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Diagnostic investigation on a Sorel and Portland cement boiserie at Palazzo Fizzarotti (1850-1908, Bari)

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***Abstract* – This paper reports the results of the diagnostic investigation conducted on the *boiserie* of the Rococo Hall at Palazzo Fizzarotti (1850-1908) in Bari. The boiserie is an artifact made of faux marble with included *seminato* elements (*marmette*) and characterized by the presence of assembly plastering.**

The study aimed to identify its constituent materials, reconstruct the production technique, and understand its conservation state to carry out a critical restoration work which respected the boiserie from a material, historical and aesthetic point of view.

Non-invasive analysis took place in situ (colorimetry, pXRF, UVF) and in laboratory (POM, SEM-EDS, µRaman, XRPD).

The results revealed the use of Sorel cement for the faux marble elements (including the assemblage plastering) and the use of Portland cement in the *seminato* elements and in the structural layers of the panels, other than the alteration products. Macroscopic and petrographic observations made possible to reconstruct the technique of realization of the boiserie and guide restoration.

I. INTRODUCTION

Palazzo Fizzarotti was constructed between the 1850 and 1908, in the eclectic architectural style, blending elements of Baroque, Neoclassical, and Art Nouveau designs. It is situated in the Murat district and holds great architectural and historical significance [1].

The building's facade is adorned with intricate stonework, sculptures, and decorative motifs, showcasing the craftsmanship and attention to detail of the era. The grand entrance features a large arched doorway leading to a spacious courtyard, adding to the palace's majestic appearance.

Fig. 1. The panel of the boiserie of the Rococo Hall at Palazzo Fizzarotti.

It constitutes a testimony to the productive, economic and industry of the *Meridione* reality of the early 20th century where, at the turn of the 19th and 20th centuries, Apulia witnessed exponential economic growth determined by the numerous industrial, commercial activities that took place in the territory and which were a direct consequence of the technological development and the industrial revolution that had embraced all of Europe.

In particular in this context of great growth in the South, the city of Bari saw the rise of several factories and the development of a bourgeois-industrial social class of which Emanuele Fizzarotti was one of the main exponents.

Over time, the building has undergone renovations and restorations to preserve its historical value and maintain its structural integrity. Today, it continues to be a symbol of Bari's rich cultural heritage and an essential part of the city's architectural landscape.

The artifact here investigated is one of the six elements of the boiserie of the *Salone Rococò* in Palazzo Fizzarotti (Fig. 1). Interrupted by five doors and one window, it lines the lower part of the wall along the entire perimeter of the hall and forms a connecting element between the walls of the hall, richly decorated with stucco, gilding and mirrors, and the *terrazzo alla veneziana* floor.

The objective of this study is found in the reconstruction of the technique of execution of the boiserie of the Rococo Salon and the study of its constituent materials, from a chemical-mineralogical and historical point of view, based on the diagnostic analyses, the bibliographic sources and oral testimonies collected. In fact, only through a thorough study of the artifact in its historical, aesthetic instance and in its physical consistency, it is possible to carry out a critical restoration intervention, selective and respectful of the integrity of the substrate and its cultural values.

II. DIAGNOSTIC STRATEGY

In line with today's methodological approach and the definition of restoration understood as the methodological moment of recognizing the cultural good in its physical consistency and in its dual historical and aesthetic polarity [2], before proceeding to direct intervention on the artifact, it was decided to carry out in-depth bibliographic research and a series of diagnostic investigations aimed at investigate the constituent material, the execution technique and the state of conservation of the paneling.

In particular, understanding the production context, the consistency material of the artifact, the technique of execution and the phenomena of degradation that affected it made it possible to carry out a restoration work that respected the criterion of minimal intervention and to achieve a degree of knowledge of the *boiserie* such that it could be properly enhanced.

A. In situ analyses

Non-invasive analysis took place in situ (colorimetry, pXRF, UVF). The colorimetric measurements were performed using a portable spectrophotometer Konica-Minolta CM-2600d equipped with standard illumination using a Xe lamp (Fig. 3). An overview of the colors measured in the boiserie is shown in Fig. 4.

A portable ED-XRF device consisting of a X-ray source (Amptek) powered up to 50 kV and with Au targets, a detector X-123 SDD which provides a resolution of 0.135 keV on the Kα line of Mn. The pXRF, working in air, allows to identify elements with Z>16 (S). Data acquisition was conducted using Surface software, which manages the tube and detector simultaneously.

The surface of the boiserie was observed under the UV radiation of the Wood's lamp, with a 360 nm peak wavelength to identify fluorescence (Fig. 5) signals. In Table 1 is reported a summary of the in-situ analyses and the position of the specimens for the laboratory analyses.

Fig. 3. Execution of a spectrophotocolorimetric analysis on the right panel of the boiserie.

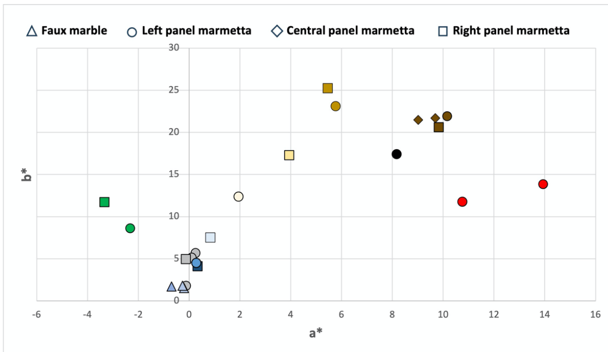

Fig. 4. Mean values of the color coordinates of the boiserie. The color of the symbols approximates the observed color.

Fig. 5. UV fluorescence of the right element the boiserie.

Table 1. Summary of the results of the in-situ analyses and sampling. Abbreviations: B = pale blue fluorescence; W = milky white fluorescence.

Artifact	Sample	Position	UVF	pXRF
Faux marble	PFB1	upper right corner	B	Cl, Ca, Fe, Sr
	PFB5	bottom right corner	B	Cl, Ca, Fe
	PFB9_2	between the central and right panels	B	Cl, Ca, Fe, Sr
	PFB9_3	between the central and right panels	B	Cl, Ca, Fe, Sr
	PFB10	between the central and right panels	B	Cl, Ca, Fe, Sr
Stucco	PFB2	upper right corner	W	Cl, Ca, Fe, Sr
	PFB3	upper right corner	W	Cl, Ca, Fe, Sr
	PFB4	bottom right corner	W	Cl, Ca, Fe
	PFB6	upper side	W	Cl, Ca, Fe, Sr
	PFB7	upper left corner	W	Cl, Ca, Fe, Sr
	PFB8	between the central and right panels	/	Cl, Ca, Fe, Sr
	PFB9_1	between the central and right panels	W	Cl, Ca, Fe, Sr
Venetian-style floor	PFP_R1	Rose 1 (seminato)	W	Cl, Ca, Cr, Fe, Zn
	PFP_R2	Rose 2 (seminato)	W	Cl, Ca, Cr, Fe, Zn
	PFP_V	Rose 3 (seminato)	W	Cl, Ca, Cr, Fe
	PFP_GY	Decorative ribbon (seminato)	W	Cl, Ca, Fe

B. Laboratory analyses

A multi-technical approach was performed on 16 samples through micro-destructive analyses as stereomicroscope observation (OM), polarized microscope observation (POM) on thin sections, scanning electron microscopy combined with energy dispersive spectroscopy (SEM-EDS), Raman spectroscopy (RS) and X-Ray Powder Diffraction (XRPD).

III. RESULTS

A. Materials

POM and SEM-EDS analyses revealed the use of Sorel cement for the surface mortar layer in the faux marble elements (including the assemblage plastering) and the use of Portland cement in the *seminato* elements and the plastering depth layer (Fig. 6). The Sorel cement found great use because of its characteristics and properties: it was, in fact, a conglomerate that gave rise to artifacts with an appearance like marble, characterized by high fire resistance, low thermal conductivity, good resistance to abrasion, static weights, compression and traction [3]. Figure 7 shows the spathic calcite grains used as aggregate in the faux marble.

The clinker relics composed of C_3S, C_2S and C_4AF show the use of Portland cement (Fig. 8) for *seminato* elements, mixed with limestone fragments as aggregates and pigments.

µRaman was very useful to identify pigments used. In both the decorative elements of the floor and the faux marble, particularly in correspondence of the blue color, chromium oxide green (CrO_3) was identified due to the presence of the peaks at 307, 347, 553, 614 cm^{-1} (Fig. 9) and confirmed by pXRF. The blue pigment is ultramarine, whereas red and black are hematite and C black, respectively.

By irradiating the surface with UV light, it was possible to detect a fluorescence phenomenon at the assembly plastering and corners (milky white), of the joint interfaces between the cornices and the finished marble panel and between the cornices and the *marmette*. A diffused pale blue fluorescence is related to the use of an organic protective on the surface of the artifact (Fig. 5).

B. Technology

POM investigation and UVF revealed traces of a serial production technique, including the successive pouring of mortar layers in a fluid state into molds, the creation of original assemblage plastering and localized surface treatment application.

The technology to produce the paneling, for both the faux marble and the Venetian-style *marmette* involved the creation of three layers of material, one on top of the other, having varying composition and thickness.

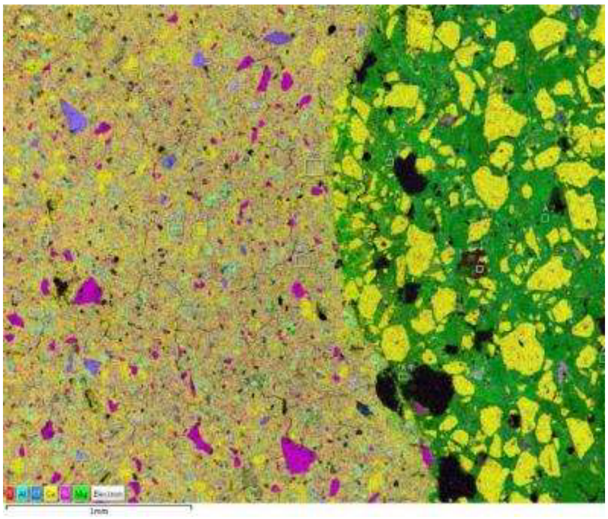

Fig. 6. PFB7: Layered EDS maps which shows the contact between the Portland-based mortar (sx) and the Sorel-based faux marble (dx).

The first to be made was the visible finishing layer (*nobile*), with a thickness of about 13 mm and consisted of a mixture obtained from white cement – or Sorel cement for faux marble - marble powder, microgranule of colored stones, oxides and water.
This was followed by the second layer, called *spolvero*, which generally had a thickness of 4-5 mm and consisted of a mixture of Portland cement and stone powder with a medium-fine grain size.
The last and third layer, called *sottofondo*, had a thickness of 15 mm and consisted of a mixture obtained from gray cement, stone powder with medium-coarse grain size and water.

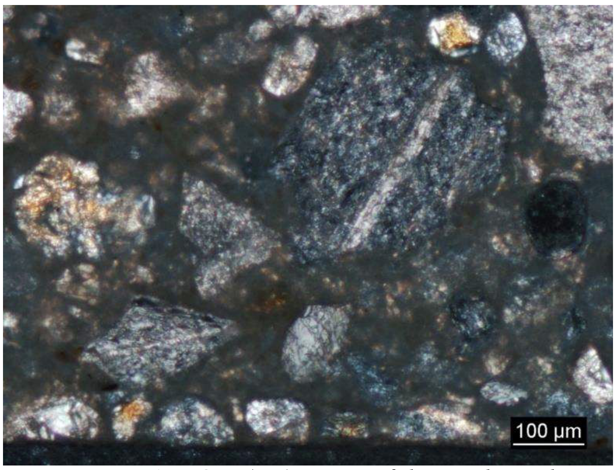

Fig. 7. PFB1: POM (XP) image of the spathic calcite used as aggregate in faux marble.

Fig. 8. PFB4: SEM-BSE image of clinker relic found in the Portland cement mortar layer of the boiserie.

Specifically, from an operational point of view, it is believed that three different metal molds, specially created, for the fabrication of the elements that constitute the thesis artifact. A mold was made larger for the creation of the central element consisting of the faux marble with frames and the mirroring with marbling; and one mold each (for a total of two) for the creation of the faux marble elements with frames and *marmetta* with decorative motifs, placed on the sides of the central element.
Further, for the production of Venetian-style *marmette*, additional molds were adopted, characterized by a shape similar to that of each of the three mirrors and a slightly

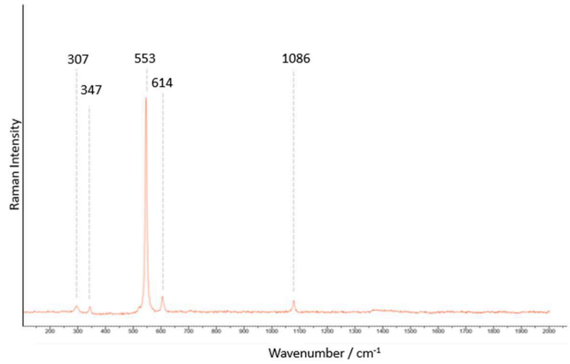

Fig. 9. PFP_R1: Raman spectrum of chromium oxide green.

larger size. This finding is supported by the observation, at the frame of the faux marble panel of the central mirroring, of a grit element that emerges at the intersection of the frame and the faux marble back panel.
For the faux marble, in particular, the execution technique is the creation of artifacts with Sorel cement. SEM-EDS

and XRPD analyses show the presence of hydromagnesite that formed due to excess water to ensure the fluidity of the mixture for molding.
The assembly and anchor plastering show a similar mode of preparation. In particular, for the stucco corresponding to sample PFB2 and for the surface layer of sample PFB8, a better preparation of Sorel cement mixture was found (Fig. 10).
Once the installation and surface finishing work were completed, the entire artifact was polished with wax (Fig. 11). In addition, on the anchor plaster is believed to have been applied material of an organic nature that was revealed by observation of the surface with Wood's lamp (milky white).

C. Conservation state

The boiserie was in a poor conservation state determined by the interaction between the constituent materials, the production techniques, and the environmental and usage characteristics.
Specifically, it was locally affected by abrasions, detachments, fractures, and missing parts. It was covered by deposits of various kinds, differently coherent and adhering to the surface, stains, and localized phenomena of chromatic alteration which contributed to compromise its legibility.
In particular, the removal and attenuation of the effects these last phenomena (deposits, stains, and chromatic alteration) had on the artifact were some of the main aims of the restoration work.
Through spectrophotocolorimetric analysis, it was possible to verify and highlight the reaching of this goal by taking a series of measurements before and after the intervention. The determined ΔE values allowed to prove the cleaning process efficiency by objective evidence: in particular, a value of $\Delta E^*ab = 5.03$ was determined for the *marmette*, which were characterized by a less persistent layer of deposits and chromatic alteration; on the other hand, for the faux marble, the analysis showed a value of $\Delta E^*ab = 11.43$ (according to the major consistency of the phenomena and a more challenging cleaning process).
The μRaman and XRPD analyses identified hydromagnesite $[Mg_5(CO_3)_4(OH)_{2-4}(H_2O)]$ and chlorartinite $[Mg_2(CO_3)(OH)Cl \cdot 2H_2O]$ as alteration products of one of the two components ($MgCl_2$) that give rise to the formation of the Sorel cement when mixed together with periclase (MgO) and water. The carbonatation of Sorel cement is a typical alteration which enhances water stability thanks to a protective semi-insoluble layer of chlorartinite [4]. Moreover, Ba et al. [5] reports an increase of compressive strength and decrease of the internal porosity. The formation of hydromagnesite occurs after destabilization of magnesium oxychlorides (MOCs) in the presence of excess water [3], prevalently in the faux marble.

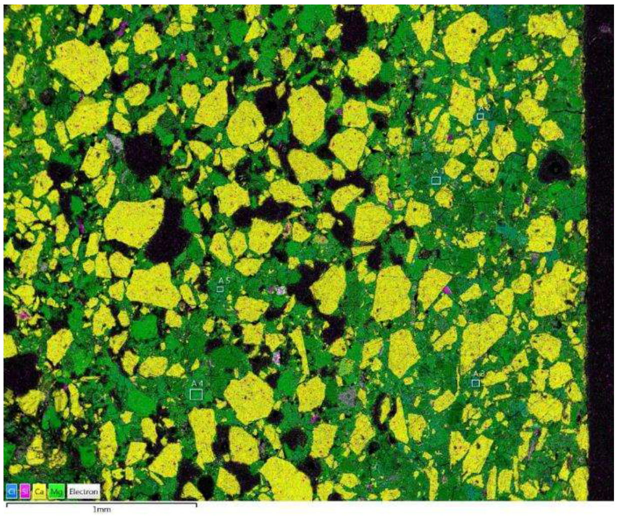

Fig. 10. PFB8: Layered EDS maps which shows the contact between the Sorel cement faux marble (sx) and the plastering with similar composition (dx).

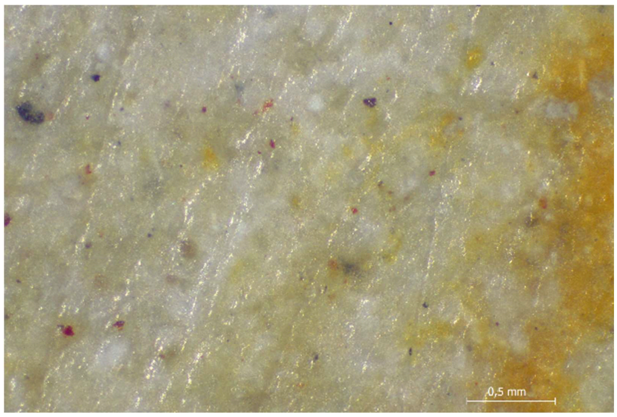

Fig. 11. PFB1: Smoothing and polishing marks identified under the stereoscope (OM).

IV. CONCLUSIONS

Through the study and research conducted on the production context of the late 19th and early 20th century, it was possible to gain insight into a period rich in innovation, experimentation and curiosity on the part of the scientific communities, techniques and craftsmen in Europe that, likewise, would not have been highlighted.
The discovery of the use of Sorel cement, as the constituent material of faux marble, made it possible to learn in depth about this rare binder, mostly in disuse, and to consult numerous journals, manuals and treatises written by engineers and architects of the last century. The breadth of information found, interwoven with each other, allowed for a rich information picture which, together with the diagnostic analyses and craftsmanship evidence of the current manufacturers of this this material, made it possible to reconstruct the technique of realization of the boiserie - particularly complex and articulated - and to

appropriately approach the restoration work.

In addition, the study of Portland cement, Sorel cement and the production techniques of faux marble and Venetian-style *marmette* allowed to expand the knowledge of modern materials and types of artifacts that have been widely used in the European territory until a few decades ago.

Furthermore, SEM-EDS analysis shown a high water/solid ratio during preparation of Sorel cement, which favored the molding, but also chloride leaching and MOCs destabilization. Two of its alteration products were identified (chrolartinite and hydromagnesite) by XRPD and RS. POM investigation and UVF revealed traces of a serial production technique, including the successive pouring of mortar layers in a fluid state into molds, the creation of original assemblage plastering and localized surface treatment application. Based on the results, it was possible to carry out a critical and appropriate restoration work and limit the worsening of the boiserie conservation state.

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