A ROCK CHURCH PREVENTIVE CONSERVATION PROJECT: THE CASE STUDY OF THE CRYPT OF ONE HUNDRED SAINTS IN MATERA

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Abstract - The church of the Hundred Saints, now better known as the Crypt of the Original Sin, is located in the gorge *"Gravina di Picciano"*, about ten kilometers from Matera. The rock church and its decorations, dated back to the ninth century, were in critical condition when it was discovered and later acquired by the Zetema Foundation of Matera. In 2000, a monitoring project was started under the scientific direction of Michele D'Elia, and is still ongoing in collaboration with specialists from the ICR (now ISCR), from UniromaTre, and various technical experts. The project aimed to design a conservation plan and to find solutions not only for the specific problems, but also to develop a protocol for the conservation and maintenance of similar rock-art sites. The wall paintings were colonized by different microorganisms and showed problems of salt efflorescence and carbonatation. A program was set up to control bio-growth, carry out characterization of materials, test treatment products and perform interventions to resolve the site's conservation problems. After concluding conservation treatment in 2004, two check-up and maintenance interventions followed in 2010 and 2017. These involved evaluating new degradation phenomena, the efficacy of biocidal products, the new cleaning method and the validity of the treatment choices adopted.

Keywords: biological patina, disinfection, cation exchange resin, laser cleaning.

I. INTRODUCTION- PRELIMINARY DIAGNOSTIC PHASE

The rock church, was discovered in 1963 by the *Circolo La Scaletta* of Matera. The paintings, dated to between the second half of the 8th and the 10th centuries, are found only on two walls of the principal space: wall A (Fig. 1a, in 2003), parallel to the gorge, and wall B (Fig. 1b, in 2003) perpendicular to it.

Fig.1a, b Wall A and B in 2003, before treatment

Microclimatic monitoring was carried out in 2001 both outside and inside the crypt and sampling was carried out to determine water content and the presence of soluble salts.

At the same time, between 2001 and 2002, diagnostic sampling was carried out in agreement with the scientific laboratories of the ICR. This involved the study of biological and chemical alteration phenomena, both inside and outside the crypt. Microscopic examination and microbial cultures of various dark green, bright green, black and brown colored biological patinas led to their identification as different species of algae and cyanobacteria (Nugari et al.,

2007). Pink patinas which were not identified at the time were also present, as were sporadic lichens in the form of dusty gray-or-whitish patinas, or yellow incrustations and small ferns. The external flora, constituted by several grasses and bushes of the Mediterranean garrigues, was also surveyed (Caneva and Pacini 2002-3).
In the same campaign, chemical degradation phenomena were also analyzed. These were above all salt efflorescence – essentially calcite and gypsum – in the form of either white veils on the paint layers, or, where there were losses in the plaster, generally thicker encrustations with at times spherical formations (Fig. 2), orangish in colour (Caneva and Pacini 2002-3; Giovagnoli et al, 2005).

Fig. 2 Spherical formations due to salt efflorescence.

In 2003, a 1:20 scale graphic survey of the frescoed surfaces was also carried out (Studio M.C.M.) to document the various deterioration phenomena and sampling locations. This map showed the distribution of the biological phenomena had changed significantly compared to previous years, with an evident increase the pink areas. Consequently, in addition to the monitoring of the extent of biological growth, detailed diagnostic study was carried out on the pink patinas using molecular techniques. This showed that the pink patinas were the result of carotenoid formation due to the growth of a xerophilous bacterium *Rubrobacter radiotoleran*s (Imperi et al., 2009).
These analyses showed that external climatic conditions, and their variations, have strong repercussions on internal biological colonization: while heavy rains favour algal patinas, prolonged periods of drought favor halophilic xerotolerant bacteria.

At the conclusion of this diagnostic phase, micro-climatic, biological and chemical data were used as the basis for the project of waterproofing of the area above the crypt, which was performed in 2004.

II. MATERIALS AND METHODS: THE SELECTION OF PRODUCTS AND THEIR APPLICATION

To address the treatment of biodeterioration phenomena, tests were carried out to choose between three different biocides at two different concentrations: Rocima 110 (Acima), a quaternary ammonium salt + tin naphthenate; Preventol R80 (Bayer) benzalkonium chloride; Umonium 38 (Huckert's International) benzalkonium chloride + alcohols. Evaluation of results included observation under UV (Wood's lamp) and fluorescence (Figs 3a and 3b).

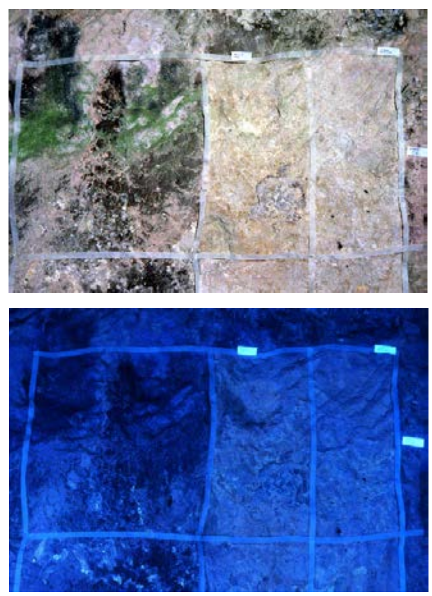

Fig.3a and b Biocide test using natural light and UV light

The biocide chosen was mixed in distilled water at 2% concentration and was applied by brush on the painted layer, and by brush and by spray (at 1.2 atmospheres) over the entire crypt; we tried to reach, as far as possible, to the bottom of all the deepest cavities of the stone, including the karstic cave on the right of the wall A.
The undecorated walls received only a minimum intervention: initial treatment with biocide

followed by mechanical cleaning with airbrasive, and a second biocide treatment. For spontaneous flora, Arsenal (Cyanamid) was selected to treat exclusively aggressive woody species. This involved two injections into the plants' root systems, with an interval of about three months between treatments.

Removal of carbonate deposits was carried out with electric micro-drills (Proxxon) with various different tips (abrasive, diamond, synthetic brushes of various hardness). For final cleaning of carbonate veils two types of cationic exchange resins produced by PHASE were tested. The first was the commercially available Descalbante 90, which was composed of the ionic exchange resin plus supporting material. The second product was the ion exchange resin on its own, with no supporting material, and was not commercially available. Both products were mixed with deionized water and applied by brush and/or spatula.

Consolidation of the stone was limited to where the plaster borders were delaminating and needed micro-filling. After testing, this consolidation was carried out by an ethyl silicate.

In the last phase of the intervention, laser cleaning was tested for the removal of white salt veils. These tests employed a EOS 1000 LQS laser at 380mJ with an impulse frequency of 10Hz, and 6mm spot. Trials were also performed with the THUNDER COMPACT laser.

Fig. 4 Cleaning with EOS 1000 LQS laser

From 2005 (immediately before the opening to the public) to 2008, four monitoring campaigns were carried out. These included biological and chemical characterization (FTIR and IC) of salt efflorescence, checking of surface colour using colorimetry and, in the last survey, video-microscopy of the surfaces. This last survey was aimed at documenting the state of the surfaces three years after conservation treatment, with particular attention given to the forms of deterioration present on the painted surfaces (Giovagnoli et al, 2009).

III. RESULTS AND DISCUSSION: THE MULTITEMPORAL MANAGEMENT PLAN

During testing, none of the three biocides examined caused color changes to the surface and while both Preventol R80 and Rocima 110 (at 2% in deionized water) were effective against the microflora, the former proved more efficient. Consequently, the first treatment of the biological patinas was carried out with Preventol R80 in November 2003, as previously described. Higher plant removal was limited to the large fig (*Ficus carica* L.) near the entrance cave with satisfactory results.

Visual verification of the treatment in April 2004 showed significant changes in the various bio-patinas: pink patinas were more limited in extent; bright green areas had become greyish brown and black and brown patinas were dark yellowish brown. With the waterproofing of the overlying rock shelf still ongoing, and critical temperature and humidity conditions, the restoration work carried out in 2004. In collaboration with the company OCRA srl of Matera, we adhered scrupulously to criteria of extreme prudence and minimum invasiveness.

Mechanical reduction of the thick carbonate deposits over the paint layer required the extreme care, as did removal of even thicker deposits in plaster losses. (Figs. 5a and 5b),

Removal of the very thin white veils on the paint also produced good results.

Reintegration was reduced to the minimum as the temperature/humidity conditions found in underground sites tend to cause colours to alter and fade rapidly.

Consequently, it was decided to present filled losses as if they were abraded plaster, rather than pictorially reconstructing them, as would have been done under other less extreme conditions.

Two maintenance interventions followed, the first in 2010, the second in 2017. These were accompanied by a new series of both biological and environmental studies.

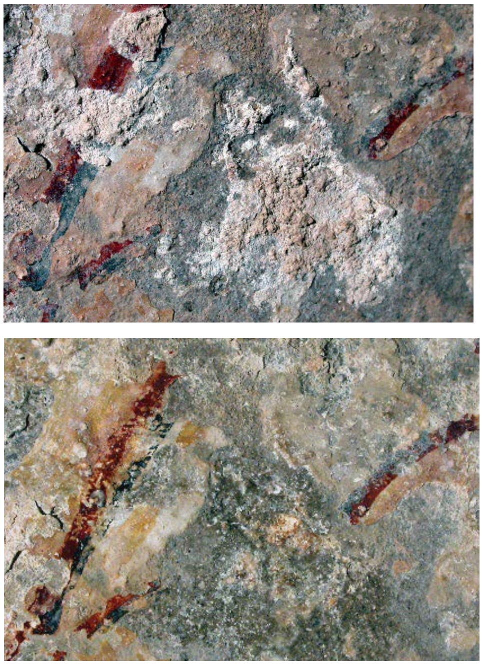

Fig.5 a and b Carbonate deposits before and after removal.

In both interventions, biocide treatments were performed that were similar to those developed during the restoration.
In the November 2017 maintenance, lasers were used to remove algal colonies in the stone at the base of the walls, after biocide treatment. Final results of this treatment still need to be verified after the subsequent treatment with Preventol Ri80 at 4% concentration.
Diagnostic investigations are still underway including the compilation of the ISCR *Environmental Data Sheet* and monitoring of the biodeterioration.

IV. CONCLUSIONS

The treatment as a whole has proved to be very effective, thanks also to the evident improvement of the environmental conditions due to the waterproofing of the calcarenite shelf, the partial closure of the wall towards the ravine, and the shading of the crypt with mechanized blinds.
However, white veils over the paint layers have reappeared, and significant carbonate encrustations have formed along the edges of losses and there has also been a limited amount of algal regrowth. To keep in check bio- and chemical degradation, it will be necessary to provide for maintenance treatments at no more than four yearly intervals. This rhythm would also mean that white veils could be reduced without resorting to aggressive means.
The conservation intervention discussed here, even considering the problems which have emerged, represents an exemplary case of long-term scheduled maintenance.

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