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Microanalyse
Sciences des Matériaux Anciens et du Patrimoine - Etude des objets d'art

STUDY OF A STONE SCULPTURE: *Statue of Chicomecoatl* (H.: 91. 5 cm)
Assumed provenance and period: Mexico, Aztec, 1400-1521 AD

This study was performed for:

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NOTICE

The purpose of this study, performed following established norms of scientific integrity, is to carry out scientific investigations to provide analytical data concerning the manufacturing mode of the studied cultural property, the possible weathering of its constitutive material, either natural or artificial and to characterize the deposits or surface treatments on the object.

The investigations based on optical examination and physicochemical analyses of samplings of the object; follow the methods briefly described in the report, which are long-standing standards and protocols employed by the scientific community.

Comparison of the results obtained with the data actually available in the scientific community allows concluding if the physical evidences of the object are consistent or not with its supposed origin and period of time.

These scientific investigations are carried out not taking into consideration historical research, iconography and stylistics statements about the object. Information about provenance, period or attribution of the cultural property are under the responsibility of the owner or its authorized agent and written in the report only as indication. However, this given information is used in the discussion for final statement.

OBJECTIVES

Study of a stone sculpture: *Statue of Chicomecoatl* (H.: 91. 5 cm)
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Characterisation of tool marks, material from which the object is made, weathering and any surface deposits, for determining whether it was subjected to natural, long-term weathering, compatible with its assumed age and whether it was carved in accordance with traditional production techniques.

SYSTEMS USED

Stereoscopic microscope; Inverted optical microscope; Scanning Electron Microscope (SEM) with back-scattered electron (BSE) and secondary electron (SE) imaging, coupled with energy-dispersive X-ray element analysis (EDX).

SAMPLES

The study was carried out on six samples obtained by making replicas of the object's surface, three micro-samples of the stone and one micro-sample of the black crusting deposit:

R1: surface replica on the back, in the upper part of the sculpture, left side;
R2: surface replica on the back, in the upper part of the sculpture, right side;
R3: surface replica on the front, on the left-hand side, on a corncobs;
R4: surface replica on the front, at the level of the headdress, above the forehead;
R5: surface replica on the back, in the upper part of the headdress, at the level of the second crenellation to the left;
R6: surface replica on the back, near micro-sample P1;
P1: micro-sample of the stone performed from the back, on the left-side external edge of the headdress;
P2: micro-sample of the stone performed from the back, in the upper part of the headdress, at the level of the third crenellation to the left;
P3: micro-sample of the stone performed from the back, under the crenellations, at the level of the vertical braid pattern;
P4: micro-sample of the black crusting deposit from the back of the sculpture, in the upper part of the headdress, at the level of the horizontal braid pattern.

The micro-samples of the stone were embedded in epoxy resin and a polished microsection perpendicular to its surfaces was performed. Microsections and replicas were coated with gold for the SEM examination. This operation is responsible for the traces of gold (Au) observed on the elementary X-ray spectra.

STUDY RESULTS

In this study, we examined tool marks, the type of stone, weathering and surface deposits. Our observations and analyses are illustrated on the following pages. They reveal that:

- In the absence of a petrographic analysis of a thin section, the porphyritic vesicular texture of the stone, coupled with an examination of the type and morphology of its constituent mineral phases, olivine phenocrysts embedded in a groundmass of plagioclase feldspars microlites, microcrystalline olivine and volcanic glass mesostasis, with accessory phases of iron oxide and ilmenite, identify it as a **basalt**.

- Before its carving, the rock has been submitted to general hydrothermal alteration, responsible for its red colour, which results from olivine alteration in iddingsite

- **No evidence of a meteoric weathering of the stone occurring after the carving is observed.** In particular, there is no colour modification between the sculpted surface and the stone “at heart”, Basalt is very prone to weathering due to the presence of volcanic glass end olivine, which are very reactive under meteoric alteration processes.

- Different deposits are observed on the object:

  - a beige mineral sedimentary deposit, which has been rubbed in the stone surface porosities to simulate a material coming from a burying environment;

  - an artificial silica-gel coating on the object's surface.

  - a black encrusting deposit consisting of calcium sulfate (crystallization, probably covered with an carbon rich black pigment;

- No tool marks were visible on the object, but **many iron-chromium metal shavings in direct contact with the stone could be evidence of the use of modern tools**.

These characteristics are not compatible with the object's assumed age.

Pessac, September the 18th 2015, Dr. Bertrand Duboscq

Figure 1: Overall views of the object and samples localisation.

1. PRELIMINARY OBSERVATIONS

The sculpture was carved out of a red coloured stone (Fig. 1, 2 and 3). The original rock texture clearly differs from the restored areas of the object (Fig. 2b).

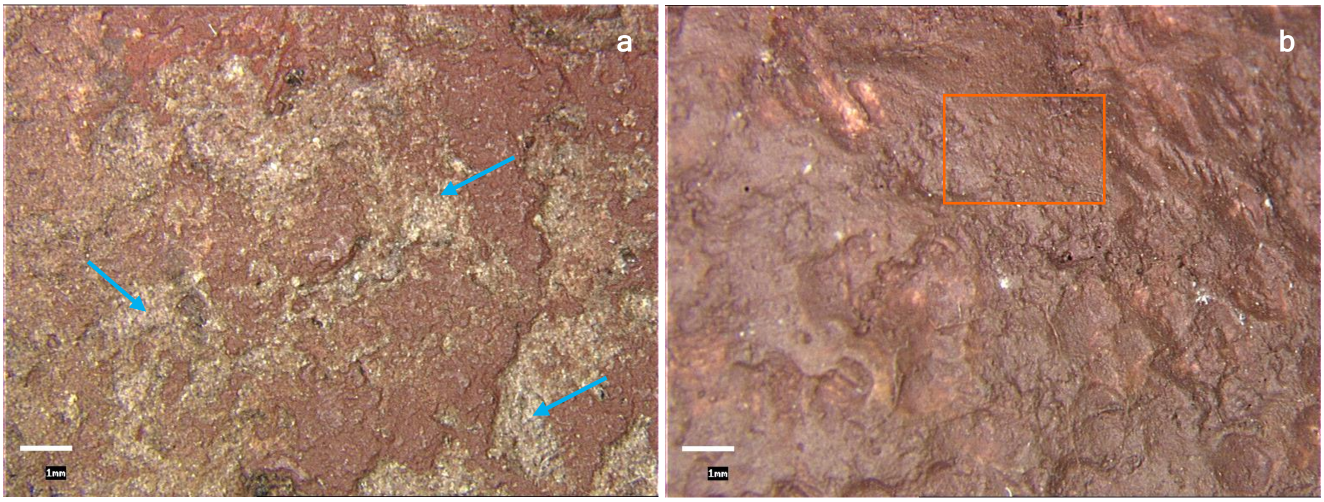
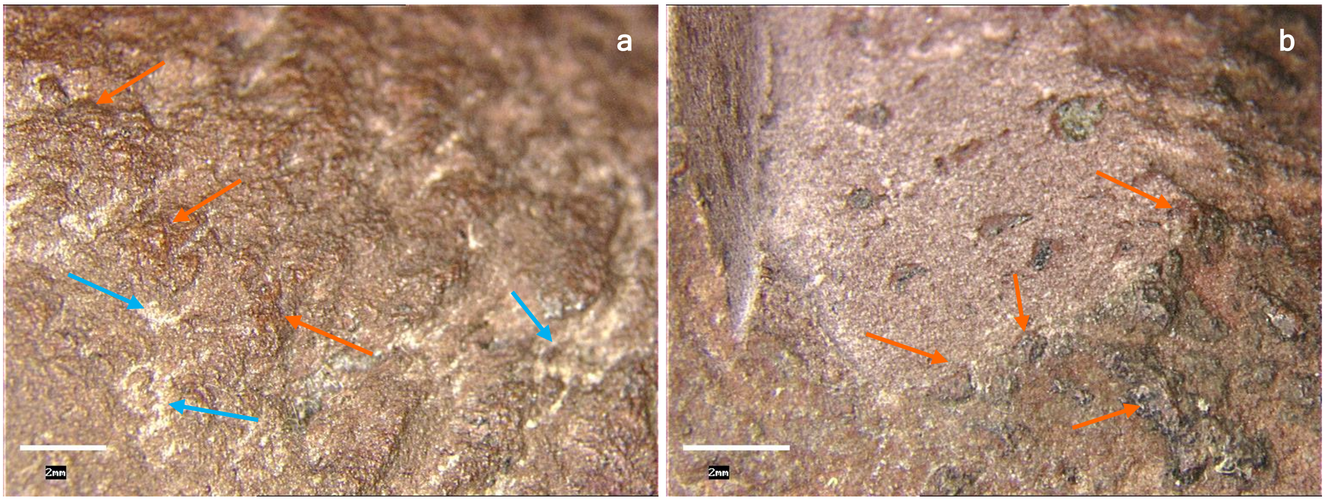


Figure 2: Detail views of the sculpture (stereoscopic microscope, x10, **a**- maize ears in the right hand, **b**- restored part on a corncobs, right-hand side).

In places, the stone appears dulled, with reddish colored reliefs (Fig. 3a orange arrows) which could be, at first sight, indicative of a weathering of the stone. Detail study of the rock shows that they consist in fact of phenocrysts (Fig. 3b, arrows) intersected by the sculpted surface.



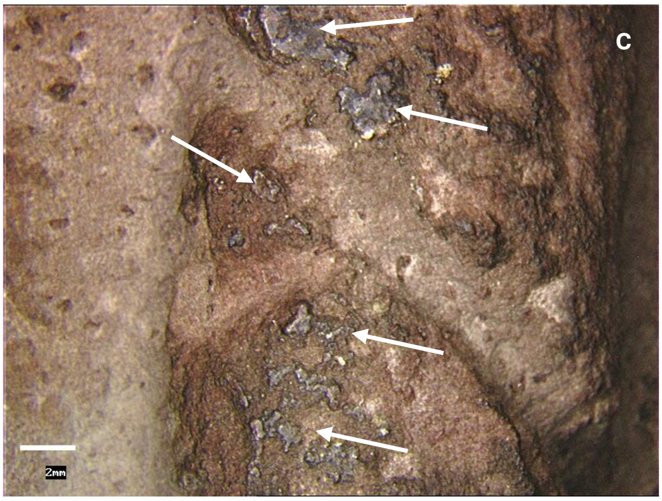


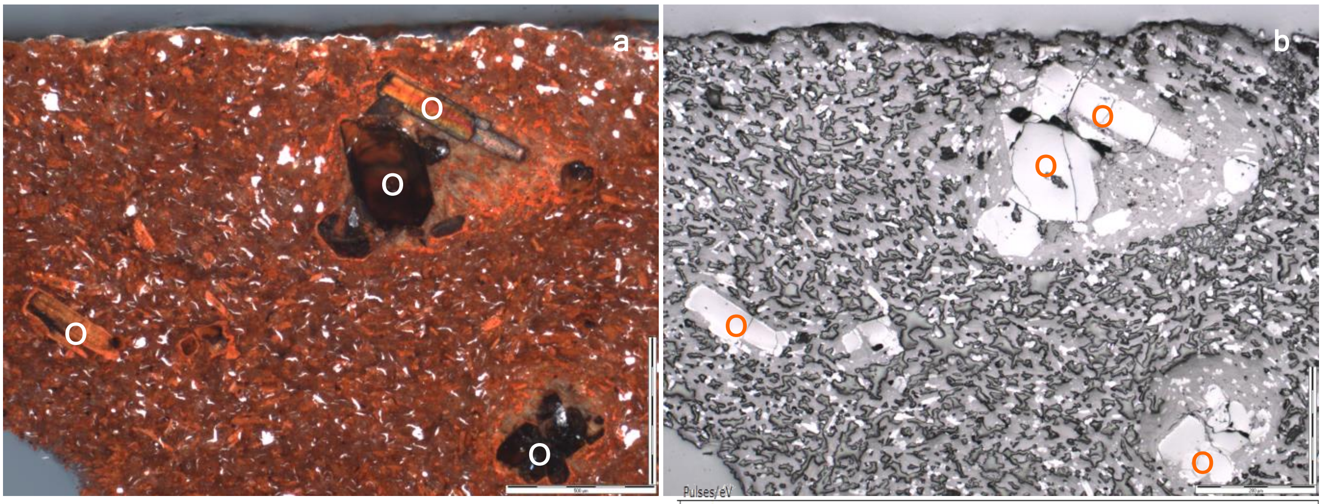
Figure 3: Detail views of the sculpture (stereoscopic microscope, **a**-, non-restored corncobs, right-hand side, x7, **b**-, at the rear, on the left-side external edge of the headdress, micro-sample P1 localization, x8, **c**- at the rear, upper part of the headdress, at the level of the horizontal braid pattern, micro-sample P4 localization, x5).

A beige deposit (Fig. 2a and 3a, blue arrows) is present all over the sculpture.

A black crusting is also present, mainly on the back of the figure (Fig. 3c, arrows).

2. TYPE AND WEATHERING OF THE MATERIAL USED TO MAKE THE OBJECT

The rock has a porphyritic texture, with olivine phenocrysts (Fig. 4, O and 4c), embedded in a red couloured groundmass (Fig. 4, M). The rock is highly vesicular, the vesicles corresponding to the spaces between plagioclase microlites clusters.



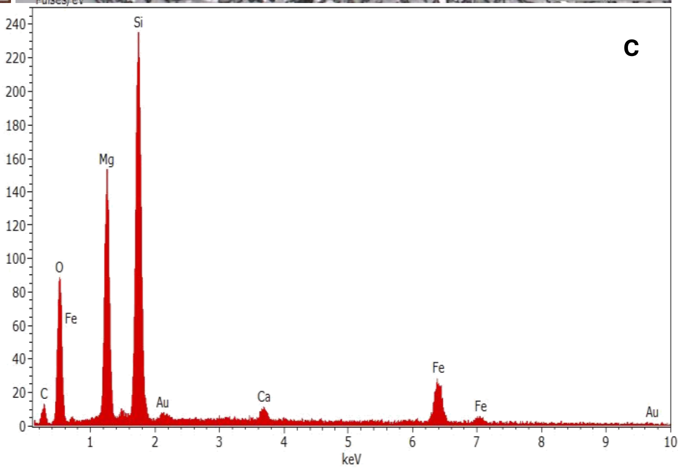


Figure 4: Detail views (inverted optical microscope, x50, same field, **a**- polarized light, **b**- reflected light) of the microsection of the sample P2 and EDX analysis spectrum (**c**-) of an olivine phase.

The groundmass consists of plagioclase feldspars microlites (Fig. 5a, F and 5b) and small olivine crystals in a glassy mesostasis (Fig. 5a, G).

The red hue of the rocks comes from iddingsite (iron oxide- or ferrhydrite-rich clay minerals) resulting from the alteration of olivine phases and from the presence of numerous minute iron and iron-titanium oxide inclusions in the matrix (Fig. 5a, arrows).

In the absence of a petrographic analysis of a thin section, the texture of the rock, coupled with an examination of the type and morphology of its constituent mineral phases, identify it as **a basalt**.

The rock was submitted to hydrothermal alteration, responsible for the olivine partial or total transformation in iddingsite.

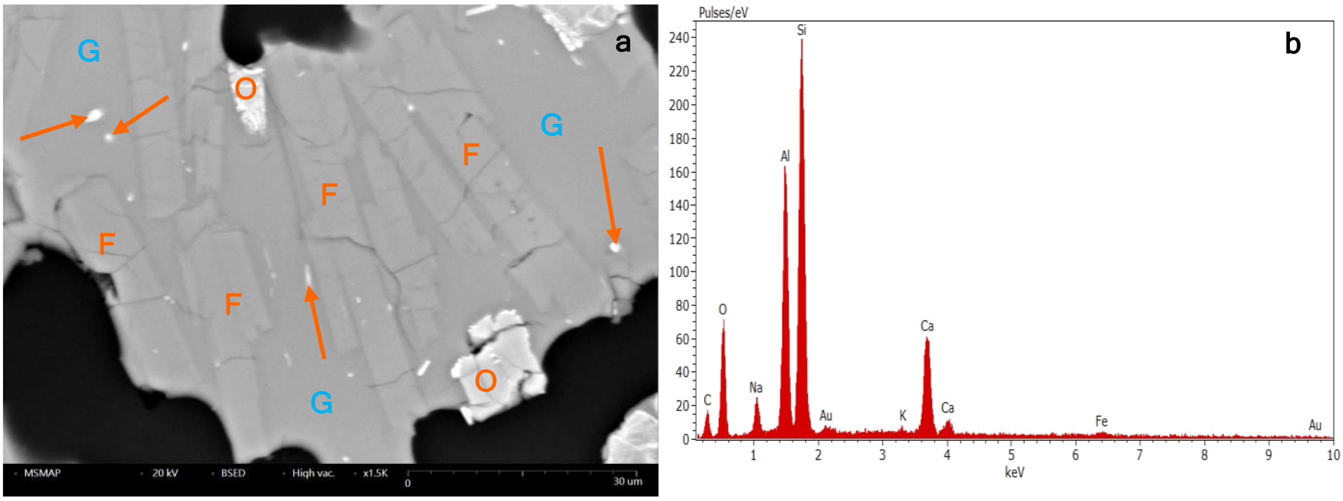
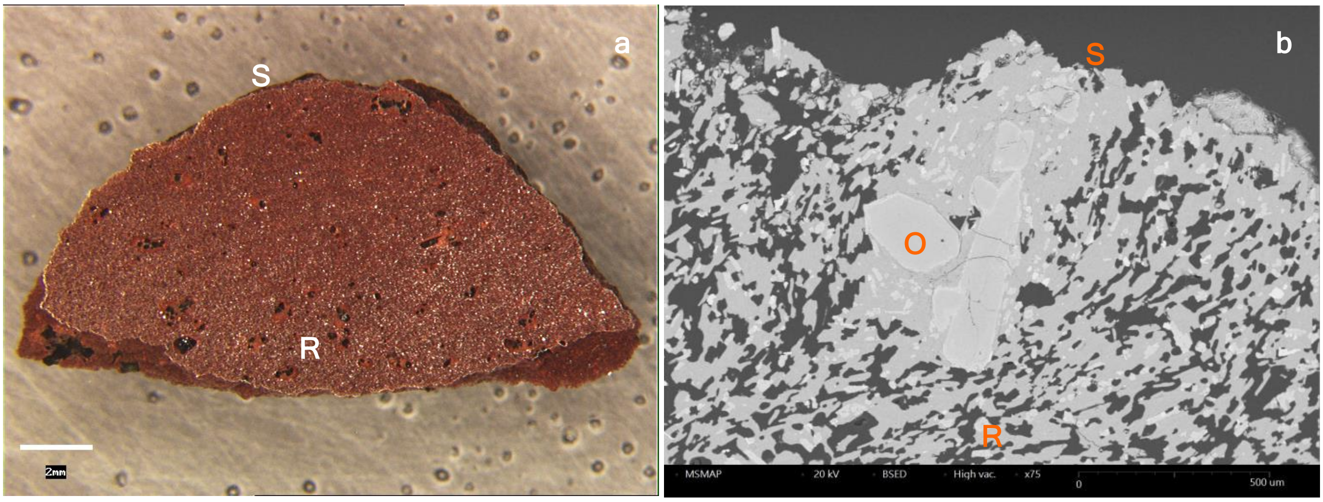


Figure 5: Detail view (**a**-, SEM, BSE, x1500) of the matrix of the stone and EDX analysis spectrum (**b**-) of a plagioclase feldspar microlite. Microsection of the sample P2.

Either on the microsections (Fig. 6) or on replicas surfaces (Fig. 7), no evidence of a meteoric weathering of the stone occurring after the carving is observed. In particular, there is no colour modification between the sculpted surface (Fig. 6a, S) and the stone "at heart" (Fig. 6a, R).



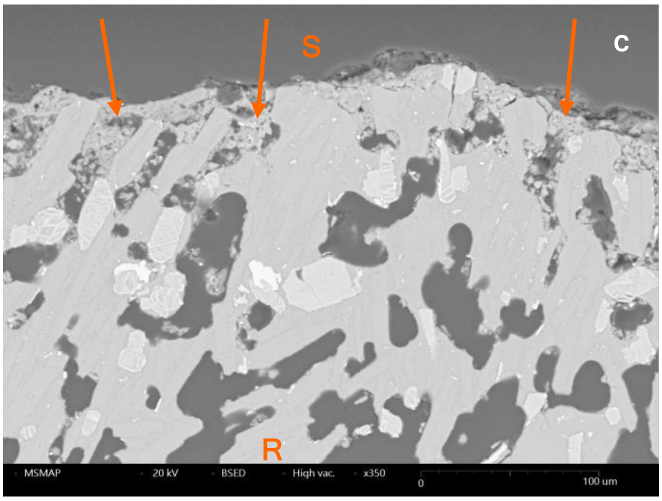


Figure 6: Detail views (**a-**, stereoscopic microscope, x6, **b-**, SEM, BSE, x75 and **c-**, SEM, BSE, x350) of the microsection of sample P1.

Basalt is very prone to weathering, due to the presence of volcanic glass and olivine, which are very reactive under meteoric alteration processes.

Volcanic glass alters usually quickly, resulting in a clayish material, which is not the case here.

Olivines (Fig. 6b, O) from the sculpture surface do not show more pronounced alteration processes (eg. total transformation in iddingsite, dissolution…) than the overall hydrothermal alteration.

Some deposits are observed filling the surface porosities corresponding to the vesicles of the rock (Fig. 6c, arrows). These deposits will be discussed later in this report

On the surface replicas (Fig. 7), the mineral phases appears also un-weathered, with only a fractured surface from the sculpture mechanical stress.

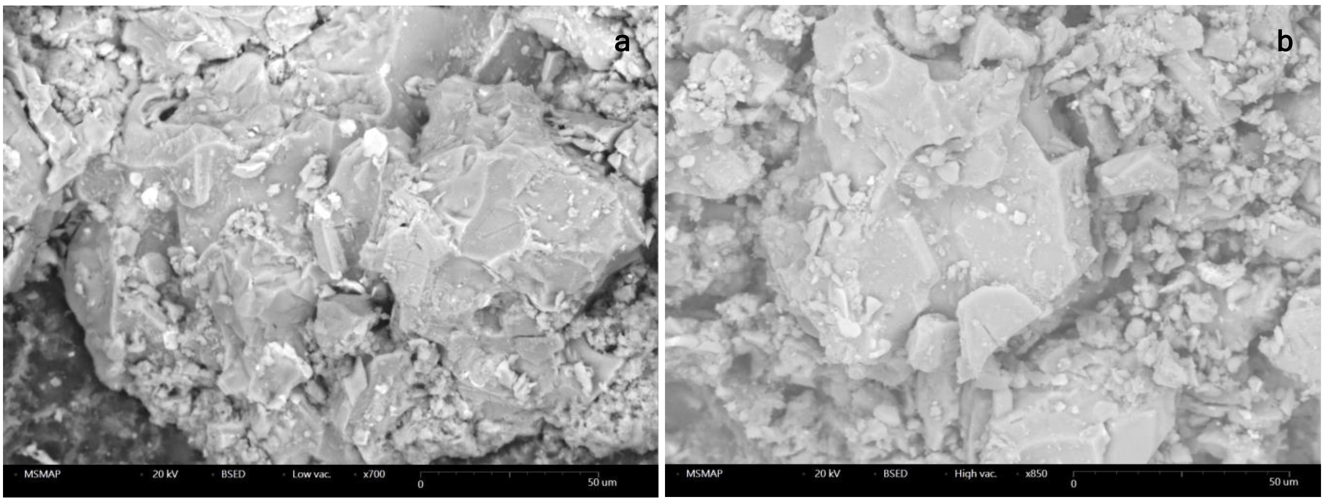
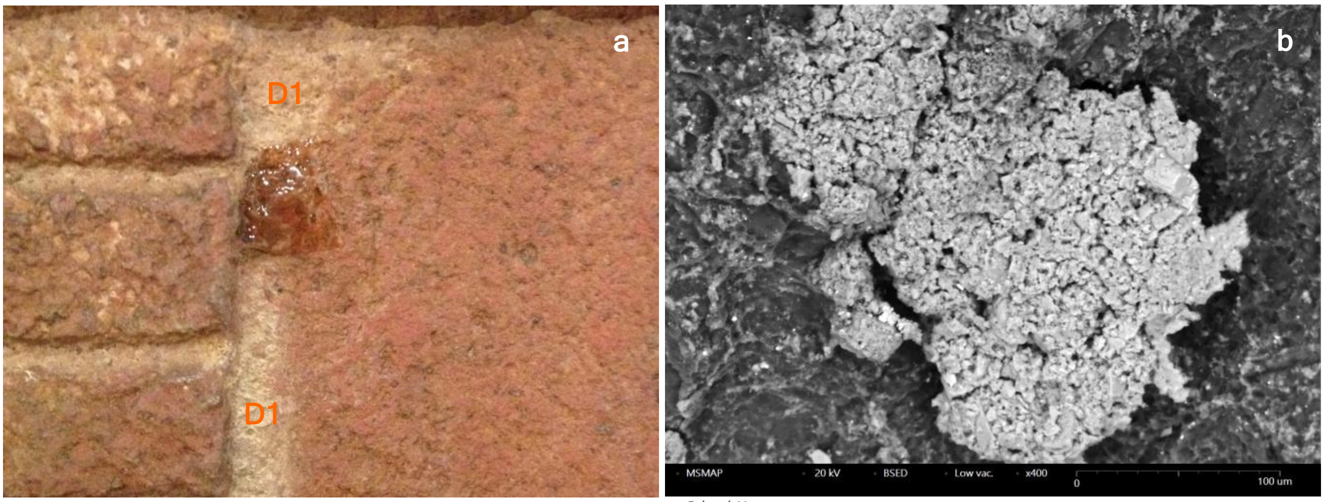


Figure 7: Detail views (SEM, BSE) of the mineral phases of the stone on the surface of replicas R2 (**a-** x700) and R5 (**b-** x850).

3. STUDY OF THE SURFACE DEPOSITS

The beige deposit present all over the sculpture is abundant in the protected depressed areas of the surface (Fig. 8a, D1, localization of replica R2).



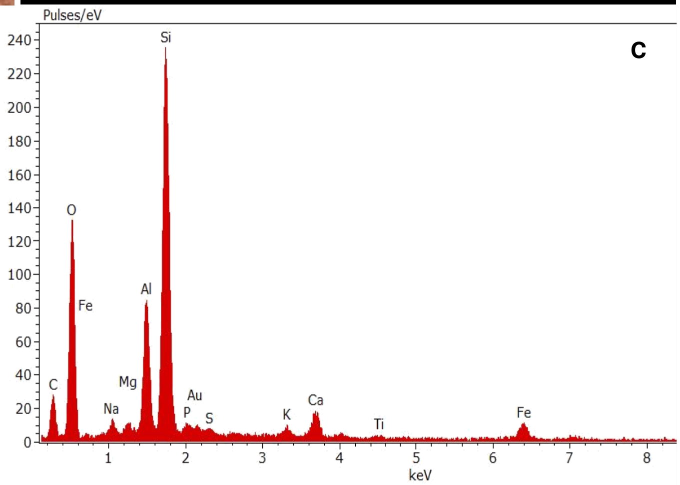


Figure 8: Detail view of the sculpture (**a**-, at the rear, upper part of the sculpture, right-hand side, replica R2 localization), detail view (**b**-, SEM, BSE, x400) and EDX analysis spectrum (**c**-) of the beige deposit.

The deposit consists of a clayish (Fig. 8c) microcrystalline material (Fig. 8b).

This material stays on the surface of the sculpture (Fig. 9, **D1** and cf. Fig. 6b) and do not seep into the rock porosities.

There is no interaction (weathering rim, leaching of the glass etc.) at the contact between the stone surface and the deposit. Some rocks fragments are present inside the deposit (Fig. but are clearly not weathered. They probably come from a crushing of the brittle intervesicles material (glass, feldspars microlites…).

Obviously, the deposit consist of a natural sedimentary material which has been rubbed in the porosities on the object surface to simulate a material coming from a burying environment.

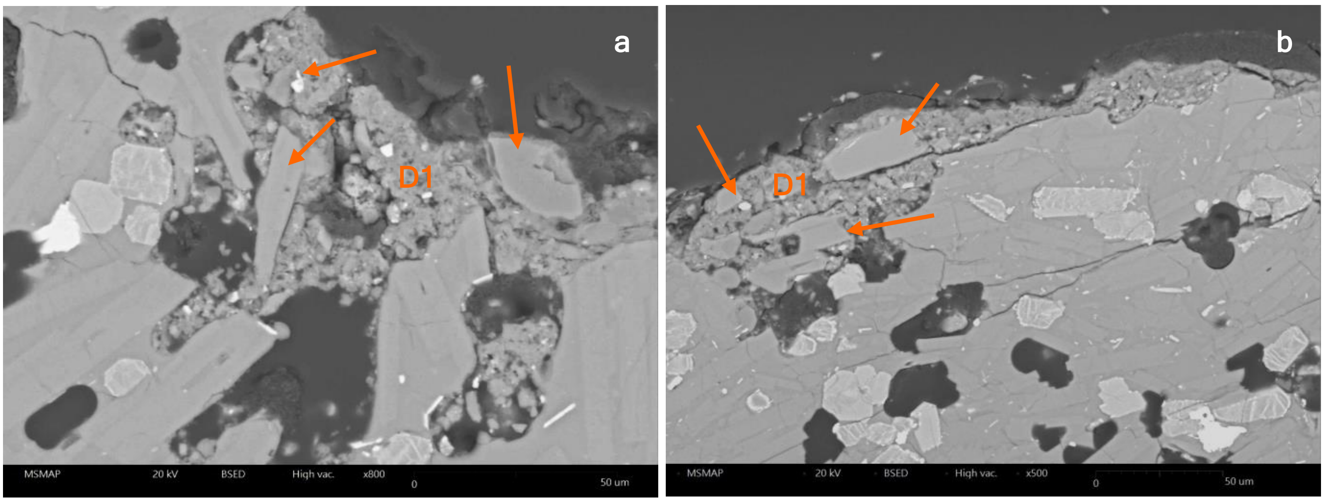
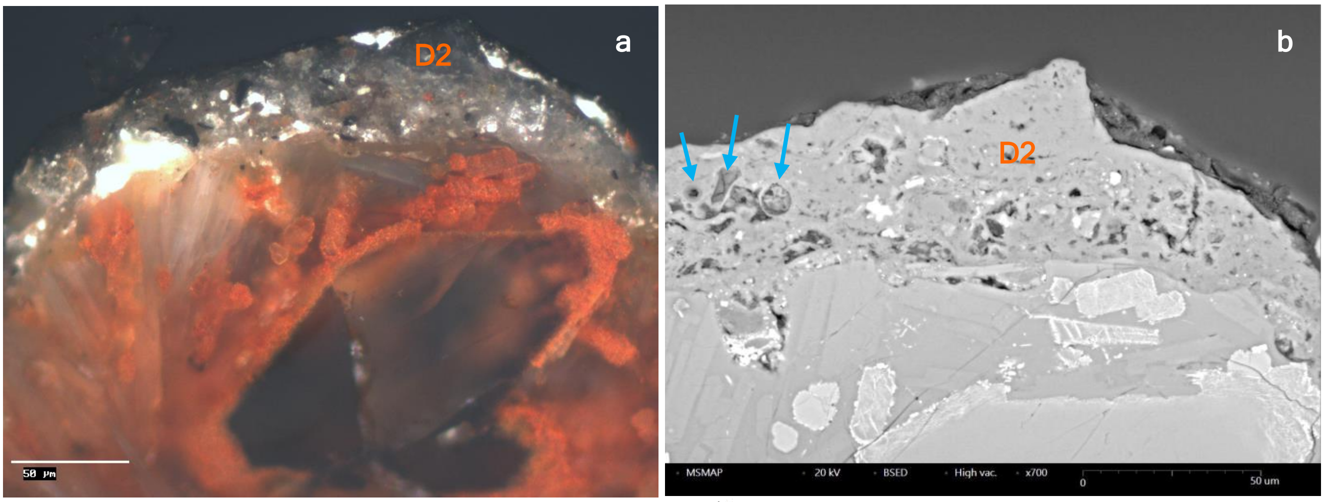


Figure 9: Detail views (SEM, BSE) of the beige deposit on the surface of microsections P1 (**a**- x800) and P2 (**b**- x500).

At the stone contact there is also quite systematically **a translucent deposit** (Fig. 10a, **D2**).



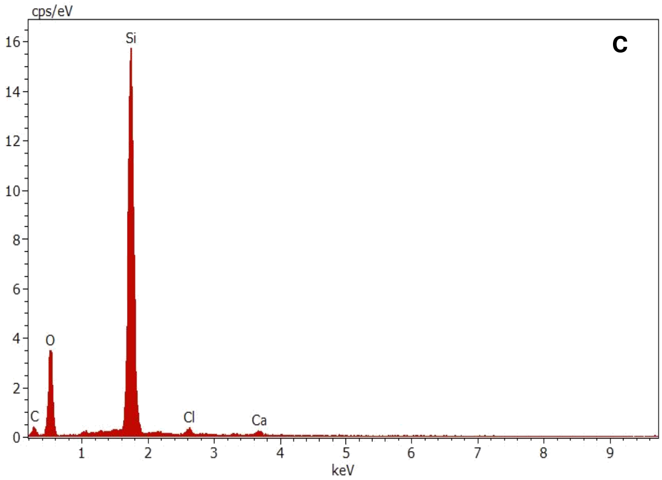


Figure 10: Detail views (**a**-, inverted optical microscope, polarized light, x500, **b**-, SEM, BSE, same field, x700) and EDX analysis spectrum (**c**-) of the translucent deposit. Microsection of sample P1.

This deposit consists of a cryptocrystalline to amorphous silicon-rich (Fig. 10b, **D2** and 10c).

This "silica gel" includes unaltered rock fragments (Fig. 11a, orange arrows), as observed in the beige deposit.
It is difficult at this analytical level to precise the nature of this material.

Inside the deposit, some structures with rounded hollow morphology (Fig. 10 and 11, blue arrows) could suggest an organic origin (microorganisms, vegetal?).

However, a bio mineral origin of the deposit, build-up during a burying phase of the object in a biologically active environment would have induce a biochemical weathering of the stone. But, under the deposit, the stone is non weathered (Fig. 11b), which is contradictory to this hypothesis.

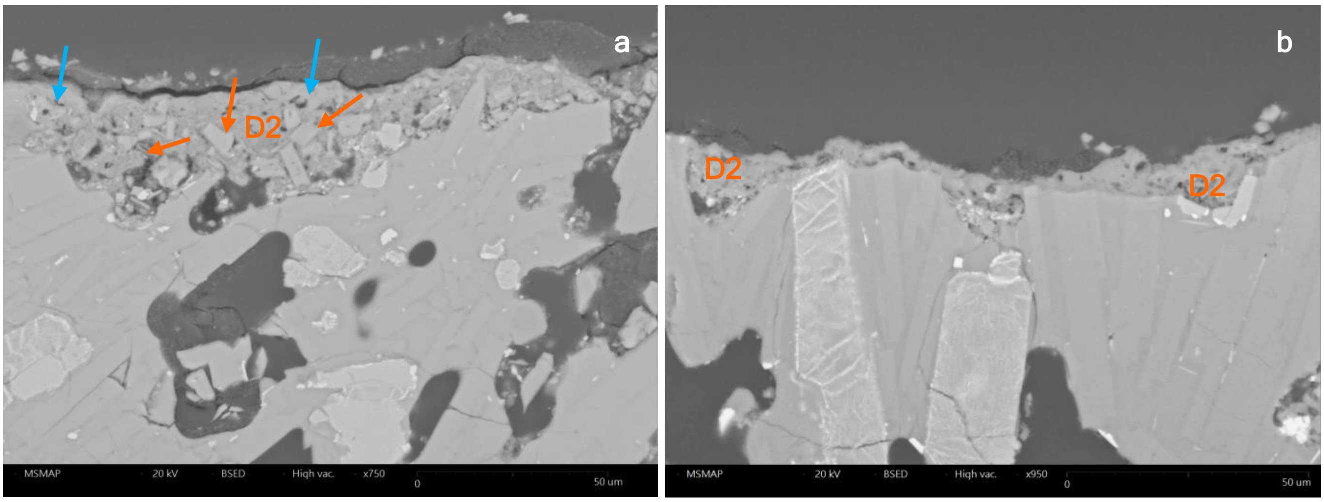


Figure 11: Detail views (SEM, BSE) of the translucent deposit on the surface of microsections P2 (**a**- x750) and P1 (**b**- x950).

The translucent silicon-rich deposit contains some barium sulfate (Fig. 12 and 13, arrows and Fig. 12b). Barium sulfate or barite is a filler or a white pigment used in painting since the beginning of the 19th century.

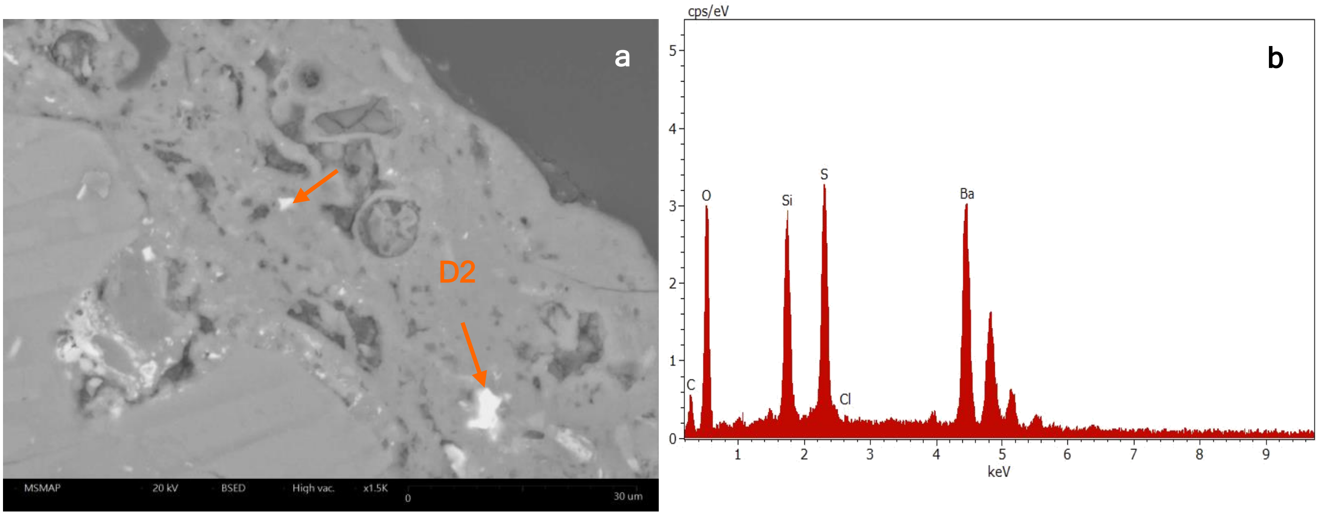


Figure 12: Detail view (**a**-, SEM, BSE, x1500) of the translucent deposit on the surface of microsection P1 and EDX analysis spectrum (**b**-) of a barium sulfate particle inside deposit.

Barite is also a mineral which can be a natural impurity in soils. However the systematical and rather important presence of this element, as the only impurity in the deposit, suggest that it has been voluntarily added to the silica-rich material.

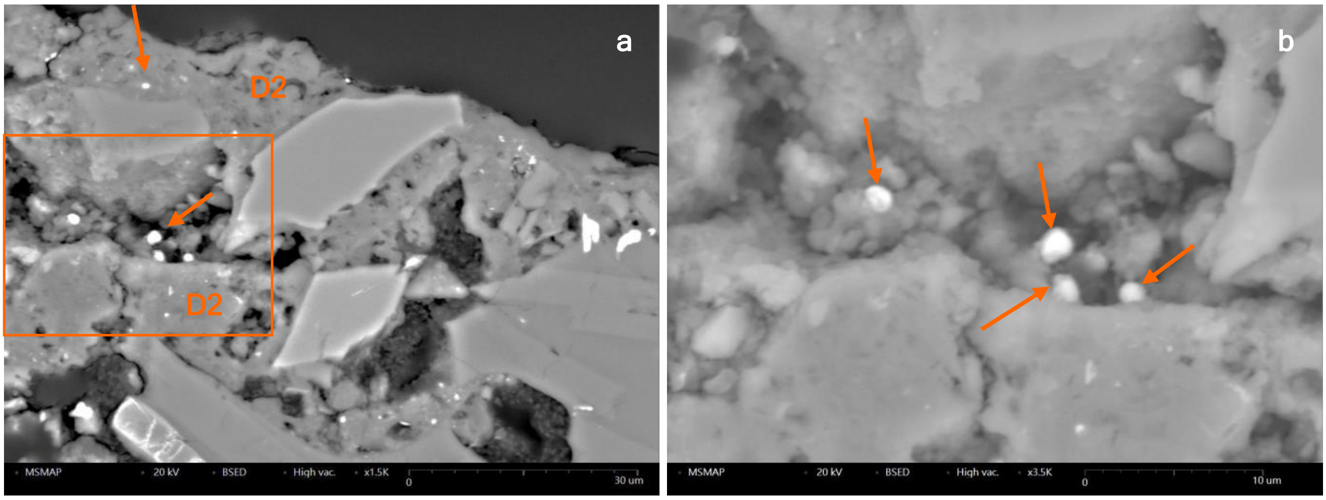
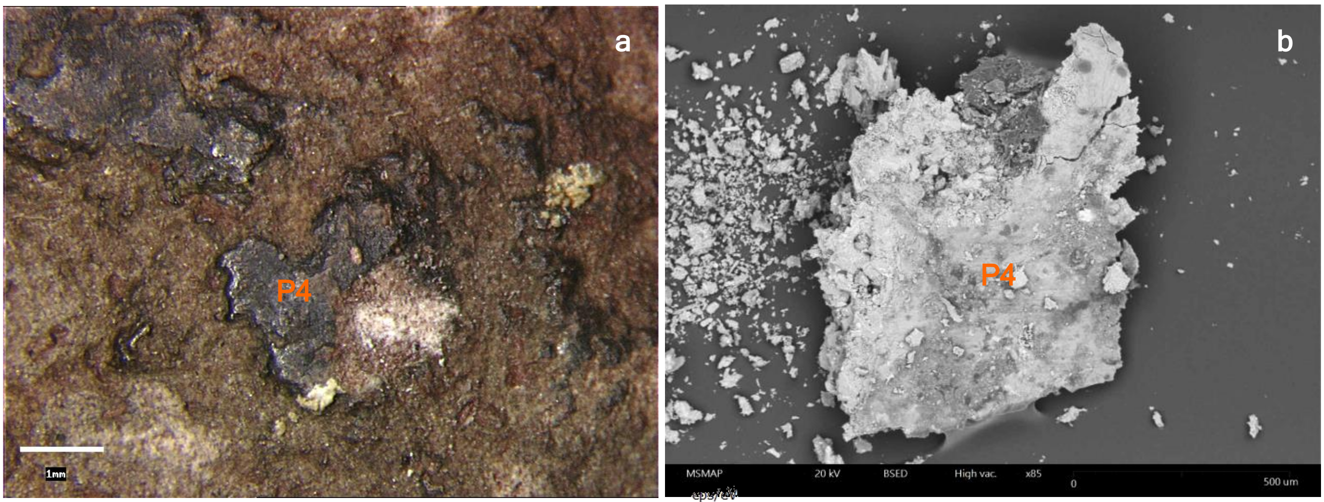


Figure 13: Details view (SEM, BSE, **a**- x1500) of the translucent deposit on the surface of microsection P1 and (**b**- x3500) of barium sulfate particles inside deposit. The box locates figure 13b.

These characteristics are in accordance with the hypothesis of the application of an artificial silica-gel coating on the object's surface.

The crusting black deposit present on the back of the sculpture was studied in micro sample P4 (Fig. 14, P4 and 14b).



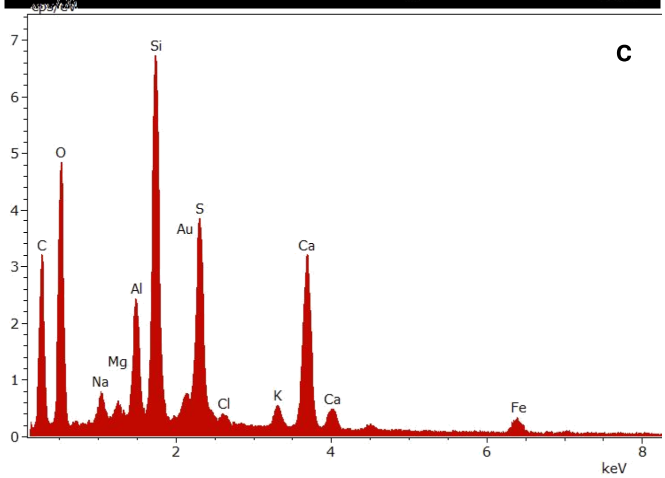


Figure 14: Detail views (**a**-, stereoscopic microscope, x15, horizontal braid pattern, **b**-, SEM, BSE, x85) and EDX analysis spectrum (**c**-) of the black deposit, and sample P4 localisation.

SEM-EDX study reveals a calcium sulfate-rich material (Fig. 14c). The silicate components in the EDX spectrum (silicon, aluminum, sodium, potassium, magnesium) come from the underlying beige deposit.

This calcium sulfate deposit (Fig. 15, SCa) has been observed also on the micro sections, lying upon the previously described translucent silicon-rich material (Fig. 15a, D2) or in direct contact with the stone (Fig. 15b).

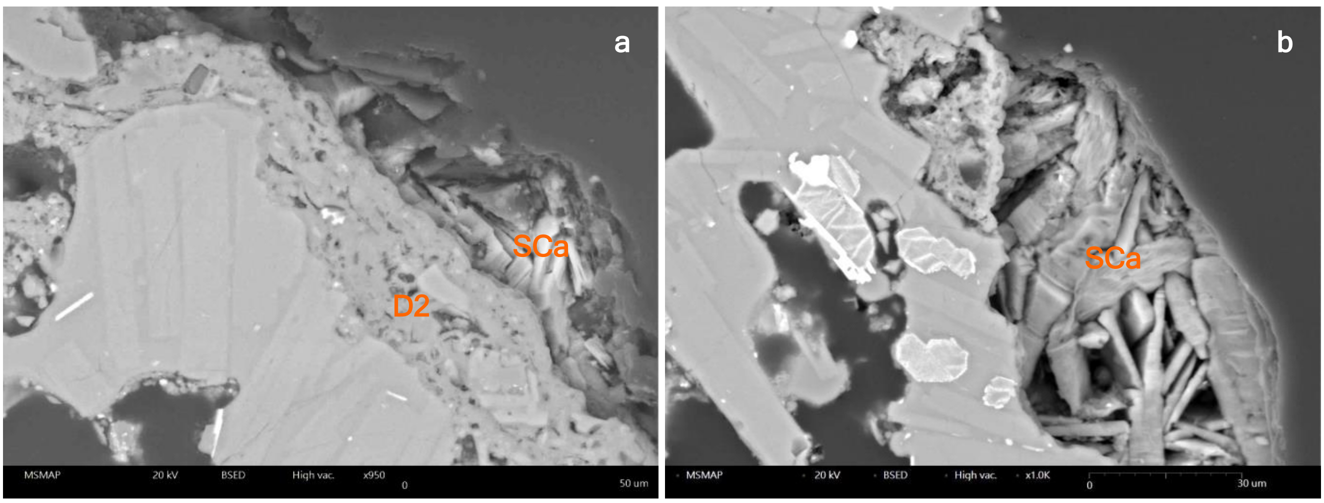
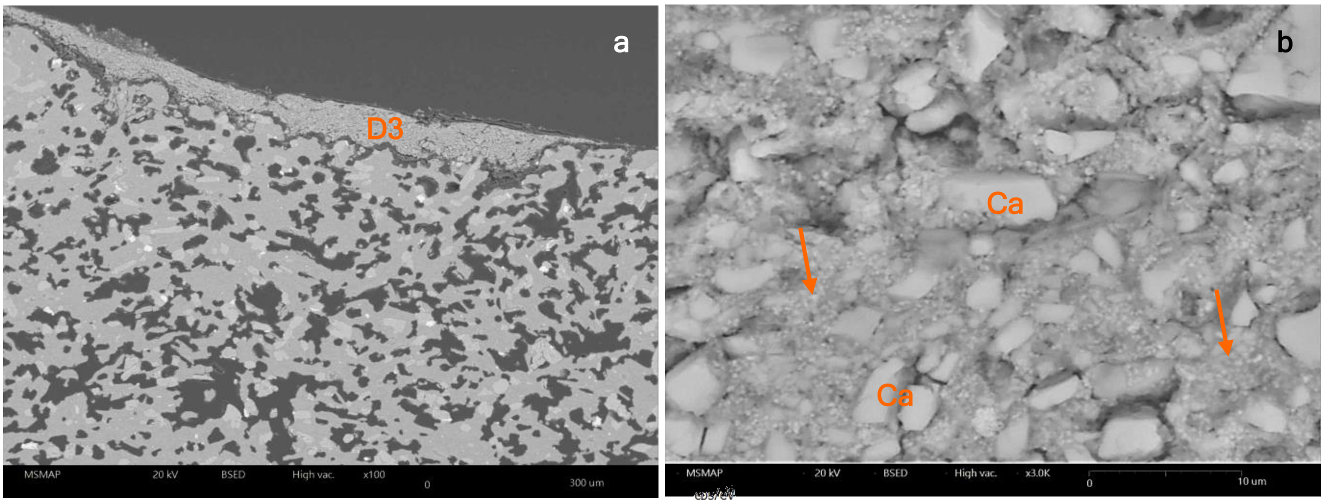


Figure 15: Detail views (SEM, BSE, **a**- x950, **b**- x1000) of the surface deposits on the surface of microsection P1.

Its position upon the translucent deposit is evidence of the artificial nature of this crusting. Its black colour may originate from a black carbon pigment applied on the calcium sulfate crystallisations.

A white deposit is observed on sample P3 microsection (Fig. 16a, D3). SEM-EDX analysis of the deposit shows high calcium and titanium (Fig. 16c) with aluminum and silicon. Chlorine is also detected, as well as potassium traces.



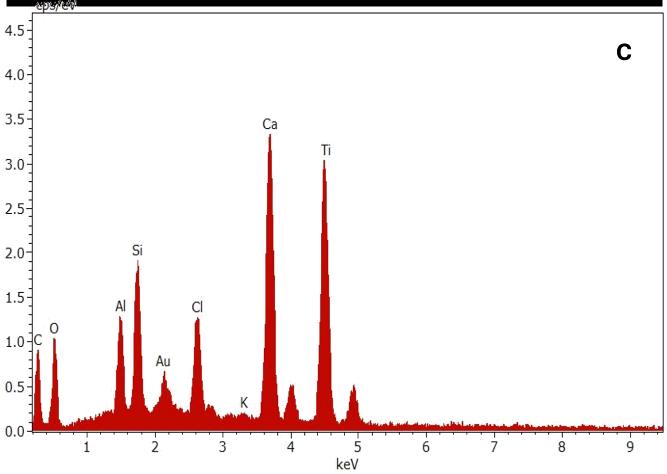


Figure 16: Detail view (**a**-, SEM, BSE, x100) of the microsection of the sample P3, detail view (**b**-, SEM, BSE, x3000) and EDX analysis spectrum (**c**-) of the white deposit.

High titanium level originate from numerous titanium dioxide white pigment micro particles (Fig.16b, arrows). Titanium white is a modern 20th century pigment used in painting.
Here it is in association with abundant calcium carbonate (Fig. 6b, Ca) and kaolin (clay) extenders.
Chlorine can originate from the paint binder.
This deposit is a modern paint. It could be a modern pollution rather than a voluntary deposit

4. STUDY OF TOOL TRACES

The traces of the tools used to carve the sculpture cannot have been studied, due to the high micro porosity of the stone surface.

Nevertheless, study of the replicas shows recurring presence of iron-chromium metal shavings in direct contact with the crushed rock (Fig. 17a, arrows and 17b) that could be evidence of the use of modern tools for the carving of the sculpture.

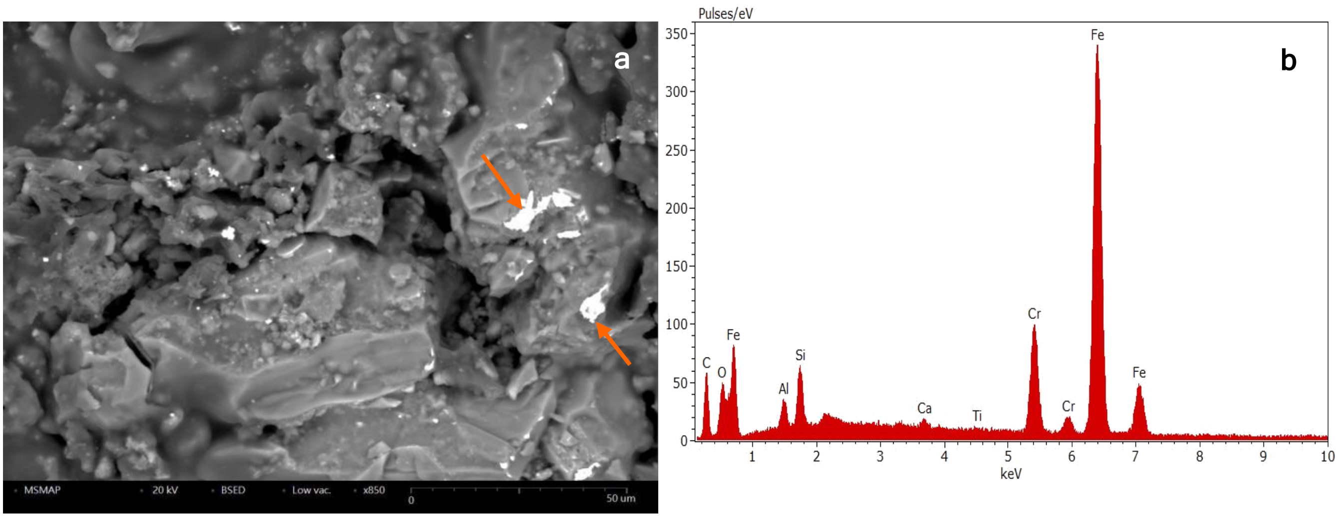


Figure 17: Detail view (**a**-, SEM, BSE, x850) and EDX analysis spectrum (**b**-) of the metallic shavings in contact with stone. Replica R4.