Condition Survey on XIV–XVIII Century Funerary Monuments in the Cloisters of St. Anthony Basilica in Padua

98

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Abstract

Most of the funerary monuments in the cloisters of St. Anthony's Basilica, being located in the centre of Padua, have suffered of marked decay processes related to the recent industrialisation which has strongly increased sulphur based-compound in the atmosphere. Extensive sampling of the monuments were performed following the European guidelines of CEN TC 346. Surface samples were collected from those areas which showed severe symptoms of stone deterioration. Care was taken to ensure that the samples were representative of each monument. Petrographic analyses of all surface crusts showed gypsum, in both microcrystalline flakes and in acicular crystals. Gypsum is the predominant phase due to sulphation processes, according to the interactions of the atmosphere in contact with the stone surface. SEM analyses (BSE images) of cross sections showed extensive micro-cracks in the limestone, parallel to the stone/crust interface, completely filled with gypsum. The study of the decay products, their extent on the surface and in depth of the stone and the causes that have led to their formation have allowed an important evaluation of decay degree and consequently the most appropriate procedure of restoration to be carried out.

Keywords

Monuments' condition • Stone decay • Black crust • Stone polychromy

98.1 Introduction

The present work aims to define the type and extent of deterioration processes in a series of Renaissance funerary monuments in the Cloisters of the Basilica of St. Anthony in Padua. As these funerary monuments are unique memorials to the history of distinguished Paduan scholars, intervention is urgently required to halt the fading of precious inscriptions from their surfaces. A condition assessment of the monument surfaces was therefore the first step taken by the conservation process. The condition of more than a hundred objects found in the cloisters was qualitatively evaluated to prioritise restoration works according to the severity of the damage.

This paper presents and discusses the results obtained on two monuments that are subjected to severe decay processes.

The funerary monument to Giovanni Calfurnio (1443–1503) was executed in the early 16th century by the sculptor Antonio Minello de` Bardi. Until 1871, the artwork was kept inside the church of San Giovanni da Verdara in Padua, and was successively moved to the Cloister of the Novitiates (Basilica of St. Anthony), in an area protected from direct water runoff. The monument is made of Nanto stone, a yellow-brown, marly-arenaceous limestone of the Middle

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Eocene, outcropping near Vicenza (Veneto, north-eastern Italy) and quarried along the slopes of the south-western sector of the Berici Hills. As restoration work is urgently required, stone characterisation and identification of decay products were carried out using classic mineralogic-petrographic and chemical methods. Photographic documentation collected in the past century enabled us to make a preliminary visual assessment. The surface showed extensive decayed areas which may be associated with the increased concentrations of sulphur pollutants measured in the atmosphere. This was thoroughly explained by many authors who carried out studies on Venetian monuments (Fassina 1978, 1988a, 1993, 1994; Fassina et al. 2001, 2002; Camuffo 1998).

The monument, located along the west wall of the cloister, is sheltered from direct rain and exposed to rain spray, fog deposition, air turbulence due to frequent condensation-evaporation cycles, and water rising from the ground by capillary migration. A north-north-easterly wind favours evaporation processes which are enhanced on the left side of the artwork, probably due to a stronger ventilation in that corner. The most severe damage is on the upper parts showing spalling and crumbling due to the combined action of salts and expansion of clay minerals. Black fly ash crusts are widespread on all stone surfaces, and crumbling, flaking, surface deposits and missing parts are visible on all surfaces. Large patches of dense efflorescence, caused by rising damp, affect the lower parts of the monuments up to a height of 70 cm above the ground (Fig. 98.1a).

The second monument examined is a St. George and dragon bas-relief, which was initially located on the external façade of St. George's oratory and was transferred inside the General Cloister in 1931. When the original bas-relief was removed, it was replaced by a copy made in the same Nanto stone. The original bas-relief, which has been preserved in a sheltered environment, exhibits widespread spalling in its most exposed sections. However, although its severe conditions of decay prompted conservation experts to shelter it inside the cloister, the extent of the damage is actually less than that observed on the copy now on the façade of St. George's oratory. In fact, several carved parts are missing from the outside work, especially on St. George's face, as clearly shown in photographs (Figs. 98.1b, c). Visual observation led us to conclude that the bas-relief copy exposed to weathering agents for 70 years has larger missing parts than the original one, which was exposed to the outside environment for four centuries (1552–1931). The more severe decay on the outside copy is closely associated with the sharp increase of atmospheric pollutant concentration that occurred after the 1960s during urbanisation and industrialisation periods (Fassina 1978, 1988b; Sabbioni 1995). The original bas-relief, which was exposed to the atmospheric agents for a much longer period (400 years) was only subjected to natural weathering, i.e., atmospheric agents of the pre-industrial period which deteriorated the artefact very slowly because only moderately aggressive.

From the visual observations we can conclude that preservation of the old bas-relief in a sheltered environment has contributed to its conservation.

98.2 Sampling and Analytical Methods

Surface samples were collected from areas showing severe signs of stone deterioration: damaged layers were scraped off, fragments of black crusts and stone were removed and salt efflorescence was sampled on the outer surface of the slabs of the ornamental stone. Special care was taken to ensure that the samples were representative of the whole monument.

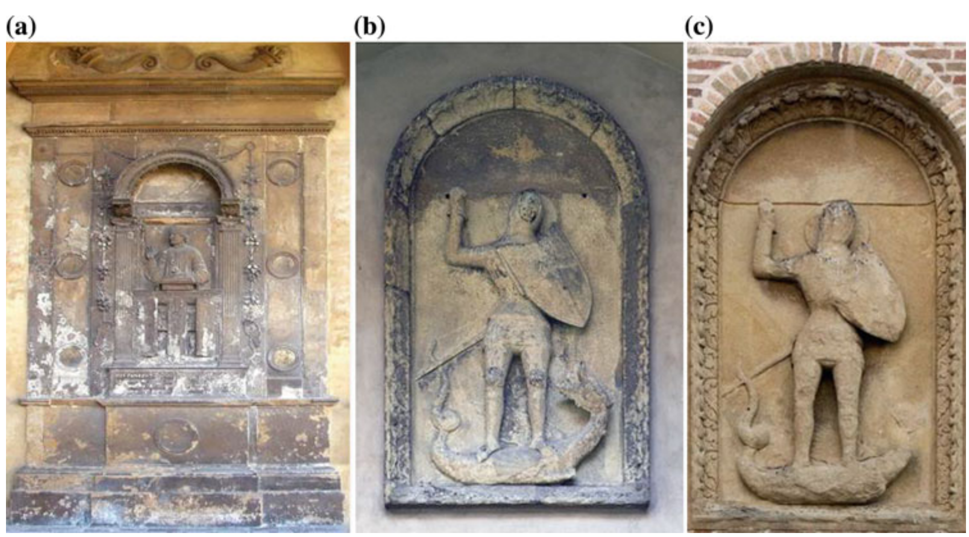

Fig. 98.1 **a** Calfurnio monuments in 2004. **b** St. George carved in the 16th century. **c** The copy exposed to the outside environment since 1931

The stone and its decay products were qualitatively and quantitatively characterised by mineralogic-petrographic and chemico–physical analyses. Optical microscope (OM) and scanning electron microscope equipped with a dispersive energy micro-analyser (SEM-EDS) were used for thin section examination. Ion chromatography (IC) measured anion concentrations such as sulphates, nitrates, chlorides and oxalates. The morphological characteristics of the black crusts were observed by examining 3D samples using secondary electrons collected by scanning electron microscopy (SEM). Organic compounds were identified by infrared spectroscopy (FT-IR).

98.3 Results

Petrographic analyses of all surface crusts of Calfurnio monument revealed the presence of gypsum, both in microcrystalline flakes and in acicular crystals. It is now well known that the gypsum formation is due to sulphation processes caused by the interactions between the atmosphere and the stone surface (Amoroso and Fassina 1983; Fassina 1983, 1988a, b). SEM analyses (back-scattered electrons—BSE images) of decayed scab cross-sections showed a dendritic crust between 30 µm and 1 mm thick. These crusts have two main features:

(i) Irregular aggregates of needle-shaped gypsum crystals (lenticular and minute crystals), sometimes arranged in a fan shape, the structure of which causes the high crust porosity. The stone/crust interface is transformed into microcrystalline calcite, which shows chemical transformation in progress.
(ii) Embedded in the gypsum crust are iron, titanium and porous carbonaceous particles whose diameters range between 10 and 40 µm and concentrations from a few percent to about 30 %-volume.

Three-dimensional images (SEM-BSE) of the black crusts show platy crystals of gypsum (Fig. 98.2a), spherical and porous carbonaceous particles emitted by heavy oil combustion (Fig. 98.2b) and smooth spherical particles mainly composed of iron and other metals due to fossil fuel combustion (Sabbioni 1995) (Fig. 98.2c).

Ion Chromatography analyses of stone materials taken by a micro-drilling technique at different depths from the stone surface (Amoroso and Fassina 1983) identified sulphates as the most abundant anions, with trends decreasing from the surface downwards. These sulphates, as previously noted, are clearly associated with the presence of gypsum. IC analyses show gypsum concentrations ranging from 27 to 36 % on the surface and falling to 1 % in depth (Table 98.1). Quantitative determination of sulphate salts may explain some of the decay phenomena affecting the monument.

98.4 Discussion

Cross-section SEM analyses (BSE images) show extensive micro-cracks in the limestone, parallel to the stone/crust interface and completely filled with gypsum.

These cracks, between 5 and 30 µm thick, may be up to a few millimetres long and up to 5 mm deep inside the stone, perhaps even deeper. These micro-fissures were observed in the samples classified as bindstone.

Although spalling is certainly enhanced by deterioration, this seems to have acted on originally discontinuous surfaces of probable cyanobacterial structure.

IC revealed different concentrations of nitrates all over the stone. Evidence of water migration through porous stone is given by efflorescence at the base of the monument, and is made up of niter, as identified by XRD analysis. Niter is probably closely related to capillary rising damp transporting salts from decomposing organic matter.

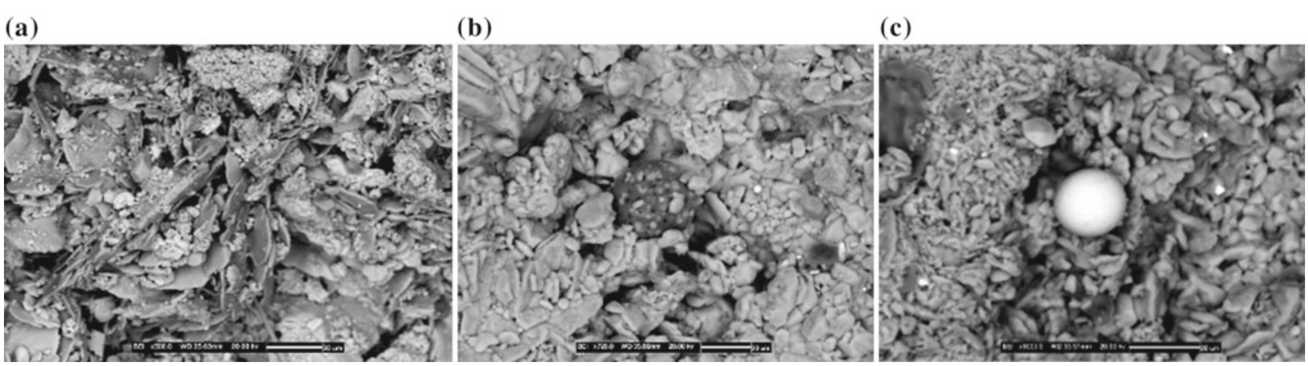

Fig. 98.2 **a** Platy crystals of gypsum (*left*); **b** carbonaceous particle (*middle*). **c** smooth metal particles (*right*)

Table 98.1 Ion chromatography (IC) was used to measure anion concentrations (%) of stone material sampled at different depths

Sample/depth	Height (cm)	SO_4^{2-}	Cl^-	NO_3^-	Oxalate
19a (0–1 mm)	370	20.10	–	0.23	–
19b (1–2 mm)	370	3.36	–	0.35	–
19c (2–3 mm)	370	3.15	–	0.33	–
23a (0–1 mm)	120	15.44	0.39	1.70	–
23b (1–2 mm)	120	1.14	0.33	1.32	–
23c (2–3 mm)	120	0.68	0.34	1.70	–

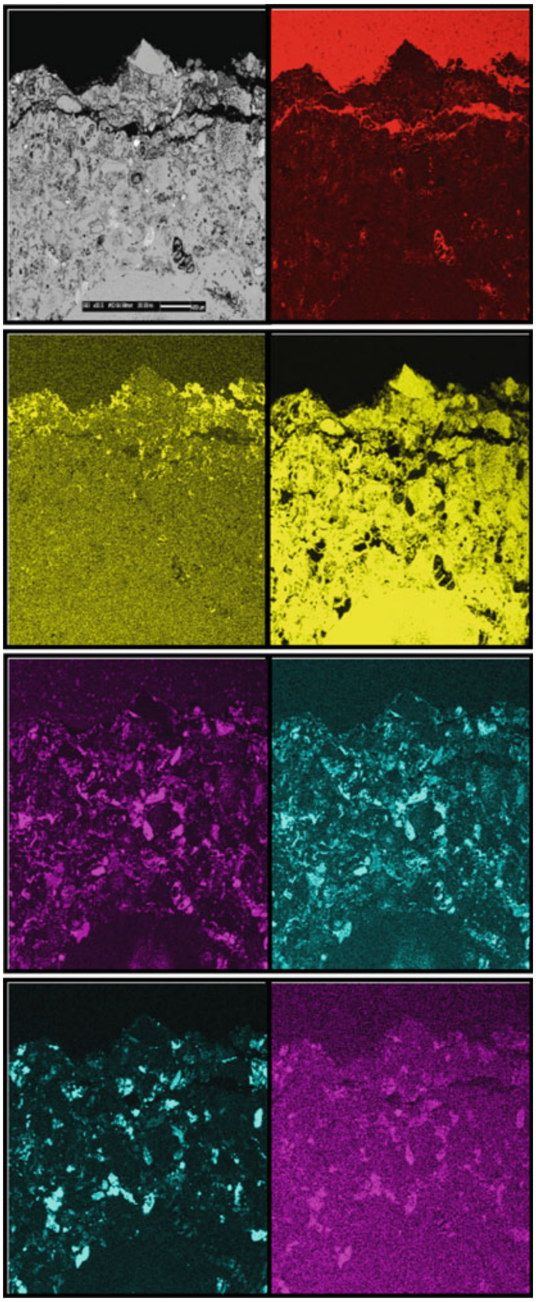

Fig. 98.3 Map distribution of elements in a sample cross-section taken from the original bas-relief preserved inside (*from left* BS electron, C, S, Ca, Si, Al, Fe, Ti)

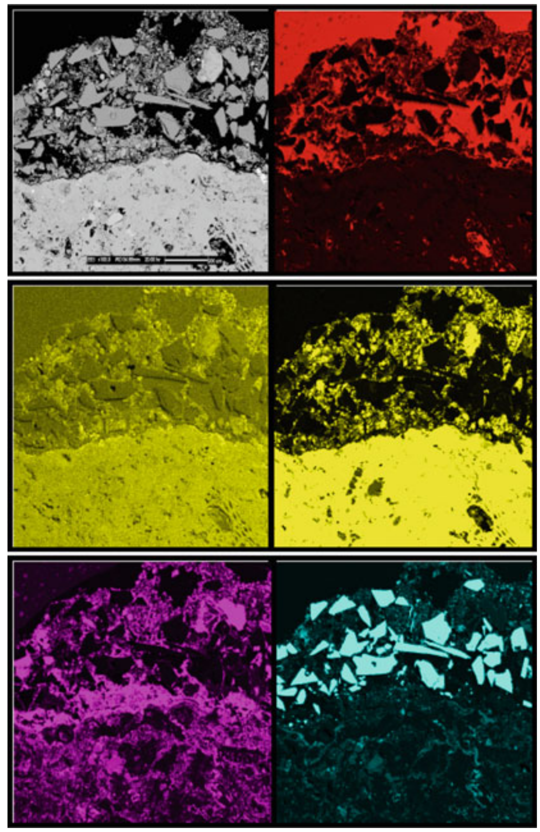

Fig. 98.4 Map distribution of elements in a sample cross-section taken from the copy placed outside (*from left* BS electron, Fe, Ti, P, K, Mg, Na)

Samples were also taken from the original St. George bas-relief and from the outside copy to compare the amount of deterioration products. The sample taken from the original shows that the artefact was affected by greater surface sulphation, up to 50 μm (Fig. 98.3). Instead, the outside copy showed greater sulphur penetration deep within the crust (Fig. 98.4). The presence of phosphates in this same specimen was attributed to an organic maintenance treatment.

Two samples were taken from the copy, one from an area protected from water runoff and one from an area exposed to it. Sulphate concentration was 39 % in the sheltered area sample and 22 % in the exposed area one. How can these baffling results be explained? The lower gypsum concentration in the exposed area sample is probably due to the efficient cleansing action of the rain. Comparison of sulphate concentration data from these two samples show that in areas sheltered from water runoff, gypsum concentration is greater on the outside copy.

98.5 Conclusions

The study of decay products, their surface extent and depth, and the causes of their formation enable us to assess the degree of decay and to plan restoration work accordingly. SEM analyses (back-scattered electrons-BSE images) of cross-sections of decayed scabs showed a dendritic crust between 30 μm and 1 mm thick. Porous carbonaceous particles were found in the irregular aggregates of needle-shaped gypsum crystals. Spherical and porous carbonaceous particles are emitted by heavy oil combustion, while smooth spherical particles, mainly composed of iron and other metals, are due to fossil fuel combustion. SEM analyses (BSE images) of cross-sections showed extensive micro-cracks in the limestone, parallel to the stone/crust interface and completely filled with gypsum. These cracks, between 5 and 30 μm thick, may be up to a few millimetres long and up to 5 mm deep inside the stone, perhaps even deeper.

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