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Full Length Research Paper

Analytical Studies of Plaster Painting and State of Conservation in Red Monastery-The Church of Saints Bishai and Bigol, Sohag, Egypt

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Abstract

This paper deals with the mineralogical and petro graphic characterization of the materials, as well as inferences about the painting techniques (suitable reference specimens were prepared for this purpose) and the state of conservation of the plaster painted . The study is primarily based on analyses of micro fragments in thin cross-sections by means of a polarizing microscope equipped for observations in transmitted and reflected light; XRD, SEM-EDS and Micro-Raman spectroscopy were also used to confirm and supplement the microscopic data. Plaster joints with a specific horizontal and vertical trend that follows the separation of the different scenes indicates method of execution. The supporting plaster, lying directly on the masonry, is mono layered. Two main types of plasters were observed: lime plaster and lime plaster with cocciopesto. In the first type plant fibres are locally present. The paint film is often multilayered. Thirteen pigments were identified, all of them used in the original paintings or, at most Two pigments, crocoite and chrysocolla, have never been found before in medieval wall paintings. The finding of crocoite (very probably of natural origin) is of particular historical-scientific importance. The most typical micro stratigraphies in the main figurative elements are illustrated. The painting techniques used are fresco (including the variant lime fresco painting), tempera and lime painting, very often combined in the paint film. The distinguishing petrographic features of each technique are described and illustrated. The main results of the study are discussed in regard to their historical and artistic significance, and they are compared with materials and techniques known in other contemporary pictorial cycles. The state of conservation of the paintings before the restoration is illustrated and related to the complex history of the room hosting the paintings. Referenced digital mapping of the preservation status was carried out for the major scenes using a Geographic Information System (GIS), which allowed adequate processing of the entire data set.

Key words : *Red Monastery – plaster – Analysis*

Introduction

The Red Monastery is a Coptic Orthodox monastery named after an Egyptian saint called Pishay (who is not to be confused with the famous Saint Pishoy). It is located near the Upper Egyptian city of Souhag, and about four Km north west of the White Monastery. The name of the monastery is derived from the color of the construction material of its outside walls, consisting of red (burnt) brick. These walls are considerably thicker at the base than at the top, and, just like the walls of Ancient Egyptian temples, they are surmounted by cavetto moldings. The Red Monastery is architecturally similar to the White Monastery. The history of the foundation of the Red Monastery is not known, and it is thought to have been built at the fourth century AD. by an Egyptian saint called Pishay (who is not to be confused with the known Saint Pishoy). This saint was a contemporary of Saint Pigol, the founder of the White Monastery. Almost nothing is known of the history of the Red Monastery (Deir al-Ahmar, Deir Anba Bishoi or Bishai) near Sohag, though it is one of the most famous Christian monasteries in Egypt. It lies about three kilometers north of the White Monastery at the extreme western edge of the cultivated land. However, unlike the White Monastery it is situated within a small village, and some houses lie to the south and east. The area to the north and west of the monastery is mainly covered with debris. Its name is derived from the color of its construction material, consisting of red (burnt) brick, of its outside walls, which distinguishes it from its nearby neighbor, the White Monastery which is made of stone. These walls are considerably thicker at the base than at the top, and like ancient Pharaonic temples, as well as the White monastery, are surmounted by cavetto moldings. Otherwise, this monastery is architecturally similar to the White Monastery, and most likely its construction dates to the same period (probably the fifth century AD). Exterior of the Red Monastery (Deir al-Ahmar, Deir Anba Bishoi or Bishai)century, but a lot of it may well be early."The monastery was dedicated to St. Pshoi (Bishoi in Arabic), who is not to be confused with the more celebrated individual who lived in the Wadi al-Natrun. He was a contemporary of Apa Pjol, the founder of the White Monastery. In fact, it was probably St. Pjol who founded this monastery as well. In his "Life of Shenute", Besa says that, "The holy apa Pjol and the young man Shenoute went out walking together, and with them also went apa Psoi (Pshoi) from Mt. Psoou. He too was a holy man who walked after godly things" (Besa 9, p. 44). Hence, one may identify "Psoou" (Psou) with the Red Monastery. While the fifteenth-century Arab historian al-Maqrizi names the monastery, he provides none of its history. The probable reason is that it was closely related to the White Monastery at that time. Dominique Vivant Denon visited the monastery during Napoleon's campaign in 1798-1799, but states that the facility had been ransacke

Experimental methods

About 300 micro fragments (mostly smaller than 1 mm) were collected from different scenes and decorative elements. Sampling was conducted in close collaboration with the restoration staff according to a principle of minimum invasiveness, i.e. taking samples from the margins of existing lacunae. The study is primarily based on analyses of fragments in thin cross-sections by means of a polarizing microscope equipped for observations in transmitted and reflected light. Observations were also carried out with non-conventional devices that increase the diagnostic potential of the method. Light microscopy allowed a preliminary characterization of the materials in the paint film and the supporting plaster, as well as exhaustive identification of the micro stratigraphy of the paint film. Light microscopy also played a prominent role in the recognition of painting techniques. For this purpose, we tested the petrographic method (not currently used for such analyses) by preparing suitable test pieces thank to determinant support of the restorers of the plaster paintings. The reference specimen were prepared using materials similar to those in use in ancient times, thus reproducing paint films applied with different techniques on an appropriately prepared plaster. Diagnosis of the painting techniques was based on the textural relationships between the various micro stratigraphical units and on a preliminary identification of the nature of the binders by optical and micro structural characters.

The analyses were usually performed directly on the collected micro samples to allow their re-use for other kinds of analyses. In some cases, the pigment under study was isolated under a stereomicroscope and directly pulverized on a silicon support wich provides a low scattering contribution. SEM-EDS analyses, using a Philips XL20 electron microscope operating at 20 kV acceleration voltage and equipped with an EDAX DX4 energy dispersive spectrometer, were carried out to confirm and supplement the optical and diffractometric data. SEM analyses were performed directly on thin sections covered by a light carbon film. The incident laser radiation was provided by an Argon air-cooled laser source with excitation wavelengths at 514.5 nm. A 50 × magnification objective was employed to focus the laser beam onto the sample, providing a spatial resolution of about 1–2 µm. The irradiating laser power was about 2 mW. The scattered light was analysed using a grating mono chromator with 1200 lines per millimetre. Spectra were recorded with a collection time up to 200 s.

ATR-FTIR. For the characterization of the pigments' molecular structure, all samples were analyzed using a Thermo- Scientific Nicolet 6700 Fourier Transform Infrared Spectrometer (FTIR), equipped with an Attenuated Total Reflectance (ATR) accessory. Transmission FTIR spectra were recorded in the mid-IR spectral region 4000 - 400 cm-1, at a resolution of 4 cm-1 and by collecting 120 co-added scans for each spectrum. The approximate collection time was about 1 min. Data processing was carried out using the OMNIC 7.1 Software. The great advantage of the ATR technique utilized is that minimum amount of sample is required without involving any preparation (i.e. KBr pelletization), enabling, thus to obtain high quality IR spectra of the samples very quickly.

Characterization of materials and microstratigraphies

The supporting plaster

The supporting plaster consists of a single layer (average thickness about 5 mm) lying directly on the brickwork and subordinately on calcareous stone masonry. Therefore, it

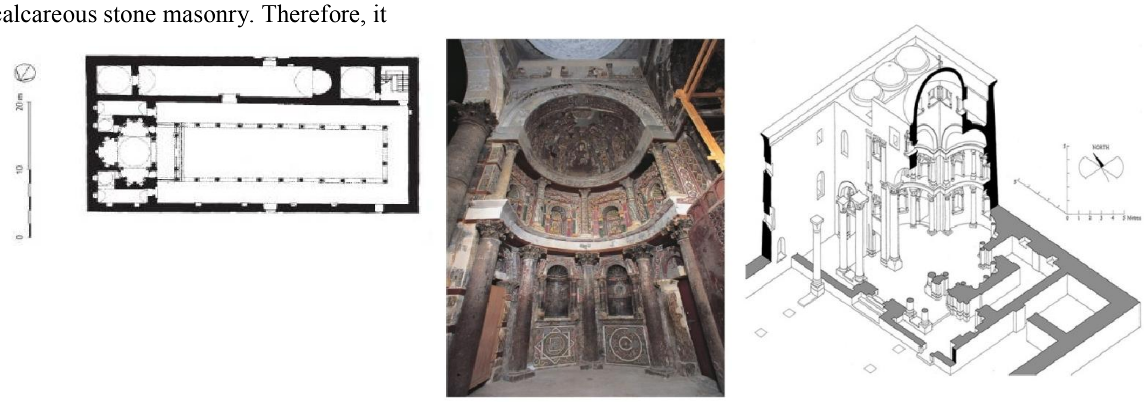

Fig 1. The image shows the appearance of the paintings

Two main types of plaster were recognized: a lime plaster and a lime plaster with cocciopesto. The plain lime plaster is based on a sandy aggregate, with grain size between 40 and 300 µm, largely consisting of quartz and calcite and, to a lesser degree, lithic fragments with prevailing Pliocene sandstone, which constitutes the geological substratum of the historical place. The binder consists of microcrystalline calcite. The binder/aggregate ratio is usually between 1/1.5 and 1/2. In three scenes on the wall The lime plaster with cocciopesto consists of a sandy aggregate very similar in composition, quantity and grain size to that of the plain lime plaster. The grains of cocciopesto are present in variable quantities; they show a wide range of grain size, with a prevalence of the fine fraction (a few µm)

Pigments

Artists' palette of colors in plaster

The identified pigments are reported in Table 1, together with their specific uses in the different pictorial elements of the paintings. Their frequent combination as overlapping layers in the paint film and/or their mixing within the same layer produced a wider range of chromatic tonalities. All the pigments are well preserved, even lead white, minion and cinnabar which are considered easily subject to alteration. Only azurite presents frequent chromatic alterations to the greenish tonalities due to transformation into paratacamite and sometimes malachite; this phenomenon has been found in many medieval paintings. There are also much localized transformations of yellow ochres into red ochres due to the heat of candle flames or oil lamps (see Section 5). These two pigments are more widely described and discussed in the following sections. Some remarks concerning green earth and lime white are necessary.

In these plaster paintings, green earth is represented by a mineral of the mica group; the first analyses indicate the presence of colacbrite. The term lime white is used here in its broadest sense, including proper lime white (water-slaked lime) and bianco sangiovanni, a pigment with a substantial proportion of calcium carbonate deriving from the ancient manufacturing process described.

Table 1. Identified pigments and their uses.

	Pigment	Main use	Use in decorative elements
Red	Cinnabar	Draperies,	No
	Red ochre	Draperies, flesh, preparatory drawing, architectural motifs, dark backgrounds, hair	Yes
Orange	Minium	Orange halos, draperies, missione (ground preparation for gold leaf), flesh, architectural motifs	No
Yellow	Yellow ochre	Flesh, draperies, preparatory drawing, architectural motifs	Yes
	crocoite	Architectural motifs, flesh and minor figurative elements (with ochres and/or minium), heightenings in reddish drapery, orange halos (with minium), outlines,	Yes
Green	Green earh	Flesh (ground tonality)	No
	Verdigris	Probable component in missione	Yes
Blue	Azurite	Sky, draperies, architectural motifs	no
Light blue	Chrysocolla	Draperies	No
Black	Coal black	Ground tonality, dark shadings in draperies, outlines, architectural motifs, dark backgrounds	Yes
White	Lead white	Missione, heightenings in draperies, architectural motifs	Yes
	Lime white	Draperies, architectural motifs, outlines	Yes

Crocoite

$PbCrO_4$, monoclinic, with a brilliant yellow color, is fairly diffuse, albeit in very small quantities, in several kinds of pictorial elements (Table 1). It is usually used, either as the only pigment forming a more or less continuous thin layer (Fig. 3a–c), or, sometimes, combined with other pigments, e.g. ochres and minium (Fig. 3e, f). Crocoite was well revealed by XRD (Fig. 4 and Table 2) and Raman spectroscopy (Fig. 5), while the SEM-EDS analyses confirmed the significant presence of Cr and Pb in the pigment (Fig. 3c, d). The peculiar history of the paintings implies that the pigment was applied before the room was filled with rubble, certainly no later than the mid-fourteenth century. The data obtained thus for plant out a diffuse use of this pigment in repainting interventions (see also section 5). However, this contrasts with current knowledge about the history of the scientific identification of natural crocoite and the production and use of synthetic $PbCrO_4$-based yellow pigments, on the whole known as "chrome yellow"; indeed, these events took place later than the second half of the eighteenth century (and references therein). Crocoite in these paintings has therefore very probably a natural origin. In nature, crocoite is a rather uncommon secondary mineral occurring in the oxidised zones of lead mineralization.

Chrysocolla

Chrysocolla, a nearly amorphous hydrated copper silicate, was found in light blue-greenish draperies of two scenes on the northern wall. The pigment was always secco applied by the lime painting technique. No single investigation was able to identify the pigment. Instead, the combination of several results obtained from different analytical methods allowed its determination. In thin section, the grains of the pigment appear almost round, or rarely fibrous or sharp-cornered, with grain size usually between 10 and 50 μm. Under transmitted plane polarized light, the grains show a pale blue color, sometimes with greenish shades. In reflected light dark field, the grains show a dark bluish appearance. Under transmitted light with crossed polarizers, the pigment shows isotropic features, or, more frequently, the grains show a faint birefringence with an inhomogeneous, undulating extinction. Sometimes the grains contain irregularly shaped inclusions of azurite. The association between chrysocolla and azurite in the samples can be explained by the fact that the two phases are often associated in natural copper mineralization. The images in BSE obtained at the scanning electron microscope better underline the microstructural characters of the pigment, while the analyses with EDS microprobe show that it consists mostly of Si and Cu (Fig. 6). The low crystallinity of the compound is confirmed by XRD analyses (Fig. 7).

Fig. 8 shows the Raman spectrum of the pigment, which does not match the spectra of known pigments. A more detailed Raman spectroscopy study is necessary because of

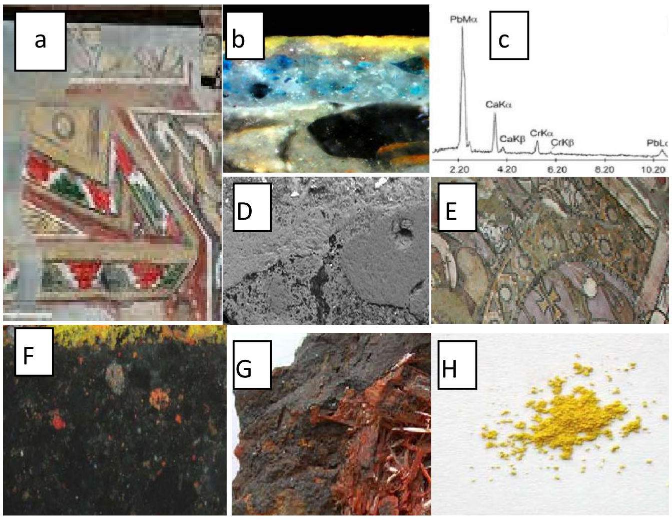

Fig. 3. (a) An example of the use of crocoite in architectural motifs (Visitation scene), and (b) relative microstratigraphy (reflected light darkfield). A: lime plasterwith sandy aggregate. B: azurite secco-applied in lime binder (probably St. John's white). C: veil of crocoite applied on a thin underlying lime layer. (c) Same image obtained by SEM with BSE (Crc = crocoite; Az = azurite, Cal = calcite). (d) EDS spectrum of crocoite in the previous image (calcium is an expression of the underlying lime layer). (e) Use of crocoite in an orange halo (Crucifixion scene), and (f) relative microscopic appearance of the paint film (reflected light darkfield); crocoite (Crc) is mixed with minium (Min) in the paint film. (g) A sample of natural crocoite from Dundas, Tasmania (with thanks to the Museum of Natural History, Accademia dei Fisiocritici, Siena). The well-developed prismatic crystals have a bright translucent reddish colour. (h) The relative powder, instead, is brilliant yellow.

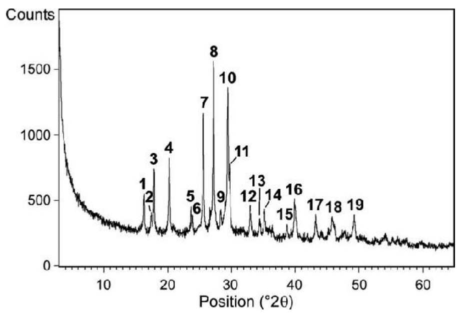

Fig. 4. XRPD spectrum of crocoite separated under the stereomicroscope from the sample shown in Fig. 3a.

Data for each of the main peaks indicated with numbers are reported in Table 2. Table 2 Data relative to XRPD spectrum of crocoite in Fig. 4 XRPD compared to X-ray diffraction data of a natural standard crocoite (PDF 1-74-2304 from ICDD database) the chemical and structural variability of the compound and the lack of standard reference spectra in the literature. The presence of chrysocolla seems to be exceptional for wall paintings. Thus far, the pigment has only been reported in ancient wall paintings in Egypt, India and China [28,29].

Some significant microstratigraphies of the paint film

The paint film can be mono- or, more often, multilayered. In many cases, two or more layers are observed: one acts as preparation or ground tonality, while the overlying layer represents the finished colour; this layer, in turn, can be surmounted by thin and discontinuous glazings (heightenings and shadings). However, even more complex microstratigraphies can be found, for example in repaintings (Fig. 10b) and in zones where contiguous fields of colour overlap. A preparatory drawing is often present at the base of the paint film, generally represented by a very thin, sometimes discontinuous, fresco-applied layer consisting of yellow and/or red ochres e.g. (Fig. 10a).

Similar pictorial elements of the various scenes may present marked microstratigraphic complexity and variability. Nevertheless, we will describe and illustrate (Figs. 9 and 10) some of the more significant micro stratigraphies in the main pictorial elements, also indicating the respective painting techniques (fully discussed in Section 4). The following elements are considered here: sky, red and blue drapery, flesh, golden and orange halos and decorative elements

Peak number	Sample data		Standard data		
	d (Å)	I (%)	d (Å)	I (%)	hkl
1	5.434	21.4	5.42668	19.2	–101
2	5.080	19.2	5.08832	8.8	110
3	4.956	33.3	4.95112	17.9	011
4	4.388	36.0	4.38351	38.9	–111
5	3.761	10.8	3.76297	8.9	111
6	3.721	18.6	3.71800	8.3	020
7	3.480	65.1	3.48889	59.2	200
8	3.27	100.0	3.28127	100.0	120
9	3.15099	9.3	3.15852	12.5	210
10	3.036	82.8	3.03003	56.9	012
11	3.009	36.5	3.00315	29.1	–112
12	2.71	17.0	2.71334	15.7	–202
13	2.60	7.2	2.59905	12.8	112
14	2.548	14.7	2.54895	15.1	–212
15	2.324	7.3	2.32198	10.8	031
16	2.25	25.8	2.25276	15.6	–131
17	2.09	13.7	2.09321	20.0	212
18	1.981	11.9	1.97813	17.8	–132
19	1.849	14.3	1.84831	21.8	–322

Table 2. Data relative to XRPD spectrum of crocoite

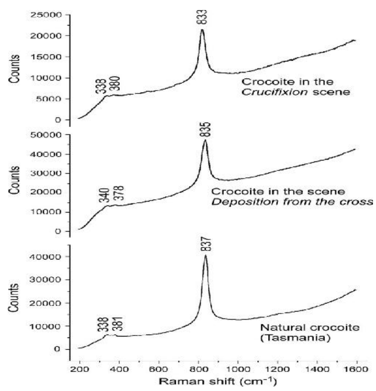

Fig. 5. Raman spectra of two crocoite samples from the wall paintings, compared with Raman spectrum of natural crocoite (sample from Dundas, Tasmania, see Fig. 3g).

Blue

The blue color of the background representing, blue is always due to azurite, present as coarse crystals (up to about 100 µm) applied with the tempera technique (preliminary GSMS data indicate the use of egg yolk as binder—M.P. Colombini, personal communication). Azurite is often applied in two consecutive layers of considerable thickness (on the whole, up to 300 µm), separated by a thin calcium oxalate level deriving from transformation of the original organic glue. The thin oxalate level is easily distinguished by light microscopy because of its greater durability than the binders of the single layers. The azurite usually lies on a ground layer of coal black in lime binder, mostly secco-applied on the supporting plaster (Fig. 9a).

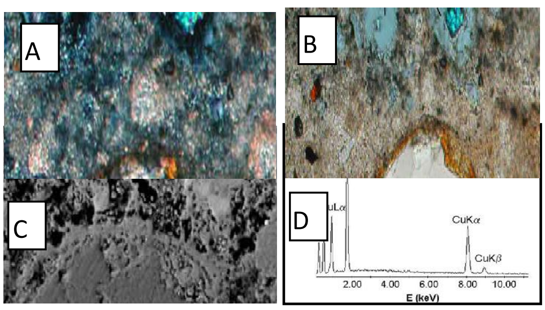

Fig. 6. Use of chrysocolla in light blue draperies.

The pigment (Ccl) is plunged in lime binder; the layer is secco-applied on the underlying plaster (pl). An azurite (Az) inclusion is highlighted. From top to bottom: transmitted plane polarized light, crossed polarizers, BSE image obtained at SEM-EDS and compositional spectrum of chrysocolla.

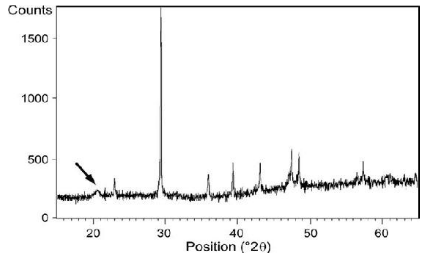

Fig. 7. XRD spectrum of the surface of a microfragment with chrysocolla. The main peaks refer to calcite associated with the pigment as binder; the wide peak indicated by the arrow (d = 4.275 Å) can be referred to the peak of maximum intensity of chrysocolla.

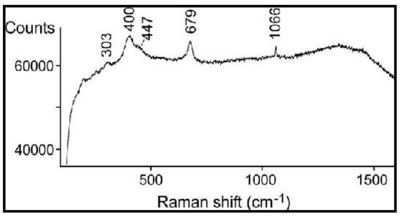

Fig. 8. Raman spectrum of chrysocolla in the plaster paintings.

Red

Red and blue colors are here considered, since they are the most diffuse types in the paintings. In the reddish drapery, the red colour is due to red ochres (normally fresco-applied), often surmounted by a level pigmented with cinnabar or minion (Fig. 9b–d). Shadings were usually obtained by mixing the basic colour with more or less abundant coal black. Blue is usually characterized by a secco-applied layer of azurite grains in lime binder (Fig. 9e,f). As mentioned above, a lighter blue pigment, chrysocolla, was used in two scenes in the northern walls, always secco-applied with lime binder (Fig. 6). Heightenings were created by a thin spreading of lead white (rarely lime white), while shadings were usually made with a glazing of azurite.

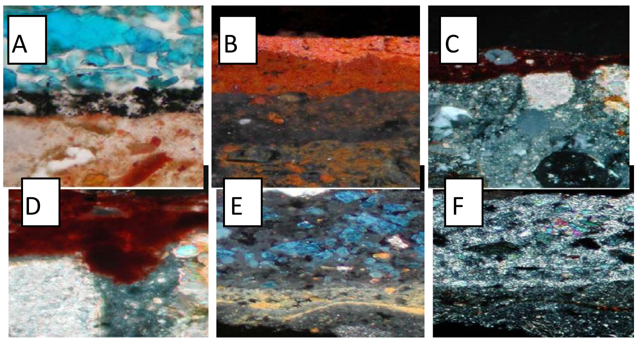

Fig. 9. Some significant microstratigraphies of the main pictorial elements. (a) Microstratigraphy representative of sky (reflected light darkfield with bright background). A: lime plaster with sandy aggregate and cocciopesto. B: coal black in lime binder secco-applied (lime painting). C: azurite tempera-applied in two layers separated by a calcium oxalate layer (ox). (b) Microstratigraphy representative of reddish drapery (reflected light darkfield). A: lime plaster with sandy aggregate and cocciopesto. B: red ochres fresco-applied, with overlying cinnabar. (c) Another example of a micro stratigraphy relative to reddish draperies (crossed polarizers with converging lens). The fresco application of the red ochres is evident: the paint film adapts itself very well to the texture of the plaster. (d) A detail of the previous image. (e) Micro stratigraphy representative of bluish drapery (reflected light darkfield). A: lime plaster with sandy aggregate. B: yellow ochres fresco applied (preparatory drawing). C: azurite in lime binder secco-applied (lime painting), with overlying heightenings in lead white. (f) Same microstratigraphy as the previous one, transmitted light, crossed polarizers.

Yellow

Colors were generally obtained by applying a layer of yellow ochres in lime binder on a ground layer of green earth secco-applied (lime painting) on the underlying plaster. Super- ficial shades were obtained with yellow ochres, red ochres and, subordinately, minium and crocoite fresco-applied on the underlying layer (Fig. 10a,b).

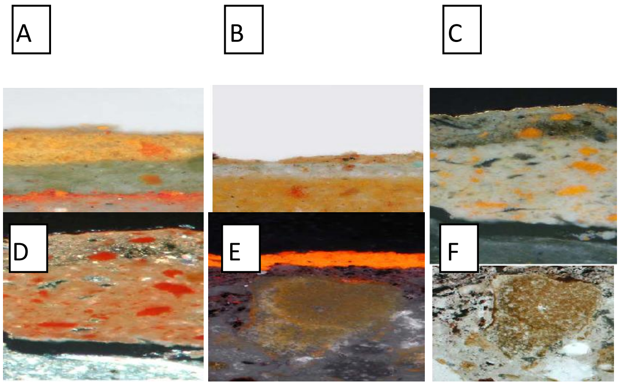

Fig. 10. Other significant microstratigraphies. (a) Microstratigraphy representative of flesh-chest of Christ in the Crucifixion scene (reflected light darkfield with bright background). A: lime plaster with sandy aggregate and cocciopesto. B: red ochres fresco-applied (preparatory drawing). C: green earth (lime painting). D: yellow ochres secco-applied with lime binder, with a fresco-applied superficial veil of red ochres and subordinately minium. (b) Repainting of the face of Mary Magdalene in the same scene (reflected light darkfield with bright background). The layers in the repainting are applied over a thin layer of lime –lm–, and they are repeated in the same sequence as the underlying layers but are much thinner. (c) Microstratigraphy representative of golden halos (reflected light darkfield). A: lime plaster with sandy aggregate. B: lead white, minium and probably verdigris in organic binder. C: lead white, minium, probably verdigris and unidentified micrograins in oily adhesive (missione). D: gold leaf. The entire paint film is detached from the plaster. (d) Same microstratigraphies as the previous one, transmitted light, crossed polarizers with converging lens. (e) Microstratigraphy representative of an orange frame in the scene God asks Cain about the lot of his brother (reflected light darkfield). A: lime plaster with sandy aggregate. B: coal black and rare red ochres in lime binder fresco-applied (fresco lime painting). C: minium fresco-applied on the underlying layer. (f) Same microstratigraphy as the previous one, transmitted plane polarized light.

Gold

In golden halos, the gold leaf (thickness of about 1 μm) is applied on a ground preparation composed of lead white, minion, probably verdigris and unidentified micrograins in an oily adhesive (missione; Fig. 10c,d): these are the materials cited by Cennini (chapters CLI–CLII) to make the mordant gildings, in which the lead-based pigments serve to accelerate the drying of the oil .
In orange halos, the paint film mainly consists of a single layer of minium, sometimes accompanied by crocoite (Fig. 3f).

Decorative elements

It is not easy to provide a representative characterization of the decorative elements, since they are very different both from the iconographic point of view and in regard to the materials and painting techniques. As an example, the microstratigraphy of an orange frame is shown in Fig. 10e,f.

Painting techniques

The painted walls contain plaster joints with a specific horizontal and vertical trend that usually follows the frames of the different scenes. The sequence of execution of the paintings is inferable from the way the joints overlap: one can observe a series of horizontal bands succeeding each other in the single walls of the room from top to bottom and from left to right, indicating method of execution. The pigments were applied by means of the following basic painting techniques: (a) fresco (including the variant lime fresco painting as defined in [21]); (b) tempera; (c) lime painting (a technique performed on dry plaster like the preceding one). As shown by the micro stratigraphies, these basic techniques were often combined with each other according to the desired pictorial effects or the specific characteristics of the pigments used.

Recognition of the painting techniques was based on thin section in Figs. 9 and 10 microscopy, which allows direct investigation of the ways the various stratigraphic units of the paint film were applied via the examination of reference specimens. The main characters of the various techniques are discussed below. The classic fresco technique is characterized by the heavy accumulation of pigments in the paint layer. In transmitted plane polarized light with high magnification, some pigments occasionally betray the microcrystalline structure characteristic of the carbonate binder. It is also possible to observe the adaptation of the pigment layer to the texture of the plaster, i.e. it appears thinner in correspondence to aggregate elements near the surface of the plaster, while it thickens in correspondence to binder (Fig. 9c,d). The latter characteristic is even more evident in the lime fresco, where the pigments mixed in lime milk variably penetrate the plaster until they become an integral part of it (Fig. 10e,f). It should also be mentioned that cocciopesto plaster was a limiting factor in the use of the fresco technique, because of its coloration and hydraulic properties which accelerate the process of carbonation.

In the two secco techniques, tempera and lime painting, the contact between the plaster and overlying paint film is usually clear and is prevalently rectilinear. Identification of the binder is obviously crucial for their recognition. In lime painting, the carbonate binder containing the pigments is easily distinguished with the polarizing microscope; if the paint film lies on the plaster, there is an evident discontinuity at the contact, shown by the different optical properties and micro structural characters of the respective binders (in particular see Fig. 9f).

The discontinuity is often highlighted by a very thin line, of dark color under the polarizer and with high reflectance, present on the carbonate surface of the plaster (Fig. 3b). Preliminary analyses with the transmission electron microscope revealed a much finer granulometry (average 10–20 nm) than that of the microcrystalline calcite forming the binder of the plaster (average around 0.5–1 μm). In general, the tempera applied paint film also presents the aforesaid discontinuity with the supporting surface (see for instance Fig. 9a). Organic chemistry is necessary for the precise recognition of this painting technique. In favorable cases, microscopic observations allow at the most the recognition of the presence of microcrystalline calcium oxalate (weddellite), deriving from the transformation of the original organic binder.

Finally, we should mention the relative frequency in the mixed techniques of thin fresco- or secco-applied layers (veils) to complete some pictorial elements, e.g. heightening in clothing (Fig. 9e). The petrographic method generally provided important information about the painting techniques (especially those using lime binder), as it is based on the evaluation of several parameters. However, it has two main limitations: the reduced scale of observation and the need of supporting investigations in some circumstances. The first limitation is due to the fact that a thin section of a paint film (especially one spread over a large surface area) might not be sufficient to make a reliable diagnosis that can be extrapolated to the whole surface. Hence, two or more microfragments sampled far apart should be analyzed. The second limitation refers to the fact that organic chemistry is sometimes essential to identify the specific nature of the organic binders and also of possible organic substances added to the lime binder. In several cases, pigments considered very incompatible with the alkaline environment and humidity for their alterability, such as lead white, cinnabar, minion and azurite, were found fresco-applied or as lime painting. To overcome this incompatibility, protein or oily organic substances were probably added to protect the pigments, as often found in other contemporary wall paintings.

Conclusion

Important from the methodological perspective is the development of a petrographic method for the study of the painting techniques and micro stratigraphies, which have been described in detail for the most significant figurative elements. In future, since the restoration work is only a little more than half completed, the mineralogical-petrographic approach will be further developed and supplemented with other methodologies
and also used to resolve specific problems of conservation

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