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The church of Saint Martin (Trujillo, Spain): Study of the stone degradation

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ABSTRACT

The Church of Saint Martin is located in Trujillo (Caceres, Spain) and it was built in the 15th century. The sub-soil is of granitic type. The climate of this area is Mediterranean type and the air pollution is scarce and of little relevance in terms of stone degradation. The predominant stone in the monument is of granitic type originated from local quarries. After a careful sampling of the building, a mineralogical-petrographical analysis was performed applying the following analytical techniques: X-Ray Diffraction and Polarized Optical Microscopy. Through visual inspection it was determined that the general conservation state of the building was quite good; however grain disgregation was detected in areas affected by raising damp and therefore some sculptural decoration was ruined. Abundant saline efflorescence also existed. Furthermore, a great variety of mortars that has been used during previous restoration works was also detected. The composition of these mortars is based on lime and crushed stone, Portland cement and arid-containing plaster that could be the source of the high level of efflorescence. This study has allowed proposing some actions to protect the monument.

1. Research aims

This study focused in setting the nature and composition of stone, and the weathering factors of the church of Saint Martin (Trujillo, Spain).

The main research aims are:

- study of deterioration indicators and alterations factors;
- chemical characterization of samples of stone, efflorescences and mortar;
- analyses of climate and pollution of the area;
- petrographic and mineralogical characterization of stone using X-Ray Diffraction, IR spectroscopy and Polarized Light Optical Microscopy.

This study has allowed proposing some actions to protect the monument.

2. Experimental

2.1. Introduction

The church (Fig. 1) was built between s.XV and s.XVI in Trujillo, town located at 50 km from Cáceres (Extremadura, Spain), about 500 m above sea level. The sub-soil is granitic type (called "El Berrocal").

The weather data, provided by the National Institute of Meteorology can be summarized as follows:

It is Mediterranean climate (Continental Extreme). The average annual frost days are 4.5. July and August are the warmest months with an average monthly temperature of 26 °C, but the monthly average maximum temperature in these months is 32 °C. December and January are the coldest month with an average temperature of 8 °C and the monthly average minimum temperature in these months is 5 °C.

The mean annual relative humidity is 57%, with a maximum in December and January (76%), and a minimum in July and August (35.5%). The hygrometric variations, more important as a deterioration factor, reach a maximum in July, from 70% at 17:00 pm to 35% at 13:00 pm.

Soft winds from west prevail during the year and from the south-west in winter and spring.

Traffic around the church is moderate, so air pollution is supposed to have little influence on the stone alteration.

There are many biological agents: algae, lichens and, plants, and there are storks that nest on the towers.

2.2. Materials

Five samples have been studied: mortar (TR-1), efflorescences (TR-2), and three stone samples (highly-altered stone, TR-3; medium-altered stone, TR-4; non-altered stone, TR-5). All samples were taken from the most altered areas in the church.

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Fig. 1. The church of Saint Martin.

2.3. Methodologies

XRD: X-ray diffraction for the identification of crystalline minerals. It allows a semiquantitative analysis.

MOP: Polarization Optical Microscopy: to identify major and minor minerals (not detected by XRD) and petrographical properties study.

2.4. Deterioration indicators and alteration factors present in the building

Although visual inspection of the building showed a good conservation state, the following deterioration factors were detected in some areas (Fig. 2):

- the most important deterioration indicator is grain disgregation due to the combined effect of dampness and salt-rich mortars;
- there are exfoliations and contour spalling, pitting in wet and windy areas and some crater formation related to grain disgregation;
- there are damages due to freezing in wet areas;
- spalling is related to the grain disgregation and to temperature changes in elements with high surfaces exposed to air. There are big fissures due to mechanical actions and sysmicity;
- there are a lot of efflorescences due to the mortars used in reparation and restoration works;
- biological factors (algae, lichens and plants).

2.5. Results

2.5.1. Stone

Three samples show similar mineralogical composition (Table 1) consisting primarily of quartz (mineral majority), followed by plagioclase and alkali feldspar, mica and to a lesser extent (muscovite or white mica, and biotite: black mica). Some Fe oxides were observed.

Quartz is the most abundant mineral with grain size in the range of 3–0.2 mm. Micas (muscovite and biotite) are usually larger than previous ones (3–4 mm), but are also very small crystals up to 0.1 mm.

Quartz shows low alteration and it usually appears clean and without chemical alteration. Plagioclases and feldspars are very altered, mainly in the surface by the action of the environmental factors, due to those minerals can be transformed by hydrolysis processes in clay minerals.

Sometimes around the grains of feldspar and plagioclase, clay forms by hydrolysis, causing crystal separation and disgregation, with a greater relevance in sample TR-3, in which even the quartz grains show small cracks. The transformation in clay minerals is much higher in the sample TR-3 (Fig. 3), but it is also important in TR-4 (Fig. 4) and TR-5 (Fig. 5). Furthermore, micas are also altered in some areas due to the above-explained hydrolysis.

Stones are included in the group holocrystalline plutonic igneous rocks, composed entirely of well-defined crystals, which were cooled gradually in earth crust. Regarding the color, they correspond to a leucocratic felsic stone, in which light colored minerals predominate on dark colored ones. The grain size range from medium to fine-grained (5 to less than 2 mm), being mostly fine grains.

Based on above-mentioned characteristics, stone are included in the group of granitic rocks. The stone can be classified between granite and fine-grained diorite depending on the relative

Fig. 2. Deterioration factors present in stone.

Table 1
Mineralogical composition of stone samples (%).

Sample	Description	Quartz	Feldspars	Plagioclase	Mica (moscovite and biotite)
TR-3	Very weathered	38	31	20	10
TR-4	Weathered	38	17	33	11
TR-5	Not weathered	39	19	32	10