Microanalytical study of the *fresco* 'the good and the bad judge' in the medieval village of Monsaraz (Southern Portugal)

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This article describes a study carried out on the emblematic mural painting so-called 'fresco of the good and bad judge' located at the medieval village of Monsaraz (southern Portugal).

This painting, with two distinctic narratives, is thematically unique in Portugal and rare in the context of European Renaissance art. Scientific research was undertaken to clarify doubts about the chronology of the two painted scenes through a technical study and a material characterization of its constituents, namely, mortars, pigments, and binders.

Elemental and chemical analyses were performed by scanning electron microscopy with energy-dispersive X-ray spectroscopy detector, optic microscopy, μ-Raman spectroscopy and Fourier transform infrared microspectroscopy.

Comparative examination revealed that along with the stylistic similarities, there are no recognizable differences in the painting technique (garments and carnations) nor in the structure and composition of the pictorial support and chromatic layers. The mortars of both scenes are made of lime with different ratios of calcium (Ca) and magnesium (Mg) mixed with siliceous and granitic aggregates. An *intonachino* made with a more calcitic lime is visible in all carnations. The pigments identified in both scenes were mercury sulfide (HgS), red and yellow ochres (Fe_2O_3 and $FeO(OH)$ as chromophores), carbon black (C) and azurite ($2CuCO_3.Cu(OH)_2$). The extensive areas of chromatic losses seem to indicate that a mixed pictorial technique was used by the artist (*fresco* and *secco*). Copyright © 2013 John Wiley & Sons, Ltd.

Introduction

Painting description and history

The so-called '*fresco* of the Good and Bad Judge' from the medieval village of Monsaraz is unique in Portugal and still raises questions in terms of Art History and History in general (Fig. 1). Discovered on the walls of the ancient City Hall in 1958, it has been studied since 1960 by several Art Historians. Up until now, no consensus has been reached concerning the date (hypothesis range from the first half of the 14th century to the final of the 15th century) and because of the lack of historical documentation, there has been also some speculation about its real iconographic meaning.

The most accepted theory is that the painting is the representation of the allegory of justice_ on heaven and on earth_ painted in two apparently distinct but complementary narratives (Fig. 1).[1–4] In the upper scene, at the center of the composition is Christ with the globe at his feet. He is flanked by two characters (presently unknown) that hold *filacteras* in the form of letters Alpha and Omega. Christ is also flanked by two trumpeting angels. This panel is framed by a decorative Moorish-inspired bar, which gives it an aspect of illumination. Traces of heraldic can be seen on each side of the painting, probably the House of Braganza or the Portuguese Crown weapons.

The lower scene is the representation of a trial scene with two Judges. One of the Judges has two faces and is accepting donations. His conduct is influenced by the devil, which whispers in his ear and has a claw on top of his shoulder. The other judge treats everyone with fairness and his good will (Fig. 1). Recently, a

new insight look at the historical data available hints that the painting located in the medieval *domus municipalis*, could actually represent the underlying ethic and moral values in Diogo Lopes Rebelo's political treatise – *De republica gubernanda per regem* – written for King Manuel I in 1496. Justice, honesty, and equality in judging people against guile, inequity, and corruption were the main proclaimed principles that all the King's officers had to swear fidelity during ordination. At the light of this historiography approach, a new hypothesis for its date was raised that attributes it to the 16th century although some doubts remained about the chronology of the two painted

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Figure 1. General view of the painting in 1958 after its rediscovering and in 2012 (images sources: Gonçalves[1] and MGil).

scenes. The two kinds of preparatory drawings (in black and with red) and the apparently aesthetic differences in the decorative program in the upper scene could be ascribed to two different painting campaigns chronologically distant from each other or later modifications. Technical and material comparison between the two scenes could give the answer to these questions. This was the aim of the present research that was conducted in the field and in the laboratory.

Past interventions and research objectives

The Old Town Hall Court was first built in the 14th century and it seems to have been rebuilt several times since then. The mural painting, which is 337 cm high by 188 cm (upper scene) and 306 cm (lower scene) width, is possibly what remains of a larger decoration. According to Rodrigues (1878)[5] and to Gonçalves[1] (1966), the mutilation of the painting occurred during the construction of the dome in D. Manuel I kingship. However, it is unlikely that the divine figure of Jesus Christ and the Coat of Arms of the Noble House of Bragança – the noblest of Portugal and the owners of Monsaraz – had been deliberately mutilated in the 16th century. Instead, the mutilation probably occurred during the 1755s earthquake that partially ruined the building[5] .When it was rebuilt, the painting was safeguarded behind a new wall constructed for this purpose. The painting was only rediscovered in 1958 during the renovation works of the architectural space (Fig. 1). From that date to 1997, the painting was subject to a number of restoration interventions for mortars and paint layer consolidation, cleaning, and repaints removal (only in 1973).

During the latest restoration in 1997, a technical and material characterization using microchemical tests was initiated by the Portuguese Institute for Conservation and Restoration (actual José de Figueiredo Conservation and Restoration Laboratory) in order to identify the painter palette, mortars composition, and binders.[6,7] The present work was undertaken to complete the previous data and to clarify the doubts about the two painted scenes chronology. Furthermore, in the near future, this painting will be the master piece of the new Museum of Fresco in Monsaraz village. To ascertain the pigments, current state of conservation will also be valuable for the future conservation and museology measures to be taken for the painting exhibition.

To achieve these goals, a multianalytical methodology was envisaged through the combination of *in situ* infrared and visible racking photography and the analysis of 38 micro-fragments by scanning electron microscopy (SEM) equipped with a energy-dispersive X-ray spectroscopy (EDS) detector, optical microscopy (OM), μ-Raman spectroscopy, and Fourier transform infrared spectroscopy (FTIR).This analytical approach allows the combination of elemental, morphological, and molecular data at the microscale with the painting analysis at the macroscale ensuring an integrated view on the paintings technique and constituents.

EXPERIMENTAL

Sampling

In an analytical study, sampling should be made before any restoration operation in order to obtain information regarding degradation products of original materials and to avoid subsequent contaminations. Because of past interventions, in this case, it was not possible and the same happened in the first sampling campaign in 1997. However, because the purpose of this study was mainly the stratigraphic analysis and comparison of the original materials from both painted scenes, this was not an impediment except for organic binder characterization.

The 38 samples were collected using a scalpel blade no.15 (*Romed*, Holland). Table 1 shows the sampling locations and descriptions. The samples were chosen on the basis of the minimum possible damage (areas with small lacunae or fissures) as well as on representativeness by trying to gather as much information about materials used by the artist(s) as possible.

Optical microscopy

The *in-situ* optical observations and respective images were made with a digital microscope (*Dinolite*, GE Nardeen, Netherlands) with 35–40× magnifications. Other photo documentation, comprising general coverage and details of the paintings in racking light, were acquired with a digital photographic camera Canon EOS 500D. Raw image output in combination with color profiling system Mini ColorChecker P/N:50111 was used in order to obtain a more accurate and comparable color registration.

In the laboratory, prior to the beginning of the embedding procedure, the collected samples were analyzed using a stereozoom microscope Leica M205C (*Leica Microsystems*, Wetzlar, Germany) with 80–160× magnification in order to register the first characteristic features of mortars and paint layers (surface and profile). Further analyses were performed on selected micro-fragments and in cross sections. Cross-section samples were mounted in an epoxy resin (*Epofix Fix*, Struers A/S, Ballerup, Danmark) and polished with 1200 and 4000 sandpapers SIC-Paper Grif in a rotation disc Drehzal Regler (Jean Wirtz, Dusseldorf, Germany).

The OM observations were obtained with an optic Leica DM2500M microscope with reflected light in dark field illumination. The corresponding photographic documentation was obtained with a Leica DFC290HD digital camera (Leica Microsystems, Wetzlar, Germany).

Scanning electron microscopy

The SEM-EDS analyses were performed in the painting fragments and in the corresponding cross sections to underline the different morphological characteristics of the mortars and paint layers, observed by OM (*in situ* and in laboratory), such as grain size, morphology, elemental composition and distribution of aggregates, pigments, and inorganic binders with energy dispersive microanalysis (punctual and elemental maps).

For this work, a scanning electron microscope HITACHI3700N was used coupled with an X-Flash5010 X-ray energy dispersive spectrometer (Bruker AXS, Berlin, Germany). The images were obtained in backscattering (BSE) and secondary electron mode in the cross sections coated with carbon and in non-coated micro-fragments, under high vacuum and variable pressure, respectively.

Micro-raman

Micro-Raman spectra were performed on a Horiba/Jobin Yvon Xplora confocal spectrometer (Villeneuve D'Asq, France) with an incident power beam between 0.1 and 0.4 mW depending on the selected laser diode source operating at wavelength of 532, 638, and 785 nm. This low power is necessary in order to preserve the samples from burning. In order to improve the signal-to-noise ratio, several spectra (between 10 and 20) were accumulated for an exposure time varying from 120 to 300 s. A 100× magnification objective with a pinhole of 300 μm was used to optimize the signal intensity and the spatial resolution on the focused pigment grains. To allow an accurate identification of the studied paint layers, the measured Raman spectra were processed using a polynomial baseline correction in order to reject the fluorescence. The identification of pigments was made possible with comparison with spectral databases (Spectral ID, Cristal Sleuth and RRuff project website).

Table 1. Sample location and description (ref., sampling date and color). The red traces indicate the *pontate*.

ref.		date	color	ref.		date	color
1	garment	1997	white	20	garment	1997	yellow
2	bar	1997	violet	21	cloud(?)	2012	blue
3	garment	1997	black	22	wing	2012	grey
4	background	1997	red	23	hat	2012	red
5	garment	1997	green (vestiges)	24	garment	2012	white
6	prep. drawing	1997	black	25	garment	2012	white
7	prep. drawing	1997	red	26	garment	2012	white
8	frame	1997	red	27	garment	2012	white
9	hair	1997	brown	28	wing	2012	white
10	garment	1997	yellow	29	background		red
11	garment fold	1997	red	30	decoratif	2012	brown
12	garment fold	1997	greyish	31	motif		red
13	background	1997	greyish	32	heraldry	2012	red
14	background	1997	grey-black	33	frame	2012	red
15	background	1997	greyish	34	prep. drawing	2012	red-brown
16	garment	1997	red	35	garment	2012	white
17	garment fold	1997	greyish red	36	garment	2012	white
18	background	1997	brownish yellow	37	wing	2012	white
19	carnation	1997	white	38	hat	2012	reddish vestiges
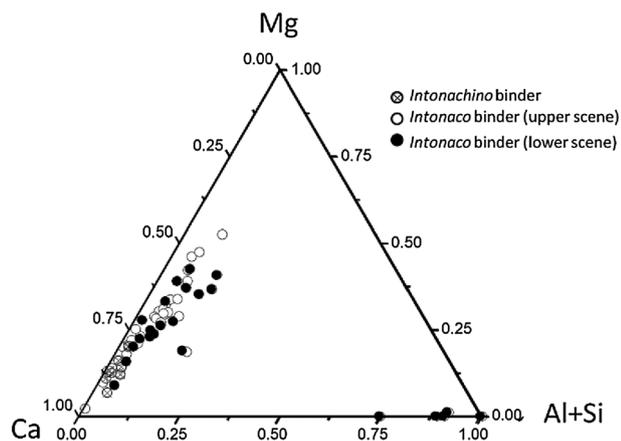
Figure 2. Comparison of Ca, Mg, and Al + Si (wt%) between the ground layers of the two painted scenes. Sixty four energy-dispersive X-ray spectroscopy punctual analyses were performed in 20 micro samples.

Fourier transform infrared spectroscopy

Selected samples were analyzed in a Thermo Nicolet Nexus 670 FTIR spectrometer (GMI, Ramsey Minnesota, USA) coupled to a Continuum IR microscope. FTIR spectra were collected in transmission mode using a compression diamond Spectra-Tech µSample Plan cell. Each FTIR spectrum is the average of 254 scans collected at $4\,cm^{-1}$ resolution in the region from $4000\,cm^{-1}$ to $650\,cm^{-1}$. Comparison was made with literature[8–10] and with three reference samples (e.g., rabbit glue from *LeFran&Bougeois*, lactic casein in powder from *Sennelier* and *paraloid B72* 5% in acetone)

RESULTS AND DISCUSSION

Pictorial support

The rendering or ground on which a mural painting is executed is often composed of two mortar layers. The first is a coarser layer called *arricio* and it is applied directly on the wall. The second, the *intonaco*, is a thinner and finer layer that receives the painting. Both layers are present in the mural of the 'Good and Bad Judge' but only the *intonaco* was sampled, along with the paint layer, for micronalytical analysis due to its thickness (1–3 mm).

The final layer was not applied all at once but from top to bottom by *pontate*, that is, by storeys of scaffolding (Table 1). In racking light, four horizontal joins were clearly visible (one on the upper scene and three on the lower one). Several *pontate* can be executed during one single painting campaign but might also indicate two or more distinct campaigns in chronological terms.

The way of plastering was found to be similar in all *pontate* and the examination of the *intonaco* in the cross sections by SEM (BSE) images and by EDS elemental analysis shows also similarities in the layer structure, aggregate, and binder composition between the mortars (Figs. 2 and 3). In all samples, calcium (Ca) and magnesium (Mg) content plotted against aluminum and silicium (Al + Si) reveals that the mortars were made from a lime binder with different ratios of dolomite ($MgCO_3$) and calcite ($CaCO_3$) minerals (Fig. 2). The Al + Si content could be assigned to the presence of silicates (as clay minerals and/or as siliceous aggregates). Only one sample, from the white mantle of the crowned judge, shows an increase of Al + Si. It is possible that a clay was used as a ground in this particular case.
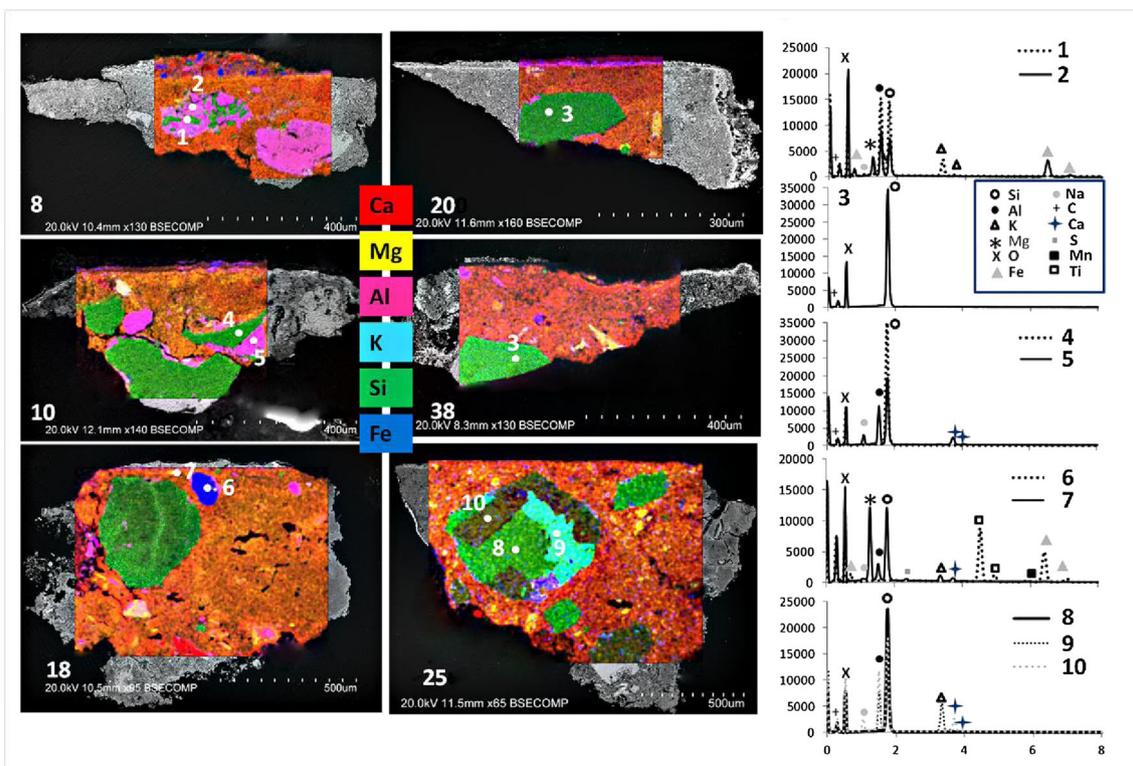
Figure 3. Backscattering images and energy-dispersive X-ray spectroscopy elemental maps of cross sections, illustrating the appearance and elemental composition of the *intonaci* binders and aggregates.

The use of dolomitic and calcitic lime mortars in mural paintings is common in Southern Portugal built heritage probably because of the geological environment, rich in carbonated rocks. Dolomitic lime $(CaMg(CO_3)_2)$ was specially used on inner layers for increasing the mortars physical and mechanical characteristics. For aesthetic purposes, the whiter calcitic lime $(CaCO_3)$ is usually preferred for the superficial layers such as the *intonaco*. However, it was not the case in this painting. In both scenes, only a thin layer was made with a more calcitic lime and it serves as a white ground and/or as pigment in the background, garments, and carnations (Fig. 2). This layer without aggregates and applied with a brush on top of the *intonaco* is usually known as *intonachino* or whitewash. Two examples can be seen in the BSE images of the samples cross sections 20 and 38 (Fig. 3).

Local sands seem to have been used as aggregates in all the *intonaci* analyzed. In Fig. 3, the variations in Si, Al, K, Ca, Na, Fe, and Mg content in the aggregates reveal the presence of quartz, feldspars, plagioclases, and micas. Granitic rock fragments were also identified (e.g., grain in sample 25). All of them can be found in the geological igneous and metamorphic environment of Monsaraz (Fig. 4). The grain sizes ranging from 80 to 382 μm and the varying degrees of roundness indicate that the aggregates are probably from river sands that suffered small transport (Fig. 3).

Paint layers

The stratigraphy and thickness of the paint layers are also very similar in the two representations. Optic and SEM observations mainly detect one or two chromatic layers on top of the *intonaco* and *intonachino*.

Yellow was extensively used as background color. Along with red, these two colors are nowadays predominant on the 'God and Bad Judge' painting (Figs. 1 and 5). By EDS analysis, the aluminum (Al) and silicium (Si) high content in all the yellow paint layers shows that an yellow ochre, a colorant earth pigment composed of phylloaluminosilicates with iron oxohydroxides as chromophores, was used in both scenes and in the frame. The brownish hue is due to the presence of manganese oxides
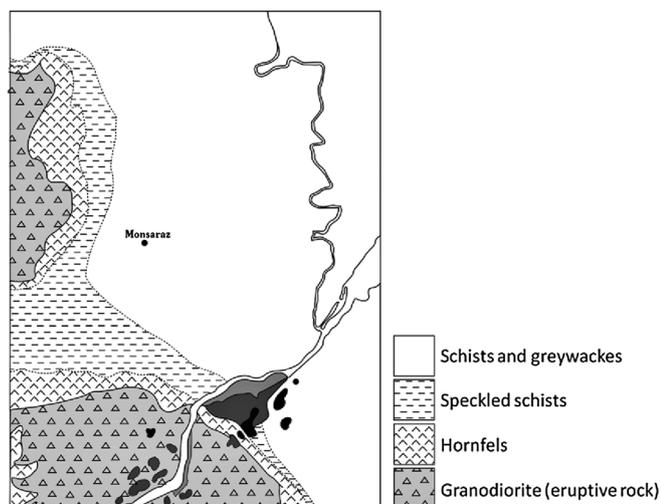
Figure 4. Geological environment of Monsaraz village (map adapted by N. Carriço from Portugal geologic plant 1978, scale 1:50,000)
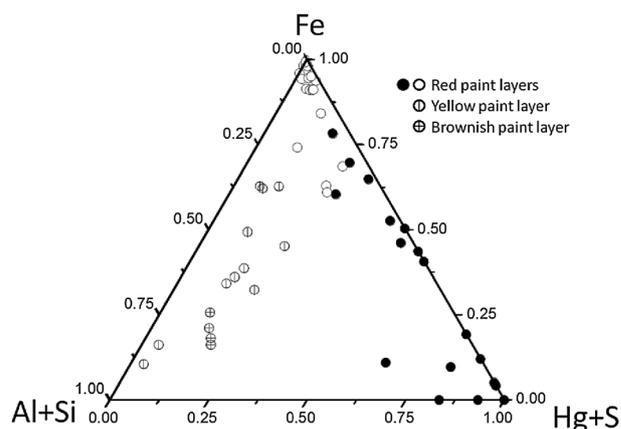
Figure 5. Comparison of Hg + S, Fe and Al + Si (wt%) in red and yellow and brownish paint layers. Seventy-three energy-dispersive X-ray spectroscopy punctual analyses were performed in 15 micro samples.

(MnO_2) (Figs. 5 and 6). The same elements (Fe, Al, and Si) but with different ratios are also present in the reds from the floor background and within the frame decoration attesting the use of red ochres, a colorant earth pigment composed of phylloaluminosilicates with hematite as chromophore (Fig. 5).

On the areas of vivid red, mercury sulfide (HgS) or its mixture with red ochre were identified by SEM-EDS and by μ-Raman (Fig. 7). The mineral origin of HgS (cinnabar) seems to be attested by the variety of the morphology and particle sizes (Fig. 7). Unlike earth pigments, cinnabar was an expensive pigment. The extensive use in the mantle of Christ highlights not only the iconographic importance of this figure but also the economical power of the painting contractor. This pigment (or traces of it) was also found in both scenes in smaller decorative details in the remaining figures (e.g., mouth, hats) and in the red and white backgrounds. This pigment does not show signs of blackening, a current light induced degradation phenomenon of mercury sulfide.[11] The grayish strokes in the shadows of Christ's mantle are a mixture of red ochre (Fe_2O_3 as a chromophore) with carbon black (Fig. 8).

The basic copper carbonate azurite $(2Cu.CO_3.Cu(OH)_2)$ was found punctually in the upper scene. This natural blue pigment was the most used during medieval times in Europe until it was almost entirely substituted by smalt, a cheaper pigment, from the 16th century onward.[12] It is possible that azurite was also used in the figures garments in the low scene as was suggested by the microchemical analysis of one sample in 1997. Nowadays, this blue pigment is only visible in a cloud (?) near the fragmented angel and it lacks cohesion. This could be attributed to a gradual weakening of the binding power, or less likely, to accidental removal during past interventions.

In what concerns the blacks and grayish color layers, only carbon black (charcoal) was identify by μ-Raman (Fig. 8). Phosphates $(PO_4)^{-3}$ that are normally assigned to bone black pigments were only identified as a minor or trace element within the paint layer matrice of calcium carbonate and the underlayer ground.

Charcoal and red ochre were detected in the outlines of the upper composition, whereas in the low scene, the preparatory drawings and respective *repentimenti* were made mainly with red ochre. In both cases, they seem to have been performed freely by the same hand.
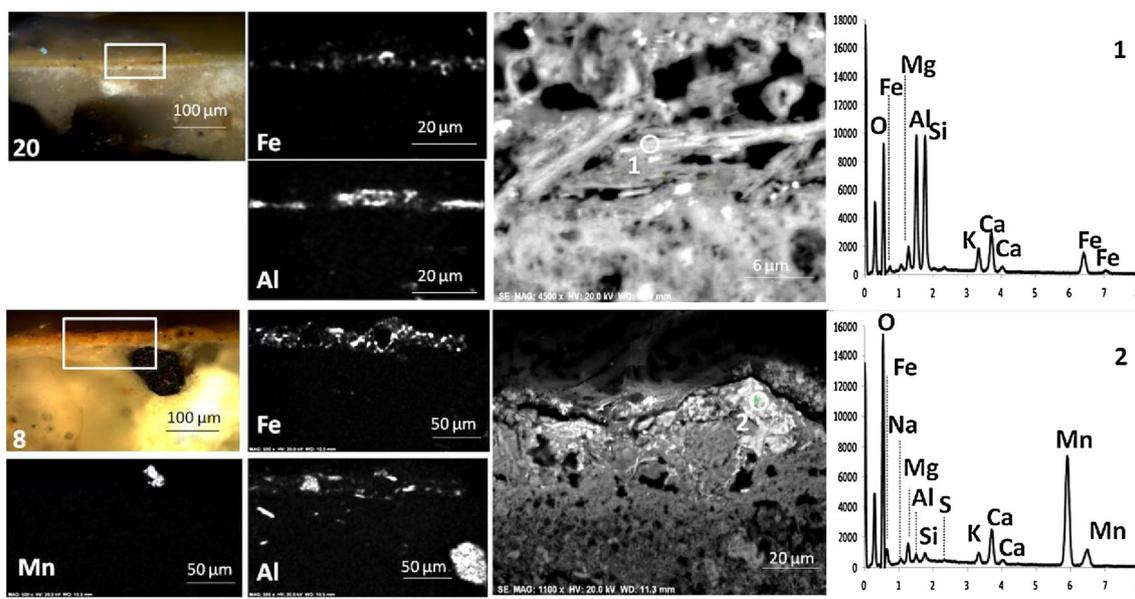
Figure 6. Scanning electron microscopy-energy-dispersive X-ray spectroscopy elemental maps of Fe, Al and Mn and punctual analyses of a yellow (51-96-20) and brownish paint layer (51-96-18). The backscattering images show the morphology of the chromophores in the paint layers. The laminar habit of philosilicates is perceptible in the yellow ochre paint layer detail of sample 20.
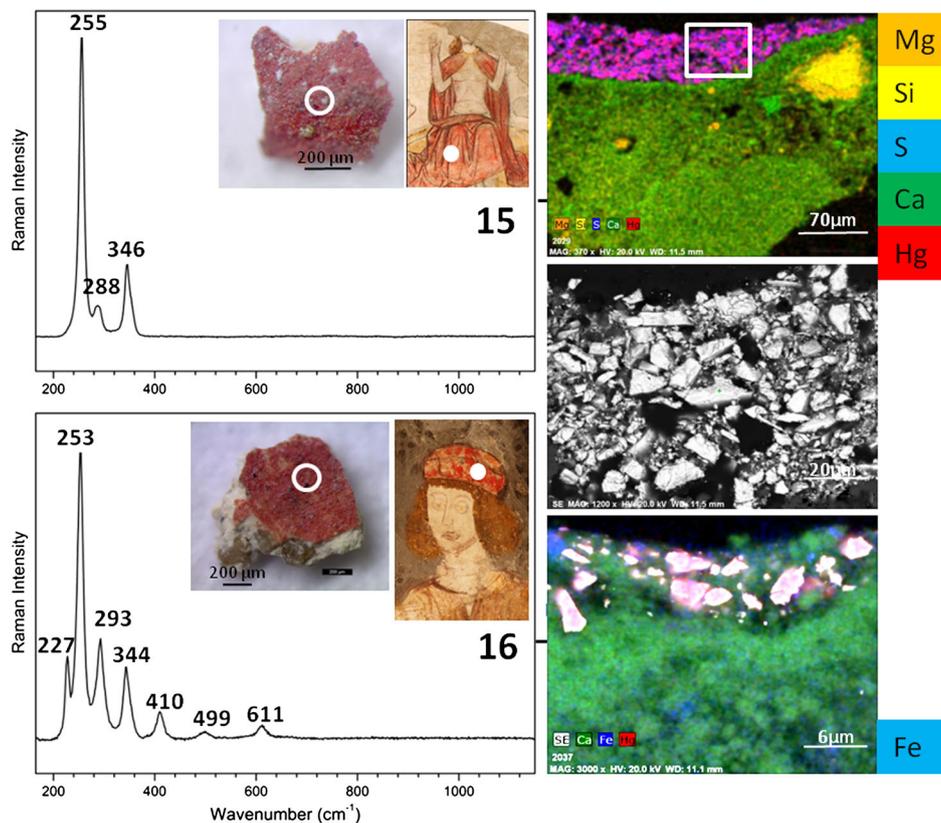
Figure 7. Raman spectra and scanning electron microscopy-energy-dispersive X-ray spectroscopy elemental analyses of samples 15 (cinnabar) and 16 (cinnabar mixed with hematite Fe_2O_3).

In general, there are similarities in the style and way the compositions were executed. In both paintings scenes, the modeling of the faces and garment folds are not achieved with soft color gradations but rather with a linear drawing (Fig. 9). Flesh tones were the latest to be lied down and were achieved with a dilute red or gray strokes on top of the *intonachino*. Only the body of Christ
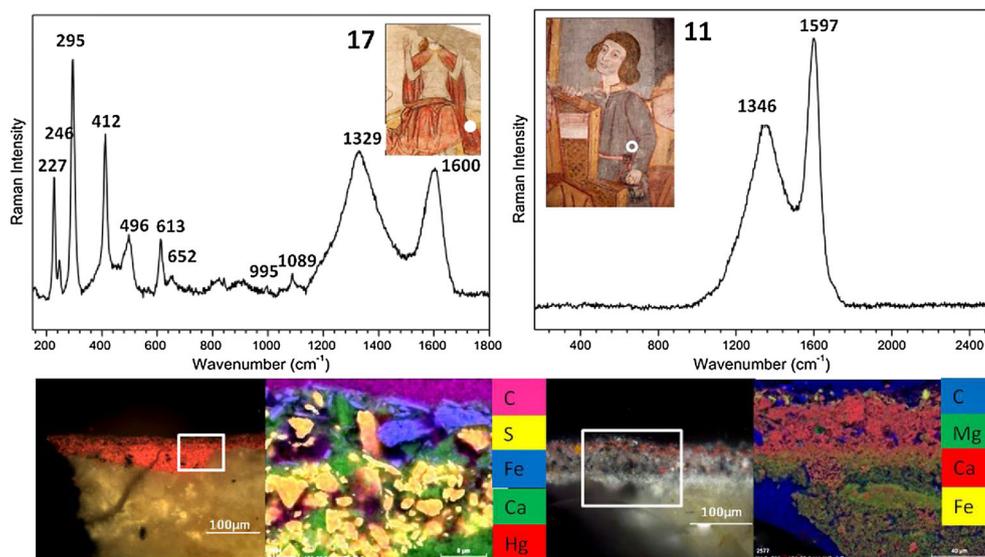
Figure 8. Raman spectra and scanning electron microscopy-energy-dispersive X-ray spectroscopy elemental analysis of samples 17 (carbon black (C) mixed with hematite Fe_2O_3) and 11 (carbon black C in the grayish layer).
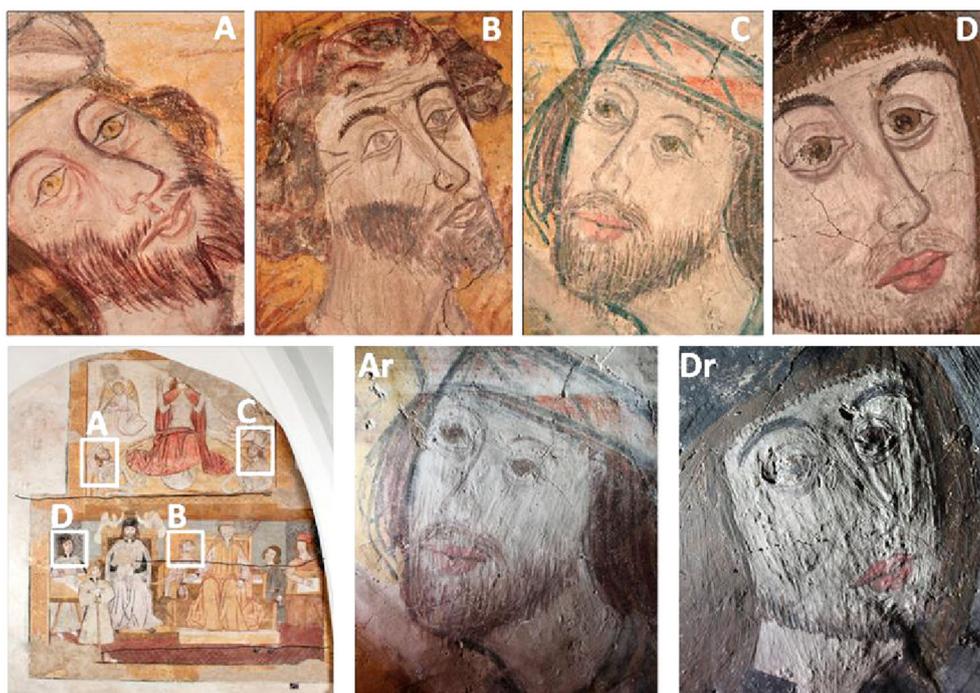
Figure 9. Details of the features of the figures from the two scenes in visible frontal and racking light (Ar and Dr) (photo MGil2012).

has gradations in the flesh tones with shadings made with yellow and red ochres. Many finishing details in the figures' faces (e.g., eyes pupils, color of the lips, hair) and garments seem to have disappeared. Many vestiges made with carbon black, red ochre, and mercury sulfide are visible in both scenes. The aesthetic differences in the upper register between the two angels could be related to changes or additions into the initial decorative program.

Painting technique

In general terms, fresco refers to a technique of painting on which the pigments are applied into a damp plaster by daily working zones (*giornate*) or scalfolding storey's (*pontate*). The pigments are dispersed simply in water (in this case, it is a *buon* or *vero fresco*) or can be mixed with an emulsion of lime ($Ca(OH)_2$). On the other hand, in a *secco* technique, the painting is executed on a dry plaster. The pigments can also be blended with calcium hydroxide and/or with an organic binder. In this case, *giornate* are absent but the painter can still be working by *pontate*.

In the wall painting under inspection, the absence of *giornate* and the several chromatic losses strongly suggest that the painter employed a mixed technique (*fresco* and *secco*). Microscopy observation of the cross sections revealed different degrees of
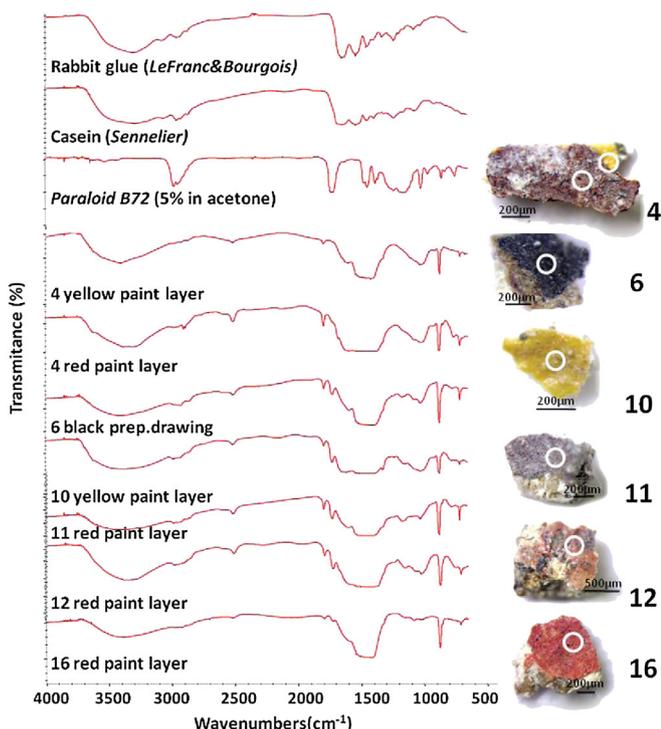
Figure 10. Fourier transform infrared spectroscopy analysis spectra of all samples show absorption bands due to the presence of calcite (2513, 1795, 1400, 876, and 713 cm^{-1}) and silicates (broad absorption at 1000–1100 cm^{-1}). The absorptions at *ca.* 1730 cm^{-1}, 1240 cm^{-1}, 1150–70 cm^{-1}, and 1027 cm^{-1} indicates the presence of an acrylic resin – most likely *Paraloid B-72*.

diffusion between the paint layers and the underlying subtrate (*intonaco* or *intonachino*). When the pigments grains slightly penetrate the mortar, it is possible to conclude that the technique of *buon fresco* was used. However, in the majority of the paint layers analyzed by SEM-EDS and by FTIR, the pigment is dispersed in a matrice of calcium carbonate ($CaCO_3$) that has

a clear interface with the underlayer. The matrice thickness is between 40 and 90 μm and the distinctive composition of the *intonaco* below indicates that the pigment was intentionally mixed with calcium hydroxide (Figs. 7 and 8). In this case, the painter could begin to paint in a damp mortar and continue during its drying. Lime thus seems to have been used as a pigment and as a binder even with pigments that were advised to be used mainly in *secco* techniche (e.g., azurite and in some extent mercury sulfide)[13,14].

Among the materials used in wall paintings, organic materials are the most prone to deterioration because they are more fragile than inorganic paint layers to aging and to the external factors of weathering (ex. humidity, biodecay).[15] By FTIR, no natural organic binder was found in the paint layers analyzed but only traces of an acrylic resin (Paraloid B72) (Fig. 10). This synthetic resin was applied in past interventions for fixing the powdered paint layers. Its presence is clearly detected on the surface of some of the fragments (Fig. 11).

CONCLUSIONS

The application of this multi-analytical approach allowed a new insight on the iconic mural painting 'The Good and the Bad Judge' from the medieval village of Monsaraz, Portugal.

Comparative *in situ* and laboratory analysis of the two painted scenes show that there are not recognizable differences in the painting technique and in the structure and composition of the pictorial support and paint layers. Lime with different ratios of Ca and Mg was used as binder in all *intonaci*, whereas a more calcitic lime was preferred for the *intonachino* (or whitewash). The pigments identified in both scenes are the same, namely, yellow and red ochre (FeO(OH) and Fe_2O_3 as chromophores), mercury sulfide probably for mineral original (HgS), azurite ($2Cu.CO_3.Cu(OH)_2$), and carbon black (C). They were mixed with calcium hydroxide ($Ca(OH)_2$) and laid down on a damp and possibly dry *intonaco* (mixed technique). From the extensive
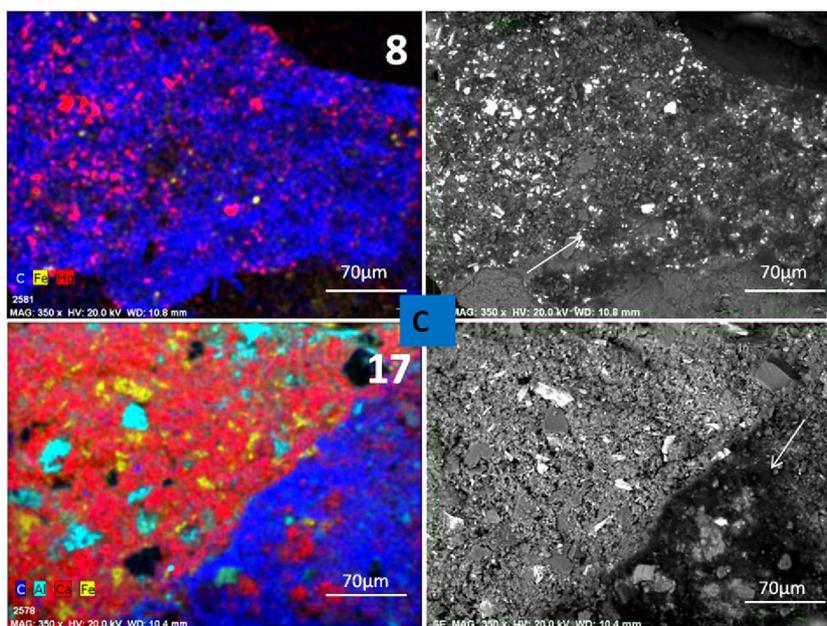
Figure 11. Elemental map of C (carbon) in the painted surface which shows the presence of organic material (possibly *Paraloid B72*).

chromatic losses, it is possible to assume that mainly the parts painted in *fresco* technique remained today.

The similarities between the mortars, pigments, and the pictorial techniques of both scenes lead to the conclusion that the two registers are most likely contemporary of the same painting workshop and not executed in two chronological distant periods, as was thought as first. From the viewpoint of museology, the obtained results are also valuable for future conservation purposes because, from now on, special attention should be given to mercury sulfde pigments taking into account its susceptibility to photodegradation.

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