the 12th century. It was built some decades before the Almohad muqarnaṣ of the Friday mosque of Seville (built after 1172).[23] Some fragments of this dome are preserved in the Museum of the Convent of Santa Clara (Murcia), where several stalactites with pictorial decoration can be seen (Carrillo Calderero 2009). It is interesting to remark that the king Ibn Mardanīsh founded his kingdom like a continuation of the Almoravid government of Al-Andalus, and he fought against the Almohads until his death in 1172. In this context, it can be assumed that the use of a muqarnaṣ dome to ornate one of his palaces in Murcia would have continued the same symbolic aesthetic than the one of the Almoravid muqarnaṣ, linked to the aforementioned principles of the Sunni revival, as well as a way of showing his otherness facing the Almohads, as in the previous case. Concerning the Andalusi muqarnaṣ of the following centuries, the Sunni principles continued in the Nasrid examples. Nevertheless, during this period, the growing number of muqarnaṣ in palatial spaces (92.06% of the total Nasrid muqarnaṣ) suggests an increase in its values related to the expression of political supremacy. This interpretation would explain why the muqarnaṣ domes started to be used also in the context of the peninsular Christian kingdoms, as a way of expression of the political power of their sponsors and to diferenciate several spaces reserved for the social elites within significant buildings, such as chapels or funerary chapels (Monastery of Santa María la Real de Huelgas (Burgos), built in the third quart of the 13th century;[24] Saint Andrews Church (Toledo), in 14th century; or Royal Chapel in

Cordoba, built in 1372), or palaces (Palace of the king Pedro I of Castille (Seville), between 1356–1366; Casa de Pilatos (Seville), built in 1483; or Palacio del Infantado (Guadalajara), built in 1492).

Concerning the representation of the chronological distribution, the maps generated by the GIS have made it possible to see that the Almoravid examples of *muqarnaṣ* and pointed-horseshoe arches are ones some of the most ancient in the Mediterranean context. On the other hand, these materials have shown the presence of a production centre of these elements in the west, clearly different and separate from the eastern centre.[25] The chronological analysis supports the theory that the pointed-horseshoe arches were a creation of western Islamic art, since the oldest examples of the second half of the 11th century have been documented in North Africa and al-Andalus, with a difference of more than half a century from the Oriental examples. This challenges the traditional hypothesis for the origin of this type of arch in the East (Pijoán 1949; Hoag 1975; Revault 1984), and reinforces the hypothesis that important active production centres were present in the western Mediterranean during the late Middle Ages.

Within this context, Al-Andalus must have played an important role as a production centre. As shown in our results, 19.97% of *muqarnaṣ* and 41% of the pointed-horseshoe arches in the ensembles analysed in the *ArtMedGIS Project* are located on the Iberian Peninsula. The presence of both elements in both the Christian kingdoms and Al-Andalus is probably the result of the direct influences of Andalusi production centres, with which important exchange relations were maintained, as previously mentioned. The *muqarnaṣ* in the Christian kingdoms comprise 90.7% of all the Christian examples in the Mediterranean context, and the high concentration of this element in this territory can only be explained by the Andalusi influences on peninsular Christian art.

The fact that 41% of all pointed-horseshoe arches documented are located in the Iberian Peninsula is remarkable, especially taking into account that this proportion will be significantly increased when all the collected data is implemented in the database. The current data suggests that the peninsular pointed-horseshoe arches include almost half the documented examples in the Mediterranean. This emphasises once again the presence of artistic production centres in the western Mediterranean, with great development during the Almoravid period, where the Andalusi examples would have played a prominent role.

5. Preliminary Conclusions

The important role played by the Almoravids in the distribution of artistic elements into western Islamic art has been remarked as a preliminary conclusion, based on the results obtained. The role of Al-Andalus in the context of the artistic transfers from Islamic to Christian art stands out as regards both elements studied: the *muqarnaṣ* and the pointed-horseshoe arches. These elements have an important impact in the Christian kingdoms of the Iberian Peninsula, which cannot be explained without taking into account the multiple cultural exchanges between Al-Andalus and these territories during the late Middle Ages.

Geographic Information Systems were essential for managing the great volume of data in the research about artistic transfers in the late medieval Mediterranean. It made it possible to analyse complex phenomena related to the *muqarnaṣ* and the pointed-horseshoe arches in a quantitative way, which allowed to raise some preliminary hypotheses concerning the use and distribution of both elements in the Mediterranean framework. Beyond the geospatial aspects, GIS has allowed us to analyse religious, symbolic and political phenomena. The different tools available in GIS mean that a wide variety of cartographic materials have been generated. This allowed a direct and visual analysis of the different complex phenomena described in the study.

Informed Consent Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Notes

[1] This research was framed by different research projects, among which the *ArtMedGIS Project* (MSCA—H2020, grant agreement No 699818) can be highlighted. This project was developed at the Instituto de Estudos Medievais (IEM—FCSH/UNL, Lisbon) in collaboration with the Laboratoire de Démographie et d'Histoire Sociale (LaDéHiS—CRH—EHESS, Paris) and the University of Granada between 2016 and 2018. For more information about the project, see ArtMedGIS Project (ArtMedGIS Project 2016–2018).

[2] For a more comprehensive analysis of the exchanges between Christian Kingdoms and Al-Andalus, see (Cabrera Lafuente 2019; Rodríguez Peinado 2017; Yarza Luaces et al. 2005; Calvo Capilla 2017a, 2007b; Marcos Cobaleda 2021).

[3] Many works have been published on Mudejar art, as G.M. Borrás Gualis (2005, 2012, 2017, 2018), R. López Guzmán (2006, 2015, 2016), Mª E. Díez Jorge (2001, 2007, 2014, 2016) and F. Giese (Giese 2021; Giese and León 2020).

[4] This structure consists of a square room covered with a dome. It is widely used in Islamic architecture, above all for spaces with an outstanding character. Its use is also documented in the Christian context linked to the Mudejar architecture.

[5] The incorporation of these Abbasid elements into western Islamic art during the Almoravid period can be explained by the loyalty to the Abbasid Caliph that Almoravid emirs showed since the beginning of the movement, especially in times of the emirs Yūsuf Ibn Tāshufīn and ʿAlī Ibn Yūsuf (De Felipe 2014). This relationship makes the Almoravid movement a part of the Sunni revival that took place in the Mediterranean framework during the 12th century (Tabbaa 2001). In this way, the Almoravid emirs made use of the artistic language as a transmitter of Sunni principles and aesthetics (Marcos Cobaleda 2018b), which pervaded the art of the first half of the 12th century.

[6] For more information about the *muqarnaṣ* and its use during the Almoravid period and onwards, see Marcos Cobaleda and Pirot (2016). In this paper, a deep analysis of the methodology and application of the GIS for the study of the distribution of *muqarnaṣ* throughout the Mediterranean between 12th and 15th centuries has been presented.

[7] The *Masājid al-Janāʾiz* were a construction developed during the Almoravid period. They were oratories for funerals, where the rituals of prayer for the dead took place. For a more comprehensive analysis of this specific type of oratories, see Marcos Cobaleda (2021).

[8] This method was developed by François Bouillé in 1977 (Bouillé 1977).

[9] A deeper analysis of the CDM can be seen in Marcos Cobaleda (2023). In this work more details about the application of the GIS to the Art History research can be found.

[10] The QGIS program was used as software for the different analyses in the *ArtMedGIS Project*.

[11] This is the case, for example, for Aleppo, Damascus or Jerusalem.

[12] Traditionally, these *muqarnaṣ* have been dated to the second half of the 11th century (Golvin 1965), however, A. Carrillo Calderero suggests that they would have been part of the reforms made in the *Qalʿa of the Banū Ḥammād* since 1090 and during the early 12th century (Carrillo Calderero 2009). If this hypothesis is correct, the *muqarnaṣ* of the Qalʿa would be contemporary with the Almoravid examples.

[13] No Almoravid *muqarnaṣ* ensemble has been preserved in Al-Andalus. The most ancient examples documented are the remains of a *muqarnaṣ* dome in the palace known as *Dār al-Ṣughrà*, in Murcia (Spain), built during the rule of Ibn Mardanīsh, in the second half of the 12th century (Marcos Cobaleda and Pirot 2016).

[14] The intermediate step between the *muqarnaṣ* of the Qubbat al-Bārūdiyyīn and those of the Qarawiyyīn Mosque is the pierced dome of the *maqṣūra* of the Great Mosque of Tlemcen, in Algeria. The *muqarnaṣ* here are also present in the squinches and five small cupolas in the middle of the dome (Marcos Cobaleda 2015).

[15] Much more data was collected during the project, which will be processed in the upcoming months, so this proportion will be significantly increased in the near future.

[16] In Al-Andalus, there are examples of decorative pointed-horseshoe arches in the Great Mosque of Córdoba and the Ajafería of Saragossa (a Taifa palace built during the rule of the Banū Hūd in the last third of the 11th century). There is also an example of constructive pointed-horseshoe arches in the entrance of the *alhanías* from the northern portico of this palace; however, these seem to be the result of the reforms carried out in this palace during the first half of the 12th century.

[17] The most ancient pointed-horseshoe arches in the eastern Mediterranean are the examples from the *Bimāristān* of Nūr al-Dīn, in Damascus, built in 1154 (Carrillo Calderero 2009), more than fifty years after the Almoravid pointed-horseshoe arches from Tlemcen and Algiers (Marcos Cobaleda 2021).

[18] For more information about this issue, see Fierro (2019).

[19] The start date established for the chronological registers was the second half of the 11th century.

[20] As explained before, the project ends at the beginning of the 16th century, when Mamluk rule came to an end.

[21] It should not be forgotten that these results are provisional. In the specific case of the pointed-horseshoe arches, the percentages of religious architecture will be significantly increased once the implementation of the database is completed, based on the information gathered so far.

[22] For a wider analysis of the relationship between the *muqarnaṣ* domes and vaults with Occasionalism in the Mediterranean basin, see Marcos Cobaleda and Pirot (2016).

[23] Although it is widely considered that this is the most ancient example of Andalusi *muqarnaṣ* known to date, there is an hypothesis that assume that they were already used during the Taifa period, based on a source written by al-ʿUdhrī (Al-ʿUdhrī 1965), where the author described the palaces of the 11th century built by the king al-Muʿtaṣim in Almeria. Some authors think that the *muqarnaṣ* domes were used in a reception room of these palaces, because the term *muqarnas* (ended by *sīn* س), written in the text, has been translated as "mocárabes" (Spanish translation for *muqarnaṣ*, ended by *ṣād* ص). Nevertheless, the term *muqarnas* (ended by *sīn*) is a different term from *muqarnaṣ* (ended by *ṣād*, and the correct term to refer to the artistic element analysed in this paper), and its correct translation is the one proposed by F. Corrientes: "in a grandstand" (Corrientes 1986), as it has been translated by M. Sánchez Martínez (1976).

[24] The dates included in these examples are the specific date of construction of the *muqarnaṣ* ensembles, not the general date of construction of the buildings that contain them.

[25] For a more comprehensive analysis of this issue, see Marcos Cobaleda (2021).

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