Supplying of masonry materials in the construction of the crypt of Santa María la Real de la Almudena, Madrid, Spain, 1883–1911

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The importance of the petrological and petrophysical studies of stony materials used on architecture is progressively gaining importance, both for the construction of new buildings, and for the restoration and rehabilitation of historical buildings. This work presents an example of the petrophysical studies that were carried out for the selection of the most suitable lithologies for the construction of the crypt of Santa María la Real de la Almudena Cathedral (Madrid) in the second half of the 19th century. It is also shown how, due to different causes, the type of materials used throughout the construction of the Crypt was changed. These changes affected the construction, both delaying it and resulting in a building made up with several different materials. This confirms a tendency that is very often observed on historical buildings where construction was developed during a long period of time. It is in these cases where it is especially important to carry out a detailed documentary analysis of the factors causing this variability.

The importance of this analysis mainly lies on two points. On one hand, it can reveal important historical details concerning the interpretation of the building. On the other hand, it gives us information about the quarries from where the original materials were extracted, allowing us to obtain stones of exactly the same characteristics as those once employed in order to make substitutions of architectonic elements. In that way, this work shows how the combination of both documentary and geological data can be an important approach in order to understand many subjects dealing with the history of architecture.

INTRODUCTION

The origin of materials used on a building and how it affects its construction is an interesting subject in the study of any building. The origin and transformation processes of the materials used offers us historical, socio-economical and industrial data on one of the oldest human activities: the quarrying and use of stone resources.

The determination of original quarries for a building allows for optimal restoration when material has been lost or needs to be substituted. That is an important fact because there are not only changes between stone types but there are also changes between different quarries of the same lithology. These changes could cause incompatibilities between new and original materials.

The present work mainly has two aims. First, it reveals the process of selection and the supplying history of the stone in the Crypt of the Cathedral of the Almudena (Cathedral of Madrid). Second, the study of the documentation is completed with some petrological data which allow us locate the quarries used in this building.

The Crypt has been selected because it was built with uncommon stony materials in the city of Madrid. The traditional architecture in Madrid has been made
with stone, both granite from Sierra de Guadarrama and limestone from Colmenar de Oreja, as well as clay bricks. Many of the buildings from the 17th to the beginning of 19th century have been built with those materials (Dupena et al. 1988). At the end of 19th century new materials began to be used, mainly because of the facilities introduced by the new ways of transport. The stone called Piedra de Novelda was one of the most often used (Fort et al. 2002).

The exhaustive selection process of the stone that included some petrophysical tests was another reason for the choosing selection of the building. Furthermore, since the Crypt is part of the Cathedral we can compare some aspects with the Fabric in the cathedrals of the previous centuries.

**METHODOLOGY**

The present work mainly deals with showing the results obtained in the documented sources of the building to determine the history of the supplying of the stony material. From this historical data the possible origin of the stony materials used in this building work has been established. Petrographical and petrophysical tests of samples from the building and quarries have been made to support the historical data obtained from the documents.

The location of the original quarries of the materials used in any element of architectural heritage should follow the methodology summarised in the chart of figure 1.

**ORIGIN OF THE CONSTRUCTION OF THE CATHEDRAL OF THE ALMUDENA**

The idea of building a large church in Madrid with a name of the Virgin Mary began when the dogma of Immaculate Conception was proclaimed in 1854. The Spanish people were very influential in the proclamation of this dogma and this church was destined to be the largest sanctuary of the Virgin in Spain. The name Santa María de la Almudena has its origin in the Arab word *al-mudaina* that means *the citadel* because Alfonso VI discovered an image of the Virgin in the city walls after the conquering of Madrid in 1085.

After the revolution of September of 1868 it was decided to demolish the old temple of Santa María de la Almudena to make the streets of Bailén and Mayor

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**Figure 1**

Methodological synthesis on the location of original quarries of stony material in the historical-artistic heritage (after Fort 1996).
wider moving the worship to the Church of the Santísímo Sacramento (now the military church). That church of Santa María was placed in the north corner of the present crossroad of Bailén and Mayor streets, probably in the place where an old mosque stood.

The Queen María de las Mercedes wished to help the Archbrotherhood of the Almudena and devouts in the construction of a new church. As the result, in conjunction with the demolition of the old church, it was decided to build a big temple under the name of Santa María la Real de la Almudena in the plot given by the King Alfonso XII. The king also built the temple as a mausoleum to his deceased wife.

In 1878 the Marques de Cubas was appointed as architect of the building work. The first studies of the plot were started in 1881 and on 4 April 1883 the foundation stone was laid. This temple under construction was to become the future Cathedral of the Diocese of Madrid-Alcalá erected by Leon XIII in 1884. As a result, the Marques de Cubas transformed the previous parish church project into a new one.

The Cathedral of the Almudena has had several stages in its construction from 1883. The first stage includes the construction of the crypt that lasted from 1883 to 1911. The responsible architects during this stage were the Marques de Cubas, until his death in 1899, Miguel de Olavarria, who died in 1904, and Enrique Repullés y Vargas. The second stage overlapped with the first and extended from 1910, when the first pillar of the cathedral was set, to 1944, when an announcement was made for a new contest to change the project (this stage includes the interruption of the Spanish Civil War). After the death of Repullés two architects followed: Juan Moya until 1936 and Luis Mosteiro from 1939. The third stage, following the new project of Fernando Chueca-Goitia and Carlos Sidro, lasted from 1950 to 1965. The work was then stopped until 1988 (except for a short period of work in 1969). The last stage extended from 1988 to 1993 when the church was consecrated. The work, including the inner decoration and some architectural elements, continues from 1993 to the present day.

The original project of Marques de Cubas consisted of a neoromanesque crypt and a neogothic church. This study refers to the materials used in the construction of the crypt (1883–1911) which is the only finished part of the building according to his project.

The Documented Sources of the Cathedral

The Fabric of a cathedral was one of the administrations of the Chapter economy. This budget was looked after by one of the canons that received different names in the Spanish Cathedrals: Obrero, Fabriquero or Mayordomo de Fábrica (López-Arévalo 1966; Torroja 1977; Cortón 1990; Galera 1982).

The Fabric includes not only the construction but also all things related to the conservation and improvement of the building. The costs of candles, oil or decorations for feast days were also the responsibility of the Fabric. All financial transactions had to be accounted for in the Fabric Rolls.

All the monetary deposits of the Fabric came from several sources. There were cases in which this documentation was not included in the Fabric Rolls; rather it was spread throughout several cathedral books. In other cases, like that of the Cathedral of Oviedo, Fabric Rolls were missing (Caso 1981). Finally, it should be noted that other cathedrals have registers that are not continuous.

Other important documents for the study of the Fabric of a Cathedral are the Chapter minutes. On some occasions these are the only available
documents. The work of the Fabric Canon was supervised by the Chapter and that work is often noted in the minutes, also known as the Chapter Acts.

The case of the Cathedral of Almudena is very different for two reasons. On one hand, the power and deposit capacity of the Catholic Church decreased during the 18th and 19th centuries because of the coming of the Bourbons and the Enlightenment. In Spain the culmination of this process was the expropriations (i.e. Desamortizaciones) of the 19th century until the treaty with the Holy See in 1851. As a result, the governing bodies of the Church, especially the local ones like the chapters of the cathedrals, relinquished their authority and financial capacity. Therefore the economy of the cathedrals was simplified and a new concept of Chapter was established. This new concept was a major factor in the creation of the new Chapter of the Cathedral of Madrid-Alcalá.

On the other hand, this building was not designed as a cathedral from the first moment. The project of the building was made when Madrid was obligated to the diocese of Toledo. Therefore, the structure of the documentation since the beginning of the building was not common for a cathedral church.

The documentation used for the purpose of this work comprised the 1879–1911 period of the first book of minutes of the building’s board meetings known as the Libro de actas de la Junta de Edificación del Templo de Santa María de la Almudena. This book is kept in the historical archive of the diocese of Madrid. That documentation is complemented with dozens of folders including several books of accounts and minutes. Many of those books are not well studied and are now in inventory.

The first book of the building board meeting minutes began with the initial session on 29 June 1879 and finished after the session on 29 December 1934. At the end there is a note from the secretary informing that the book was stolen during the Spanish Civil War and was later recovered.

The Building Board was established by the order of the Cardinal Archbishop of Toledo. In the first board session the Cardinal was named as president, Mr Julián de Pando, court visitor, as vice-president, the Marques de Montalvo as treasurer, Mr Francisco de Cubas as the chief architect and Mr. Manuel Calderón Sánchez, economist priest of the parish of Santa María de la Almudena, as secretary.

This board was mainly secular, unlike the chapters of the old cathedrals. The secretary was the only clergy in addition to the Archbishop. This board remained after the new diocese of Madrid-Alcalá was erected. We would expect that after this change, the chapter would look after the building works, but this was not the case. The Bishop of Madrid-Alcalá was named president instead of the Bishop of Toledo. Moreover, the Dean did not belong to the Building Board until 1899. The chapter was not often mentioned. The chapter was obligated to the Building Board and all building related matters had to be accepted by the Board. For example, in the session of 15 November 1909, the Bishop had to ask for permission to move the chapter to the crypt. In addition to the Building Board, the Executive Commission on the Construction of the Cathedral Temple of Nuestra Señora de la Almudena was created in 1909. The Commission had its own minutes book that was kept in the historical archive of the diocese.

**Process of Selection of the Building Stone**

The selection process began in 1885 but there are also some previous references to stone types dating back to 1883. That process is one of the most interesting points about the origin of the stony material. The responsible architect, Marques de Cubas, wanted a correct selection of stone instead of the main tendency in the Middle Ages when the selection of the nearest and softest stone was more important than the most lasting1 (Cubas 1886).

Therefore, the course of the selection of stone was made with careful thoroughness. The first selection process lasted from 7 February 1885, when the first proposals was taken, until 27 September 1887 when the building board finally chose one of the stone types. This process included twenty-three stone types from many points of Spain and some foreign locations.

The first proposed lithologies for the construction were White Marble from Cáceres and dolostone from Uclés (Cuenca) both offered by the same contractor (7 Feb. 1885).2 These stones had not been often used in Madrid, so the Building Board ordered Mr. de Salces, auxiliary architect, to perform inspections of the marble quarries and the conservation state of the
Monastery of Uclés which was made with the dolostone. That is a very interesting point for the field of the Geology applied to the study of heritage.\(^3\)

Proposals of other stones were also noted in the minutes: Limestone from Baides (Guadalajara), Limestone from Elda (Alicante) and Marble from Alconera (Badajoz). There was a contest with these proposals and many others received as a result of an announcement placed in newspapers. Twenty-three stone types were initially selected. These stone types were tested using arch calculations in the school of civil engineers (9 Jan. 1886).

Marques de Cubas presented a report dealing with the most suitable stones in the Building Board meeting on 9 January 1886. This report was published entirely in the Bishop Bulletin and included the results of the tests for the twenty-three types of stone (figure 3). From these results five stone types were chosen for further tests: white and grey marble from Alconera, limestone from Alhama de Aragón (Zaragoza), Limestone from Baides and Limestone from Uclés. A commission of architects was summoned for the final decision (6 Oct. 1886). This commission was formed by Mr. José María Agüilar and Mr. Joaquín de la Concha y Alcalde and concluded that all the types of stone would be valid so the cheapest and more abundant would have to be chosen. It was decided to choose the stones from Baides and Alhama (26 Oct. 1886).

The Alhama stones delivered did not have the same characteristics as the tested blocks and they possessed oxide veins that did not make it suitable. The stone coming from Baides was selected to begin the building work since the stone from Alhama was rejected (3 Feb.; 27 Sep. 1887). However, this would not be the definitive material.

There were three main ways in which the stone was supplied to cathedrals: exploitation of quarries belonging to the Chapter, exploitation by quarry workers who sold to businesses related with masonry, and contracts with quarry workers who would exploit their own stone. The first two options had been used since at least the 13\(^{th}\) century. The first way was predominant in cathedrals like Oviedo and Toledo, but in more modern ones like Segovia contractual relationships were common (Cortón 1990).

The Cathedral of the Almudena was chosen to contract with quarry workers. This fact produced serious troubles in the supplying of the material during the first years mainly due to problems with quarry contractor. This delayed the setting of the masonry stones because the contractor assured that there would be difficulty extracting the material in the terms of the contract. However, Marques de Cubas stated that he knew that other building works did not experience any difficulty. These kinds of troubles led the board to attempt to own the quarries (\(4\ Apr. 1888; 7\ Nov. 1888\)).

A new contest was created to choose a new stony material to continue with the building work. The following localities were proposed: Almería, Petrel, Estepa, Viana de Jadraque (Vianilla, sic) and Portugal (10 Dec. 1888). The stone coming from Viana de Jadraque (Guadalajara) was quickly selected because it was very similar to that coming from Baides.\(^3\) Since there was not a contract with Viana de Jadraque, the contest was abolished (3 Apr. 1889). Soon after, an agreement was reached with an English society established in Porto called Murat & Company. The company supplied stones that came from Portugal, although the minutes do not reveal the specific locality.

In the meeting of 14 January 1892, the Building Board talked about negotiations made to get softer stones to do the decorations on chapiteis and carved arches. The following were proposed: Petrel, Campanil and Portugal\(^3\) but there is no mention about the final decision.

The period from 1892 to 1900 was characterized for new troubles between quarries and the Building Board. In 1892 Porto stone increased its price because of the rise in customs taxes and there was not an agreement about the new costs of the stones (24 Feb. 1892). Apart from that there was a large worker strike in the quarry of Portugal (23 Oct. 1897). Also, the building work became slower because on 2 February 1899 the director architect Marqués de Cubas died. Therefore in 1900 contractors of Porto threatened to void the contract if a minimum order of 100 \(\text{m}^3\) per month was not completed in six months as was specifically stated in the contract (15 Jun. 1900). This did not occur because the Board refunded the deposit that was made by the contractors to guarantee the supplying of the minimum order. As a result, the Board was exempted of making the minimum order.

In 1904, the result of what stone would be used for the main building was awarded after the tests were
<table>
<thead>
<tr>
<th>Clases de Piedra y su procedencia</th>
<th>Peso de un metro cúbico (Kilogs.)</th>
<th>Peso de un pie cúbico (Kilogs.)</th>
<th>Lado de los cubos de ensayo (Cts.)</th>
<th>Carga de prueba (Kilogs.)</th>
<th>Carga de rotura por centímetro cuadrado (Kilogs.)</th>
<th>Observaciones</th>
</tr>
</thead>
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<tr>
<td>Granítica berroqueña del Berrocal (Madrid)</td>
<td>2.681</td>
<td>58</td>
<td>6</td>
<td>17.596</td>
<td>489</td>
<td>Se rajó el cubo con la carga de prueba</td>
</tr>
<tr>
<td>Mármore azulada (Alconera, Badajoz)</td>
<td>2.769</td>
<td>59'90</td>
<td>6</td>
<td>17.236</td>
<td>479</td>
<td>Idem.</td>
</tr>
<tr>
<td>Mármore Rabaggiore Coraza (Italia)</td>
<td>3.020</td>
<td>65'33</td>
<td>5</td>
<td>10.664</td>
<td>427</td>
<td>Idem.</td>
</tr>
<tr>
<td>Mármore Rojo Rentería (Guipúzcoa)</td>
<td>3.016</td>
<td>65'24</td>
<td>5</td>
<td>9.976</td>
<td>399</td>
<td>Idem.</td>
</tr>
<tr>
<td>Mármore viólico (Granada)</td>
<td>2.972</td>
<td>64'28</td>
<td>5</td>
<td>9.912</td>
<td>397</td>
<td>Idem.</td>
</tr>
<tr>
<td>Mármore blanco Macad (sic) (Almería)</td>
<td>3.016</td>
<td>65'24</td>
<td>5</td>
<td>8.600</td>
<td>344</td>
<td>Idem.</td>
</tr>
<tr>
<td>Calcárea oscura Baides (Guadalajara)</td>
<td>2.591</td>
<td>56</td>
<td>6</td>
<td>11.864</td>
<td>329</td>
<td>Idem.</td>
</tr>
<tr>
<td>Calcárea blanca Colmenar de Oreja (Madrid)</td>
<td>2.599</td>
<td>56'22</td>
<td>6</td>
<td>11.494</td>
<td>319</td>
<td>Idem.</td>
</tr>
<tr>
<td>Calcárea Petrel (Alicante)</td>
<td>2.300</td>
<td>49'75</td>
<td>5</td>
<td>5.230</td>
<td>276</td>
<td>Peso y resistencia término medio</td>
</tr>
<tr>
<td>Calcárea Morena Tafalla (Navarra)</td>
<td>2.588</td>
<td>55'98</td>
<td>6</td>
<td>9.444</td>
<td>262</td>
<td>Idem.</td>
</tr>
<tr>
<td>Mármore Vordiglio (Italia)</td>
<td>2.920</td>
<td>63'16</td>
<td>5</td>
<td>6.040</td>
<td>242</td>
<td>Idem.</td>
</tr>
<tr>
<td>Calcárea blanca Monóvar (Alicante)</td>
<td>2.204</td>
<td>47'59</td>
<td>5</td>
<td>6.040</td>
<td>242</td>
<td>Idem.</td>
</tr>
<tr>
<td>Calcárea blanca Novelda</td>
<td>2.300</td>
<td>49'75</td>
<td>5</td>
<td>3.640</td>
<td>135</td>
<td>Idem.</td>
</tr>
<tr>
<td>Calcárea morena Lamorqui, (sic) (Alicante)</td>
<td>2.281</td>
<td>49'34</td>
<td>5</td>
<td>3.080</td>
<td>134</td>
<td>Idem.</td>
</tr>
<tr>
<td>Calcárea blanca Tudela (Navarra)</td>
<td>2.030</td>
<td>43'91</td>
<td>6</td>
<td>4.440</td>
<td>123</td>
<td>Idem.</td>
</tr>
<tr>
<td>Calcárea morena Roda o Bará (Tarragona)</td>
<td>2.009</td>
<td>43'43</td>
<td>6</td>
<td>4.200</td>
<td>117</td>
<td>Idem.</td>
</tr>
<tr>
<td>Calcárea blanca Arcos (Cuenca)</td>
<td>1.813</td>
<td>39'22</td>
<td>6</td>
<td>4.200</td>
<td>117</td>
<td>Id. usada en la Catedral de Cuenca</td>
</tr>
<tr>
<td>Calcárea blanca Sax (Alicante)</td>
<td>2.093</td>
<td>45'27</td>
<td>6</td>
<td>3.640</td>
<td>101</td>
<td>Idem.</td>
</tr>
<tr>
<td>Calcárea blanca Fonz (Huesca)</td>
<td>2.280</td>
<td>49'32</td>
<td>5</td>
<td>1.960</td>
<td>78</td>
<td>Se aplastó reduciéndose a polvo en la prueba</td>
</tr>
<tr>
<td>Calcárea blanca Segovia</td>
<td>1.896</td>
<td>41'01</td>
<td>5</td>
<td>1.800</td>
<td>64</td>
<td>Id. resistencia y peso término medio</td>
</tr>
<tr>
<td>Calcárea amarillenta Uclés (Cuenca)</td>
<td>1.847</td>
<td>39'95</td>
<td>6</td>
<td>2.040</td>
<td>57</td>
<td>Idem.</td>
</tr>
<tr>
<td>Calcárea blanca Luna (Zaragoza)</td>
<td>1.907</td>
<td>41'25</td>
<td>6</td>
<td>1.992</td>
<td>55</td>
<td>Idem.</td>
</tr>
</tbody>
</table>

Figure 3
Table with the results of the tests according to the original of Marques de Cubas (1886)
completed. The stone awarded came from Sigüenza (Guadalajara) and was offered by the quarry-owner Manuel Bueno. Afterwards, a commission presented a report about the field characteristics of the stone and the stone was rejected because there was not good prospects about the supplying. The quarry owner proposed to use another stone coming from Tamajón. In 1906 it was decided to delay the selection of the stone for the main building but it was arranged that Manuel Bueno would supply the stone from Tamajón for the pavement.

The Architect Enrique Repullés announced the result of the contest for the pavement of the Crypt during the following year. For that purpose marble from Macael (Almeria) was chosen. The Tamajon Limestones were rejected because the samples did not satisfy the Board (24 Feb. 1907). In the same session the thickness of the pavement stones were set in 5 cm, less than was said in the standards for the contest, and Mr Alguero and son were designated to supply and complete the work.

The previous one is the last reference about the supplying of stones for the Crypt in the first book of minutes of the Building Board meetings.

**Economical Features of the Building Work**

The economic data referred to in the minutes of the Building Board meetings about financial sources and cost of stones allows us to compare the economy of the Fabric in the Cathedral of the Almudena with older Cathedrals. In the Cathedrals before of the 19th century the Fabric was supported with three types of deposits: Traditional incomes of the Fabric, alms and planned giving and extraordinary deposits (Cortón 1990).

Into the first types were included: The censos, which were contracts with properties that produced an annual rent. Only a little part was conceded to the Fabric (Lopez-Arevalo 1966). The excusados were tributes exempted to be paid to the King in favour of the chapter. Sometimes the quarriers had the condition of excusados (Caso 1981). The Fabric also received one third or one half of the anatas that were the annual rents of the belongings of the Church. Other deposits came from the graves or the impetras (payment for the right of begging) and a part of the chapter incomes.

In the second types we include all the planned giving offered by unions, monarchs or institutions. These were the main deposits supporting the Fabric. The extraordinary deposits included the collections, donations to Chapter, loans to the Cathedral from little parish churches and sale of chapels, ornaments or jewels (Galera 1982).

In the case of the Cathedral of the Almudena the first type of traditional incomes were non-existent and the main source of incomes was provided by donations from private institutions and non-planned giving. There was also important the extraordinary deposits coming from the sale of chapels, jewels . . .

The first income for the Cathedral was a donation of 880,000 reales coming from some members of the Royal Family. This donation was also the beginning of a public subscription (29th June 1879). The sale of burials and funerary chapels as well as wills that make donations to the Cathedral was the main source of incomes as the crypt was been finished. There were also some cases when was necessary to sale ornaments.

We also find in the minutes economic information about the cost of the stone used in the construction of the Crypt. The three main types of stone used cost the following: Piedra de Baides – 175 pts/m³; Caliza de Portugal – 240.20 pts/m³; Mármol de Macael – 41.30 pts/m³.

**Location of the Quarries of the Building**

**Ways of Transportation.**

The supplying of stones is related to the transport ways existing in each age and to the vehicles that dictates the size of the blocks that could be transported. Therefore the ways and means of transport have been a major factor for the selection of building stones and we should consider both factor for the study of historical sources of stone.

The city of Madrid was supplied until the middle of the 19th century mainly with granitic rocks from the Sierra de Guadarrama and with cretacic and tertiary limestones. These limestones was found in outcrops inside the region. The transportation lines at the beginning of the 19th century were to poor, therefore, for large volumes of rock, the distance of the quarries was limited since the transportation of stones was very hard.
The supplying of stone from outside the region began with the setting up of the railway lines. The first railway line was inaugurated 9 de febrero de 1851 and traveled from Madrid to the Royal Place of Aranjuez. That line was lengthened to Alicante in 1858. The company MZA (Madrid-Zaragoza-Alicante) was the owner of that line. As a result of the lengthening of the line new stones were supplied to Madrid because the extraction and cutting of the new stones was cheaper. Figure 4 shows the relations between the railway lines and the stone supplying in the Cathedral of the Almudena. Both the first proposed stones in 1886 and the definitive stones were related with good railway communications.

Petrological Characterization of the Materials

Even when this work is mainly based on the document analysis we should combine both documental and petrological analysis to locate the original quarries of a historical building as we said before.

The visual inspection of the crypt allowed us to locate the four stone types mentioned in the minutes. After sampling the building carefully, petrological and petrophysical studies have been made. The results of these tests were compared with those made in samples from the possible sources.

The first material is located in the lower parts of the building and came according to the minutes from Baides, Guadalajara. This material is a dolomitic pelspartite. The possible areas were located considering the data obtained from the National Geological Map (MAGNA) and the town council. The area was sampled and after the tests the quarries were located in the Barranco de la Hoz.

Dolostone beds with metric thickness of the Upper Cretaceous (IGME 1978) were quarried in this area. It can be found cut blocks with toolmarks as remains of the quarrying (Figure 5). Instead the stone is mentioned in the minutes as Piedra de Baides, the quarries belongs to the council of Viana de Jadraque at 3 km from Baides and probably the name was changed mainly because the railway station was in Baides.

The second lithology is the main stone type in the Crypt and it is a fossiliferous micrite. The samples from the Building were compared with different limestones from Portugal. The results showed that this stone came from the Jurassic Units of the Maciço
Suppling of masonry materials in the construction of the crypt of Santa María la Real de la Almudena

Figure 5
View of the abandoned blocks, remainder of the bedstones quarried in the area of Baides - Viana de Jadraque

Calcário Estremenho and it is related with the stone whose trade name is Alpinina (IGMP 1998).

The chapitels and cut archs of the façade were made of a diferent stone type. Actually, the selected material was not mentioned in the minutes, however it seems probable that this stone type came from Portugal as its supplying overlapped with the supplying of the other. If this premise it is true the stone would be the same of the Monastery of Batalha (Rosal type). The stone in the Building is an oomicrite with fossils but the type of sample did not allow to make tests for the location.

The pavement was made with poligonal granoblastic calcitic marble. The tests showed that this stone used also in other inner elements came from Macael (Almeria).

CONCLUSIONS

The construction of the Cathedral of Santa Maria la Real de la Almudena lasted for over a century. This length of time is not common in the 19th and 20th centuries even for such a large building. This delay caused the mixture of styles in the building because the original project was changed several times since its beginning. That mixture of neo-styles and its recent character compared to the oldest cathedrals in Spain might be the cause of the lack of studies about this building.

It could be seen that the strong delay in the execution of the building works in the Crypt of the Cathedral was caused not only by the lack of economical resources, but mainly because of the problems with the stone simply due to contracts. This point shows the importance of the stone in a building as a conditional factor in its construction and, of course, its durability.

The vast array of stone studied for the purpose of choosing the best material for the Crypt is detailed. In that way, the first Architect responsible for the building, Marques de Cubas, tried to improve the concept of stone supplying in the Middle Ages. Although that process was carried out with careful attention, we can see how there were many socio-economical aspects affecting the supplying and not related to the rock itself. Even when the Architect criticised that in the older Cathedrals the stone selection was related with the proximity of the quarries it could be seen how strong is the relation between the selection of the stone in a building.

The Crypt of the Cathedral of the Almudena is one of the first buildings in Madrid in which nearly all of the stony materials were from outside the region related to the beginning of new ways of transportation. The study of the ways of transport in
each age and the means of transport have to be taken into account for the purpose of locating the original quarries of stone in buildings.

The petrological and petrophysical tests of the stones of a building are always necessary for the correct determination of quarries of historical buildings as well as the design of restoration works. This work shows that this is not a new concept and that in the second half of the 19th century there was a concern about the previous tests and the durability of the stony materials.

With both document and petrological tests of the building we can conclude that the materials used on the construction of the Crypt of the Cathedral of Santa María la Real de la Almudena were: Dolomitic pelspartite from Baides, Fossiliferous micrite (Pink Alpinina type) from Portugal, Oomicrite with fossils (Rosal type?) and Granoblastic Calcitic Marble from Macael. The masonry was made with the first two stone types. They show in the building a similar aspect because they are both covered by lime. The stone from Baides comprises only the below part of the building. Most of the building is made with the Alpinina type limestone whose quarries are located near Porto de Mos.

ACKNOWLEDGEMENTS

This work could not have been carried out without the support of Antonio Astillero, Dean of the Cathedral of the Almudena and the archivists of the Historic Archive of the Diocese of Madrid. We would like also to acknowledge the Mayor and the staff of the Town Council of Baides as well as Robert Frigo and the staff of the Instituto Geológico e Mineiro de Portugal, CEVALOR and ASSIMAGRA for their help and attention during the preparation of this work.

NOTES

1. The Marques de Cubas highlighted the importance that had the selection of the stones for an architect: «Una de las cuestiones más difíciles de resolver que pueden presentarse al arquitecto encargado de la construcción de un edificio, es indudablemente la elección de los materiales» (Cubas 1886). He criticised that architects chose the materials hastily, which affected its durability «Hoy, Excmo. Señor, pagamos bien cara la precipitación de aquellos constructores, pues muchos de los soberbios monumentos que la piedad y saber de nuestros antepasados erigieran, amenazan ruina, cuando aun debieran mostrarse erguidos y rasgar las nubes por bastantes siglos más.» (Cubas 1886).

2. Dates in brackets are referred to sessions in: Libro de Actas de la Junta de Edificación del Templo de Santa María de la Almudena, 1879–1934.

3. Actually, the monastery of Uélés was not built with stone from quarries of Uélés. Therefore this attribution is wrong. (Lopez de Azcona et al 2001)

4. Both stones from Viana and Baides would be the same materials. The stone from Baides was quarried in an area belonging to the council of Viana de Jadraque.

5. That last stone was referred as the same with which the Monastery of Batalha was built. That could be a clue of the origin of that stone.

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