# Stone Construction Materials of the Vera Cruz Church

Subjects: Architecture And Design

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As part of the restoration project of the 13th century Vera Cruz Church (Segovia, Spain), a preliminary study of the stones used in its construction—dolostones of the Montejo de la Vega Fm of Santonian age (Upper Cretaceous)—and the possible location of the quarry of the provenance of these stones was carried out. For this purpose, a comparative analysis was performed between the currently active quarry of La Vera Cruz n° 88 and the historical quarry of Zamarramala. The samples were characterized using a multidisciplinary approach, combining X-ray diffraction (XRD), polarized optical microscopy (POM), and scanning electron microscopy with microanalysis (SEM-EDX).

Keywords: Vera Cruz Church (Segovia) ; provenance area ; restoration ; multidisciplinary approach

## 1. Introduction

On the occasion of its forthcoming restoration, a multidisciplinary team is conducting a study of the Vera Cruz Church in Segovia, Spain.

The research team that will be in charge of the pre-restoration studies [1] includes architects, engineers, historians, archaeologists, and geologists. The role of geosciences is fundamental in this type of study related to stone materials or geomaterials. In particular, it will provide information on the nature of the stones used, their state of conservation, and their provenance. This is relevant to the assessment of the building's heritage values, both material and non-material, including the complex approach to the concept of authenticity [2].

On the other hand, the physical and mechanical properties of the new materials to be used in the restoration must be studied to ensure maximum compatibility, for which it is essential to determine precisely which of the current quarrying areas can provide a suitable stone [2][3].

## 2. The Building—History and Former Restorations

The construction of the Vera Cruz Church (**Figure 1**) dates from the second half of the 12th century to the beginning of the 13th century. Architects and historians do not agree on the military order that founded it, although at present, according to López-Yarto Elizade, it is mostly attributed to the Order of the Holy Sepulchre [4]. From the 14th century until the middle of the 17th century, the church passed into the hands of the Order of Saint John of Jerusalem [5]. In 1663, a period of gradual abandonment began until 1835 when it was disentailed. Later, in 1846, the Commission of Monuments of Segovia took charge of the temple. The San Fernando Royal Academy of Fine Arts contributed during this period with some interventions, especially in the occasional tasks of tiling the roof [6].

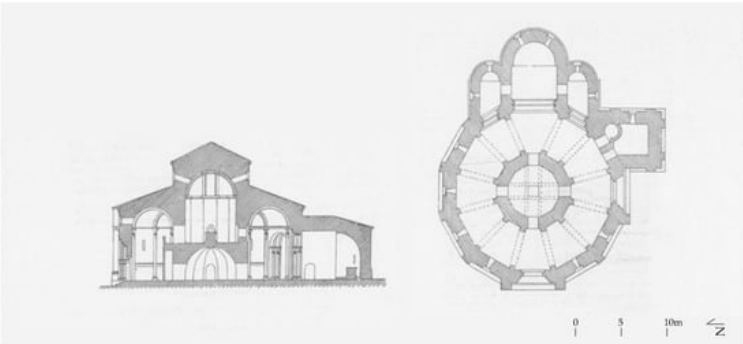

**Figure 1.** Floor plan and cross-section of the church, by Vicente Lampérez y Romea in *Historia de la Arquitectura Cristiana Española según el estudio de los elementos y los monumentos* (1930) [7].

Between 1946 and 1949, the church underwent consolidation and restoration work. The project was designed by Cabello y Dodero. An analysis of the state of the masonry was performed, which revealed water leaks inside the building and a large number of fissures in the vaults. The outer walls were in good condition, but the interior layers needed to be cleaned. Externally, the stone corbels on the eaves were deteriorated, and an interesting relief on the side door had practically disappeared, but the rest of the doorways were found to be in good condition and required only minor repairs.

In this intervention, the roof and the cornice of stone corbels were restored [8]. The 1949 restoration project for the Vera Cruz Church, also designed by Cabello y Dodero, focused on restoring the interior of the church. The cracks in the walls and the vault were sealed and a concrete ring beam was built. The stone masonry of the interior, which had been repainted and smoked, was cleaned [9].

In 1949, it was given to the Sovereign Military Order of Malta, heir to the Order of the Knights of the Hospital of Saint John of Jerusalem [5]. Since then, every Good Friday, the Knights carry the relic of the Holy Wood in a procession.

## 3. The Building—Description

Vera Cruz is a beautiful and unique building of Romanesque architecture located to the northwest of the city of Segovia, next to the suburb of San Marcos on the way to Zamarramala. It is an isolated building that sits on a promontory from where the eyes can see the Alcazar of the city.

The spatial configuration of the building and its composition are part of a characteristically Romanesque scheme that incorporates a central layout with a triple apse. The floor plan is dodecagonal, with the temple of the Holy Sepulchre in Jerusalem as a reference archetype.

The outer wall is made up of sections that follow a twelve-sided polygonal layout on the extrados, while, on the intrados, the wall follows a circular layout, except for the two sides of the polygon where the doors open, which are also straight panels on the intrados. One of these two doorways faces west and the other south. The geometric ornamentation belongs to different schools [10] where the Norman school predominates [7].

The west doorway (**Figure 2**a) consists of three pairs of columns topped with capitals and archivolts (a set of arches inscribed on top of each other to form a flared doorway). The first arch is only decorated with a thick architrave on its edge and rests on the doorjambs [11]. Men, birds, and demons embellish the capitals of the six columns. Chevron ornaments adorn the upper and lower parts of the archivolts [12]. The archivolt, which closes the whole, is decorated with a fine square billet (chequers) molding. All of them are framed by a horizontal impost of carved corbels. The carving is very fine and graceful, as Cabello y Dodero points out. The stone used for the doorways is better suited to the needs of a more precise, better quality carving, as it is finer-grained.


**Figure 2.** Church façades: (**a**) West doorway; (**b**) South doorway. Orthoimages: Luis-Javier Sánchez-Aparicio.

The south doorway (**Figure 2**b) is also flared but has only two pairs of semicircular archivolts. These are surmounted by a chequer molding as well. In this doorway, the work on the archivolts and capitals is simpler and the decoration is much less elaborate. Above this door is a bas-relief that was described in the report of the Royal Academy of Fine Arts of San Fernando. It had already deteriorated in 1919, but it was possible to identify a seated monarch or a judge in the act of administering justice on the left side, three standing women on the right, and a tree in the center [4].

## 4. Geological Setting and Quarries

The literature on comparative studies of quarry and stone heritage samples is very rich. Most of the works show an interest in the location of old quarries in order to know what trade and mining activity was like in ancient times. In some cases, this academic objective is complemented by another of an applied nature: to have a compatible resource for future restoration. Much of the work consulted is based on mineralogical and petrographic studies, using thin sections studied by PLM. The most common is the geochemical study, especially in marbles [13][14], but also in limestones [15][16] and in volcanic rocks [17], with the use of binary diagrams of representative ions and the projection in classical diagrams such as the Total Alkali–Silica (TAS).

Complementary to the use of these mineralogical, petrographic, and chemical techniques, other authors have worked on the comparative study with petrophysical tests, mainly focusing on hydric [18] and mechanical properties through non-

destructive testing [19], and even through the correlation of deterioration patterns in the monument and in the quarries [20] [21].

Several quarries have been documented as the source of the materials used in the most important historical buildings in the city of Segovia [22][23][24]. In particular, the *Piedra de Bernuy*, a fine-grained, compact, yellowish dolostone, and the *Piedra del Parral*, a fine-grained dolostone with yellow-orange tones and a certain degree of closed porosity described as dolomitic limestone or even as dolomitic sandstone [25]. Both stones come from the same geological area: Dolostones Formation of Montejo de la Vega, Upper Cretaceous (**Figure 3**). This formation follows the model of the internal carbonate platform of high to medium energy, with a parareciphalic character. The unit is homogeneous and consists mainly of recrystallized dolomite [26].

Historically, the *Piedra del Parral* has been extracted from various quarry fronts, in search of the banks with the best conditions for its exploitation along the outcrop of the Montejo de la Vega Formation in the cuts of the terrain on the outskirts of Segovia. These outcrops have even been exploited in underground mining, depending on the topography. In the literature, Refs. [22][23][24] describe the areas of the valley of Tejadilla and the Vera Cruz ravine, including those known as ‘Zamarramala’ and ‘Vera Cruz 88’ as the most recent exploitations [24].

According to the bibliography, the masonry used in the construction of the temple came mainly from historical mining areas near the building, especially the Parral and Zamarramala stone quarries [22][27].

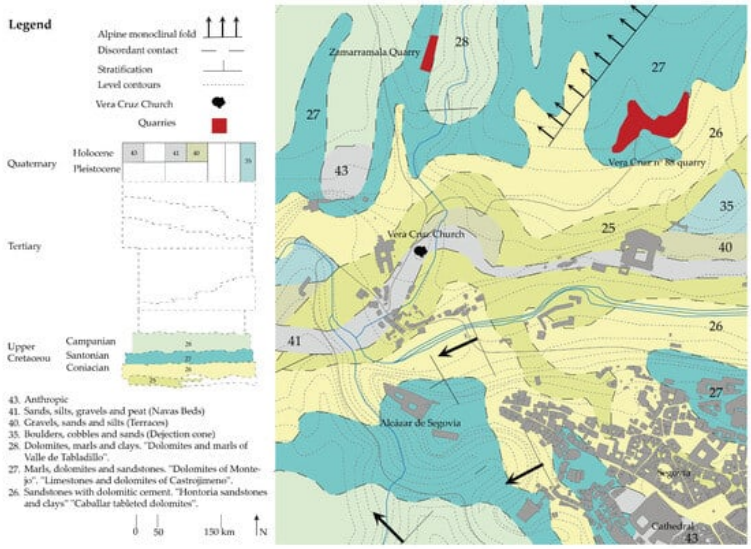


**Figure 3.** Geological map of the area. To the south (below) is the city of Segovia. To the north (top) is the town of Zamarramala. The black-highlighted building features the Vera Cruz Church. Quarries are marked in red, with the historical Zamarramala quarry on the left and Vera Cruz n° 88 on the right. Both quarries belong to the same geological unit n° 27, identified as ‘Dolostone Formation of Montejo de la Vega’. Figure constructed using cartographic bases BTN25, sheet 35037, from the National Geographical Institute (IGN) [28] and Sheet n° 483 (Segovia) of the Geological Map of Spain, E:1:50.000, second series, 1st edition (MAGNA) [29]. Segovia: 40.94808, −4.11839.

Parral dolostone is quarried at ‘Vera Cruz n° 88’ (**Figure 4**a), which is still active today, and could be used for the reconstruction of elements in the church. It is an open-cast quarry, although there are traces of underground mining. The terraces are about 10 m high on a slope front about 100 m long [24]. The stone, soft and porous, is suitable for building (**Table 1**). It is possible that the stones in Vera Cruz come from different strata and quarry faces.


**Figure 4.** (**a**) Active quarry of Vera Cruz n° 88. (**b**) Historical quarry of Zamarramala. Source: Google Earth [30].

It is a fine-grained, cream-colored dolomite with some centimetric-sized cavities on the surface. It has undergone a strong dolomitization process. Its dolomite content is between 75% and 95%. The content of siliciclastic components of quartz grains and potassium feldspar can reach 10%, with an average size of 1 mm. Its crystalline texture is very homogeneous, with crystals of rhombic sections quite euhedral and zoned [22].

Porosity can be observed macroscopically and involves the formation of cavern-type macropores that do not communicate with each other. Microscopically, secondary porosity of the moldous type is observed due to the dissolution of bioclasts [22][24].

As for the Zamarramala quarry (**Figure 4**b), it is also an open-cast quarry with traces of underground extraction and with better-quality fronts [24]. It was exploited in search of a stone with a finer grain size and lighter color, considered to be of better quality for carving.

## 5. Stone Weathering

In order to gain a better understanding of the material, an initial conservation assessment was conducted. This assessment makes possible a better understanding of the current condition of the stone and its behavior in its environment, as well as better decision-making regarding preventive measures and future interventions.

Following the terminology proposed by ICOMOS [31], alterations are identified in all the categories described in the Glossary, as visually illustrated in **Figure 5**.


**Figure 5.** Stone weathering following ICOMOS terminology.

Fracture-type cracks are observed in the masonry and are particularly evident in the apses (west façade) and interior vaults. As a result of the accumulation of water and unfortunate interventions, detachments in the form of fragmentation

can be seen in the base area and in the masonry.

The predominant alteration observed in the monument is material loss. There is pitting (unconnected cavities) in the contact zones between the granite steps and the dolostone on the south façade [22]. In addition, interconnected cavities in the form of alveolization are prevalent. Discoloration and deposits associated with damp conditions are particularly concentrated on the base and roof, giving rise to efflorescence and soiling.

Biological colonization of spores within dolostone pores causes cracking upon germination. Low intracrystalline porosity potentially hinders fungal penetration into the crystal, so they are located in spaces between dolomitic crystals. Fungi are predominantly associated with altered zones, both on the surface and in the interior [27]. In addition, plants are also found on the outer walls.

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