

Article

Material and Technical Analysis as a Support for Art-Historical Characterization of Selected Mural Paintings in Austria around 1400

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Abstract: Several medieval mural cycles in Austria were studied from the material and technical point of view, aiming to confirm (or reject) the art-historical hypothesis of their stylistic and workshop connection. These paintings can be found in the churches of Rust (“Fischerkirche”), Marz (Virgin’s Coronation parish church), Kobenz (St. Ruprecht parish church), Ofenbach (St. Veid parish church), and St. Johann am Steinfelde (St. John parish church). They were carried out around 1400 in the International Gothic style. Their workshop connections based on the style are doubtful, therefore, a material and technical study was carried out. Results showed different plaster composition, similar pigment palette, and diverse painting procedures. The murals in Marz, St. Johann, and the older register in Rust reveal important similarities such as plaster composition, predominant *a fresco* painting technique, the use of natural inorganic pigments, as well as many aspects of the painting procedure and modeling. On the contrary, those in Kobenz, Ofenbach, and the younger register in Rust differ considerably. The second group reveals lower quality in plaster composition, larger *a secco* parts, addition of synthetic pigments (Kobenz), and a rougher color modeling, indicating less skilled artists. The lower quality also results in a worse conservation state of these murals. The obtained results confirm the same workshop, but different artists in the first group, while in the second group no clear workshop/artist connection could be established.



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Keywords: Austria; medieval mural painting; plasters; pigments; painting techniques; material analysis

1. Introduction

Around 1400, the area of Middle East Europe represented an important political, economic, social, and cultural crossroad between the north and south of Europe. This can be well observed through a complex style of artworks that developed at this time, showing a mixture of Bohemian, Viennese, and Italian Trecento art, known today as International Gothic [1]. This style was strongly presented in mural paintings, with many such examples in different countries of the area been found. In this matter, Austria is one of the regions with numerous Gothic monuments that reflects the encounter of these northern and southern stylistic currents. Several mural cycles in Lower Austria and Styria were selected by the author on the basis of the most relevant art-historical studies [2–4]. The selection was carried out according to their stylistic characterization which indicates possible linkage among several painting cycles, considered by art historians as commissions of the same workshop or artists. All of them are anonymous, sometimes denominated with auxiliary names. They can be found in the so called “Fischerkirche” in Rust, in the parish churches of Virgin’s Coronation in Marz, of St. Ruprecht in Kobenz, of St. Veid in Ofenbach, and of St. John in St. Johann am Steinfelde (Ternitz). They have all been studied from the art-historical point of view, but no systematic material and technical analysis has been carried out so far. Since some of the attributions/linkages are doubtful, the present study was carried out aiming to recognize an artist’s hand based on his selection of painting

materials and procedures. In this regard, it is important to point out that materials and artistic procedures can differ between the north and the south of Europe, for example, in Italy *a fresco* painting predominates, while in the North, *a secco* or lime techniques are largely presented [5–7]. In central-eastern Europe an interesting encounter of both has occurred, which can be characteristic for a painter or a workshop.

In St. Pancratius church in the “Fischerkirche” in Rust, two pictorial registers can be found. The older one located on the lower part of the wall was probably carried out around 1400–1410, while the newer one that covers the upper part of the wall, soon after, around 1415–20. The stylistical study suggests that the author of the older register must have previously worked in Marz and in St. Johann im Steinfeld (around 1400), establishing an auxiliary name of the artist as Master of St. Johann im Steinfeld. On the other hand, the younger register shows connections to the murals in Ofenbach (1415–20) and Kobenz (1420–30), attributing it to the hand or a wider circle of the so-called Master of Kobenz. In this regard, a link to the paintings in the parish church of St. Magdalene in Sopronbánfalva, Hungary (dated in 1427) was also suggested [2–4].

The principal aim of this study is, therefore, to confirm or reject the art-historical hypothesis about the authorship of the selected murals, attributed to the Master of St. Johann im Steinfeld and the Master of Kobenz and their workshops. A material and technical study can offer valuable information about (a) the composition of the plasters, (b) the pigments and binders used, (c) the painting techniques applied—*a fresco*, *a secco*, lime technique or a mixture of them, (d) the painting procedure: preparatory drawings, incisions and pouncing, underpainting, color modeling, which all make possible (e) the comparison of the results between relevant churches. In addition to materials and technical study, a certain painting procedure is a very important matter in the understanding of an artist/workshop. Painters can be distinguished by the selection of superficial or deep incisions and pouncing, various colors for underdrawings, underpaintings under certain pigments, their brushstrokes or fine/rough modeling [5–7]. The underpainting is a uniform color layer applied under another color, in order to give it more intensity. In mural painting it was mostly used under blue, green, and sometimes red pigments, when selecting expensive azurite, malachite, or cinnabar. Azurite and malachite could have been underlaid with grey *veneda*, characteristic of the Northern-European painting [5–8], or with dark red to violet *morello* used in the Italian Trecento painting [5–7,9]. Cinnabar could have been underlaid with red earth or minium [5–7]. Around 1400, *veneda* and *morello* can both be found in Central Eastern Europe, revealing mixed artistic and technical influences. It was not uncommon to employ both kinds of underpainting in the same workshop, where two artists from different backgrounds collaborated. On the other hand, the modeling is also a very personal way of artistic expression, The form of the head, eyes, nose, lips, hands, hair, and bodies can indicate the hand of a certain painter. On the basis of his/her brushstroke, it can reveal a skillful or a less talented artist.

The study of these features can help us to identify an artist’s hand and to understand his way of creating. Therefore, the present material and technical study can tell us much more about the artist/workshop and is a necessary addition to an art-historical investigation.

2. Materials and Methods

First, all murals were studied in situ to obtain general information on plasters, pigments, painting techniques, painting procedures, and their conservation state. Next, small samples (3–5 mm³) of plasters and color layers were extracted, limited to maximum five samples per mural cycle according to the permissions obtained. Altogether, 25 samples from these five locations were taken. The samples were studied in the laboratory by non-destructive and destructive analytical techniques, used for material characterization. Although both pictorial registers in Rust are of high interest, it was not possible to extract samples from the upper layer (younger paintings) linked to the master of Kobenz, therefore no material analysis could be carried out. Nevertheless, the visual inspection of plaster, manner of the brushstroke, and general painting procedure still offer important information.

2.1. Analysis on Samples without Preparation—Non-Destructive Techniques

(1) Portable digital microscope: all samples were first examined and documented with a digital microscope. For this purpose, a digital Dino microscope model AM4113T-I2V was selected, equipped with 1.3 Megapixel camera of 20–200× magnification, including also UV and IR lights. It provided information on the basic plaster composition, its solidity, and the adherence of the pigment layers and their color. It also helped in the selection of suitable bits for the cross-section elaboration.

(2) X-ray fluorescence (XRF): this technique identifies chemical elements on the basis of their atomic number ($Z < 14$ (Si)) and offers a semi-quantitative evaluation of the results [10,11]. However, organic compounds (colorants, binders) cannot be identified, being composed of light elements, not detectable by XRF without He flow. Additionally, pigments with the same characteristic chemical elements (as lead pigments) and the same color (as copper greens) cannot be distinguished. Despite this, XRF is considered the principal non-invasive technique for most inorganic materials and is widely used in the study of artworks. In this research, a transportable Bruker XRF spectrometer ArtTAX was applied, that consists of an air-cooled, low-power X-ray tube, polycapillary X-ray optics with 100 μm measuring point diameter, an electro-thermally cooled Xflash detector, and a CCD camera for sample positioning. Although the equipment is portable, it was not possible to apply it in situ, therefore, it was used on the samples in the laboratory. The measurements were taken with a 30 W low-power Mo tube, under the same parameters: 50 kV energy, 600 μA current, and 50 s real time radiating. On each sample several points were measured to obtain more complete information on the materials present.

2.2. Analysis on Prepared Samples—Destructive Techniques

Most of the samples were prepared as cross-sections. They were embedded in silicon or methacrylate molds, using transparent acrylic two component resin *Palapres vario*. They were studied with the traditional techniques for material analysis used in cultural heritage, OM and ESEM-EDX [11–13]. Furthermore, the plasters were ground into fine powders for XRD analysis [11,12,14].

(1) Optical microscopy (OM): cross-sections were observed under a digital optical microscope Keyence VHX-6000, with 100–1000× magnification. In the study of mural paintings, this is one of the most important steps, revealing the structure of the support (plaster), possible presence of lime-wash, the number and sequence of color layers, and the painting technique applied. By observing the color and the form of the grains, some pigments and their possible changes (deterioration) can also be identified. [15].

(2) Environmental scanning electron microscope-energy dispersive X-ray spectrometry (ESEM-EDX): selected most relevant cross-sections and a few powdered samples, too small for cross-section preparation, were analyzed by this technique. It enables a much higher magnification of the studied sample compared to OM. In addition, it offers a quantitative and qualitative elemental analysis in a selected area or point, identifying also light elements; therefore, inorganic and some organic materials can be characterized. The instrument used was ESEM FEI XL30 with BSE-Detector//SE Detector. The analysis was performed in high-vacuum microscope mode between 5.0×10^{-5} mbar and 3.0×10^{-6} mbar. All samples were coated with a 10 nm carbon layer for better conductivity of the electron bombardment; for this, a Leica EM ACE600 was used.

(3) X-ray diffraction (XRD): powdered plaster samples were carefully separated from color layers and analyzed by this technique to obtain their crystalline characterization. In mural painting, XRD is used mostly for plaster identification based on quantitative phase analysis. It can reveal important relation between aggregates and binders, impurities, and some possible chemical changes. In this study, a Bruker AXS, Germany D8 Advance model was used. Samples were prepared in silicon-single crystal-sample trays and measured for 2 h in Bragg–Brentano geometry, Cu-K α 1: 1.54056 Å, Cu-K α 2: 1.54440 Å, 40 kV, 40 mA, 5–80° 2 θ , 0.02° increment (2 s per step).

3. Results and Discussion

The results are organized according to the support (plasters), pigments, painting procedures, and painting techniques. Mural cycles are compared regarding two principal groups, as suggested by art historians. The first group includes paintings in Marz, St. Johann am Steinfelde and the older pictorial register in Rust, attributed to the Master of St. Johann am Steinfelde. The second group is formed by the younger pictorial layer in Rust, paintings in Kobenz and in Ofenbach, linked to the Master of Kobenz or his workshop.

3.1. Plasters

All plasters are composed of lime as binder and sand as aggregate. However, they differ in the proportion of these materials, their cleanliness, as well as in the color and granulation of the sand. All XRD spectra show the principal presence of calcite and quartz. Calcite indicates lime as the binder; however, it could also be partially interpreted as crushed lime-rock, added to quartz as the main aggregate.

The principal difference between both proposed groups is the predominance of calcite in plasters from Marz, St. Johann, and Rust (Figure 1a,c,e), while there is a surprisingly low amount of calcite in Ofenbach and Kobenz (Figure 2a,c). This indicates different plaster preparation by corresponding workshops. In the XRD spectra of the last two locations, quartz presents a very intense peak, while also some impurities were detected, such as albite (found also in Rust), muscovite, chlinochlore, and gypsum; the last two compounds are probably a result of a degradation process caused by salts present in the wall and sulfurization [5–7,16]. Such low presence of calcite added to high amount of poorly washed sand results in weak stability of the plaster, which tends to pulverize. On the other hand, plasters in St. Johann, in Rust (older pictorial register), and Marz are more solid, being rich with lime as binder. XRD analyses are supported by optical microscopy of stratigraphic sections: plasters of the first group are much whiter (Figure 1b,d,f); the one from Marz presents a high amount of aggregate, probably containing a lot of crushed lime-rock, while those from St. Johann and Rust contains more binder and less aggregate. In Marz, calcium oxalates were also detected, probably related to some consolidant conservation treatments.

On the contrary, in the second group (Ofenbach, Kobenz—Figure 2b,d) the plaster is darker and saturated with sand, characterized by large angular grains of different colors from light yellow to brown. These two plasters are clearly different from the first group, even taking into consideration that artists generally obtained the sand from a nearby site. However, the important difference in the amount of lime and the selection and cleanliness of the sand indicate a completely different working manner among the murals of both groups. Despite that, the plasters from the first group do not show a lot of homogeneity and their material analysis is not sufficient to link them to the same workshop.

3.2. Pigments

EDX and XRF chemical analyses identified most of the inorganic pigments applied in all five selected locations, while ESEM and OM images often supported this identification regarding the shape of the pigment grains. They were characterized on the basis of their principal chemical elements, but no complementary molecular analysis could have been carried out up to now. In all selected murals a very similar palette was found (Table 1), composed mostly of traditional natural inorganic pigments that were generally used in mural painting and were suitable in the alkaline and humid environment of a *fresco* or lime technique [5–9,17,18]: lime white (Ca), yellow earths, mainly aluminosilicates (Al, Si, Fe), red earths, iron oxides (Fe), green earth (Mg, Al, Si, K), malachite or some other copper based green pigment (Cu), azurite (Cu), while for a black color carbon (C) or bone (P, Ca) blacks were applied.

Only in Kobenz, was a synthetic lead pigment detected (Figure 3), probably lead white as well as minium. The latter one can be seen as a vivid orange color that still remains partially on one sample (Figure 3a). In most areas, this lead pigment darkened, as observed already in situ by the naked eye (Figure 3b). On cross-sections, this color layer

looks brownish (Figure 3a), indicating that the pigment most likely degraded to PbS [19]. This change is confirmed by the XRF spectra of these samples, revealing the presence of S (Figure 3f). Although S K-peaks are generally overlapped by Pb M-peaks, in this sample the peak intensity of this area is higher than in the only Pb containing samples where such degradation is not observed. Lead pigments were long known to be unstable and sensitive, among others, to sulfur containing compounds, especially in manuscripts and wall paintings [5,9,17,19]. Despite that, they were still used by some mural painters, but were generally applied *a secco*.

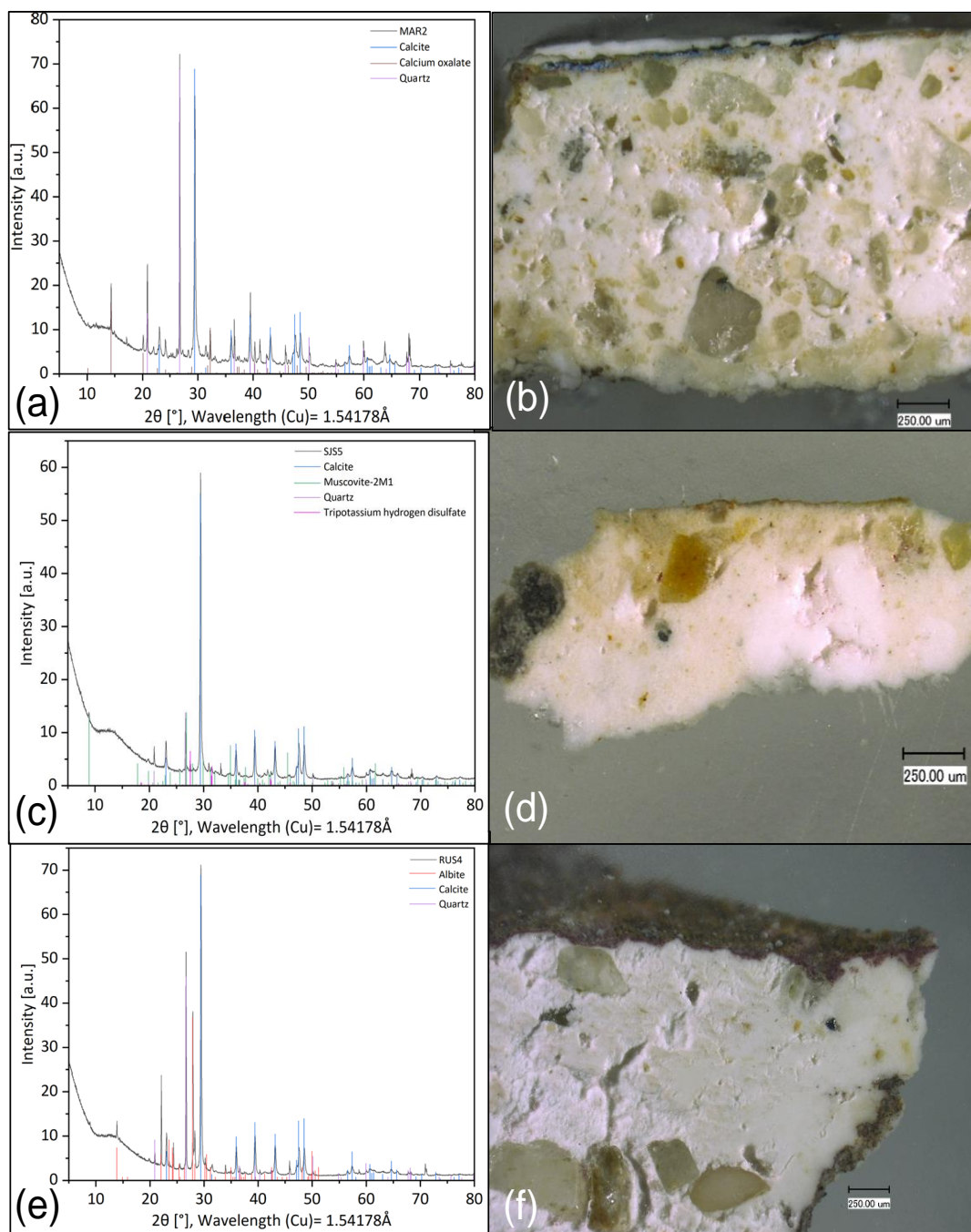


Figure 1. Plaster analysis of the first group of murals. XRD graphs of plaster samples indicating high calcite amount and low quartz amount with no impurities from (a) Marz, (c) St. Johann am Steinfelde, and (e) older pictorial register in Rust, in comparison to the OM images of the cross-sections from (b) Marz, (d) St. Johann, and (f) Rust.

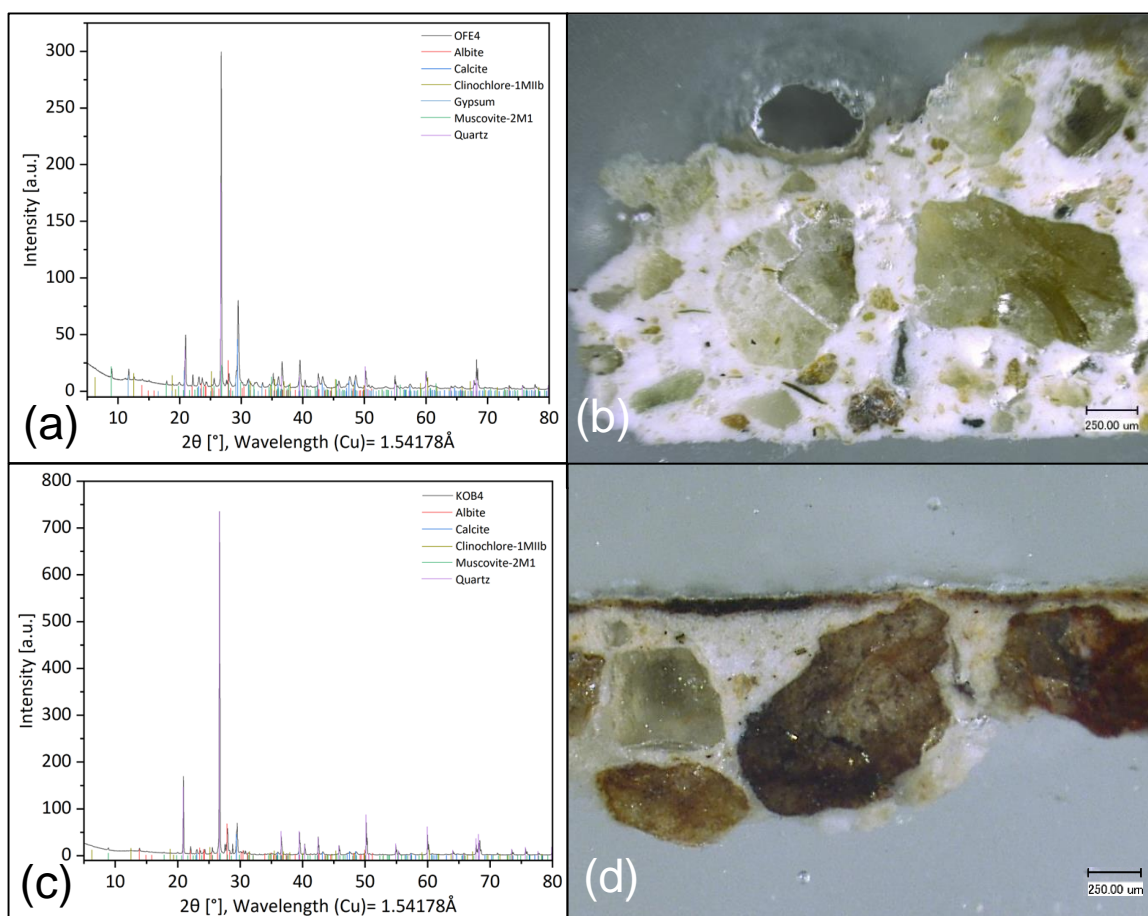


Figure 2. Plaster analysis of the second group of murals. XRD graphs of plaster samples indicate low calcite amount and high quartz amount with impurities from (a) Ofenbach, and (c) Kobenz, in comparison to the OM images of the cross-sections from (b) Ofenbach and (d) Kobenz.

Table 1. Presence of the pigments in every location, with their possible chemical changes.

Locations	Lime White	Yellow Earths	Red Earths	Green Earths	Malachite	Other Cu Green	Azurite	Carbon Black	Bone Black	Lead Pigments	Chemical Changes
MARZ	*	*	*	*	*	-	*	*	-	-	-
ST. JOHANN/ STEINFELDE	*	*	*	*	*	-	*	?	*	-	-darkening of malachite (CuO)
RUST I	*	*	*	*	*	-	*	?	?	-	-formation of copper hydroxychlorides (Cl) -darkening of azurite (CuO)
RUST II	x	x	x	x	x	x	x	x	x	-	-darkening of malachite?
KOBENZ	*	*	*	*	-	*	x	x	x	*	-darkening of lead pigment, probably minium or lead white
OFENBACH	*	*	*	x	x	x	*	?	?	-	-

* presence confirmed; - none; ? results not conclusive; x no sample.

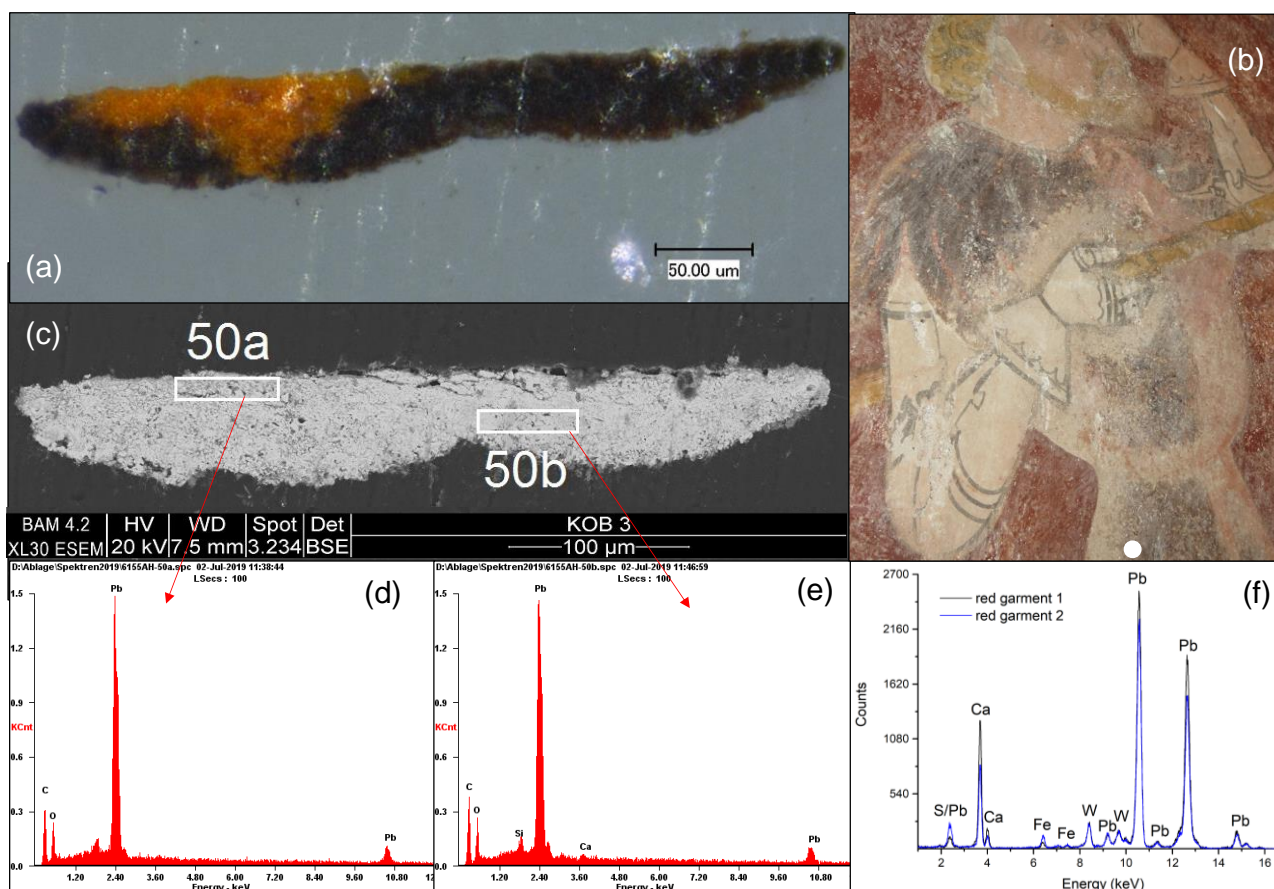


Figure 3. Lead pigment found in Kobenz: (a) OM image of the cross-section with still original orange color and a degraded brownish color, (b) darkening of the red pigment observed in situ with white point showing the area of sample extraction, (c) ESEM image with two analyzed areas with corresponding EDX spectra (d,e) confirming Pb, O, and (f) XRF spectrum showing S and Pb presence.

Regarding green pigments, painters used to mix green earth with a copper-based pigment (Figure 4), generally malachite was the most used one in mural painting. With XRF and ESEM-EDX, in several samples a copper based green pigment was confirmed by high Cu peaks (Figure 4b,e). At that time several copper-based green pigments were known [5,7,9,17] and it is not possible to distinguish them only on the basis of elemental analysis. However, in most cases, the characteristic angular form of light green grains on cross-sections can confirm the use of malachite (Figure 4a,d) [17,18]. Two degradation processes were detected: in Rust; the presence of Cl (Figure 4b) reveals the formation of copper hydroxychlorides (atacamite, paratacamite, or similar) due to Cl^- ions or chloride salts present in the plaster, sand or brick [19], while in St. Johann the darkening of some malachite grains occur (Figure 4d). ESEM-EDX spectra reveal high Cu, O, and S presence (Figure 4e), indicating the possible change to copper oxides (cuprite or tenorite), which can occur because of high temperature, or due to copper oxalates (mooloite) or other carboxylates due to acidic conditions resulting from the deterioration of organic binders [19]. A similar process of darkening was also observed on blue azurite in Rust. In Kobenz, some black areas can be seen on the surface of several green areas, but no samples were extracted for the analysis. Green earth, mixed with other pigments, could be used for the shades of the uppermost layers, as well (Figure 4d).

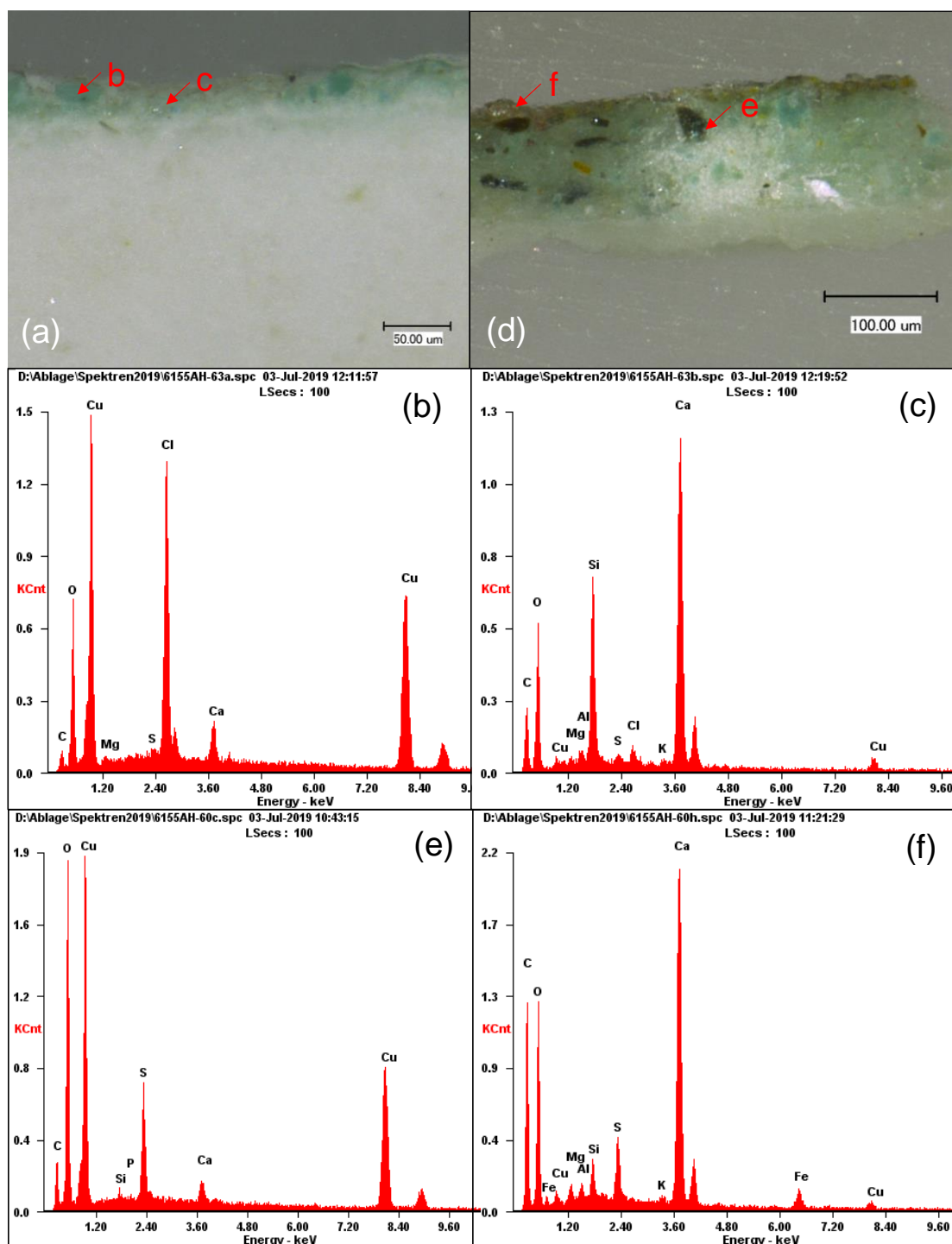


Figure 4. OM images of samples from (a) the older pictorial register in Rust and (d) St. Johann am Steinfelde. Characteristic angular forms of malachite mixed with green earth can be observed, supported by corresponding EDX spectra which confirm a copper-based green pigment (b,e) and green earth (c,f). Spectrum (b) from Rust shows high presence of Cl, while spectrum (f) from St. Johann reveals high O and S presence, both indicating chemical changes of malachite.

In Kobenz, the use of malachite cannot be determined, although the analysis shows intense Cu peaks; the pigment grains are small and rounded, indicating its synthetic origin. Perhaps verdigris was used, mixed with very low amount of a lead-based pigment, probably lead white (Figure 5).

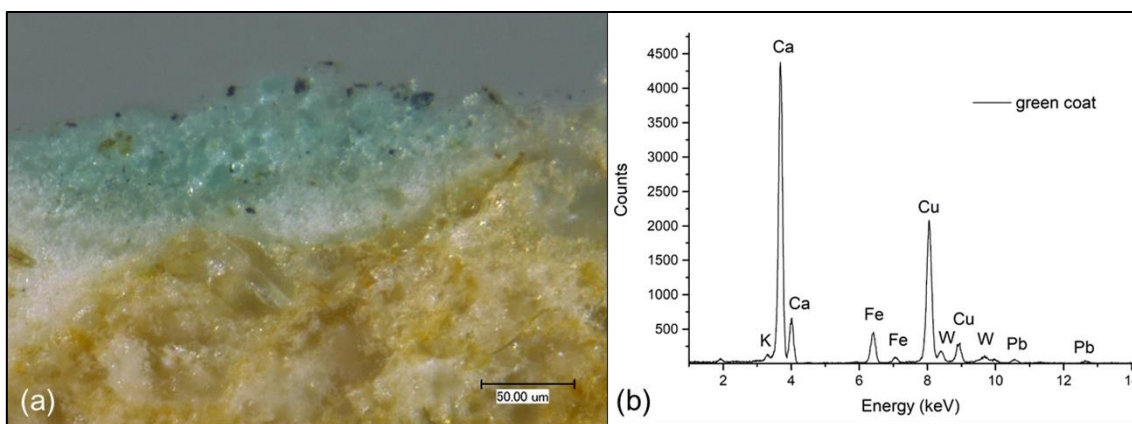


Figure 5. (a) OM image of a sample from Kobenz showing green color layer with small, rounded grains, (b) XRF spectrum characterizing a Cu based green pigment.

On the younger pictorial register in Rust, yellow, red, green, blue, and black colors are observed. Regarding material analysis carried out on other murals of this research and based on general knowledge on pigments in medieval mural painting, the palette of this register should include lime white, yellow and red earths. On the other hand, the presence of green earth or malachite (or both) and the application of azurite or a mixed blue cannot be established without chemical analysis; similarly which black pigment was selected cannot be determined. There are some black areas, which suggest pigment degradation and therefore different original color, as for example a probable green soil under the kneeling Christ in the *Gethsemane Garden* which looks black today (malachite alteration?).

3.3. Painting Procedure

In all five selected monuments, there are variations regarding preparatory drawings, incisions and pouncing, underpaintings, or modeling, which can be observed in Table 2. Deep and wide incisions and pouncing for nimbus and medallions, pressed into a fresh plaster, can be well observed in St. Johann am Steinfelde and the older pictorial register in Rust. In Marz and Ofenbach, they were used only for nimbus (Figure 6). The pouncing is mostly linear, however, in Marz and on the older register in Rust circular forms were also applied (Figure 6b,d). This could reveal a work of two principal artists in the same workshop, while, at the same time, link the Marz and Rust workshops. On the contrary, in the younger register in Rust and in Kobenz neither incisions nor pouncing can be discerned.

Table 2. Painting procedures and techniques found in the studied mural cycles.

Locations	Incisions	Pouncing	Underdrawing			Underpainting			Modeling		A Fresco	A Secco	Lime Technique
			Yellow	Red	Red Rope	Grey	Red	Other	Rough	Smooth			
MARZ	*	*	-	*	-	?	?	-	**	*			-
ST. JOHANN/STEINFELDE	*	*	*	-	-	*	*	-	*	**	**	*	-
RUST I	*	*	-	*	-	?		-	?		**	*	-
RUST II	-	-	-	*	*	?	x	-	*	*	**	*	?
KOBENZ	-	-	-	*	*	-	*	-		*	*	**	-
OFENBACH	*	*	*	-	-	?	?	-	*	?	*	**	-

* applied; ** in higher proportion; ? possible; - none; x non-existent.



Figure 6. Incisions, pouncing and face modeling observed on details from the paintings: (a,b) Marz, (c,d) older pictorial register in Rust, (e) St. Johann am Steinfeld, and (f) Ofenbach.

For underdrawing, the preparatory drawing carried out on a fresh *intonaco*, only red and yellow colors were used. In Marz, a dark red color was applied with wide brushstrokes using a half-dry brush. This can be observed in situ by the naked eye due to the loss of the overlaid color layers (Figure 7a), as well as on cross-sections (Figure 7b). A similar dark red line traced with a half-dry brush was used for the underdrawing in the older pictorial register in Rust (Figure 7c), which is another link between these two mural cycles. The red line was observed also in the upper younger register in the same location, but a brighter red was used. In addition, a pressed rope, soaked in red color, was applied for straight lines (Figure 7d), which was also found in Kobenz (Figure 7g). Here, the underdrawing was also traced in red, although difficult to discern under the color layers (Figure 7h). On the other hand, in St. Johann and in Ofenbach the underdrawing was carried out with yellow color (Figure 7e,f). In the first one it seems that on the right side of the wall, depicting the *Salvation of the Souls*, a more orange-reddish color was selected, perhaps a sign of two different artists' hands. All murals, except of the younger register in Rust, reveal a confident brushstroke.

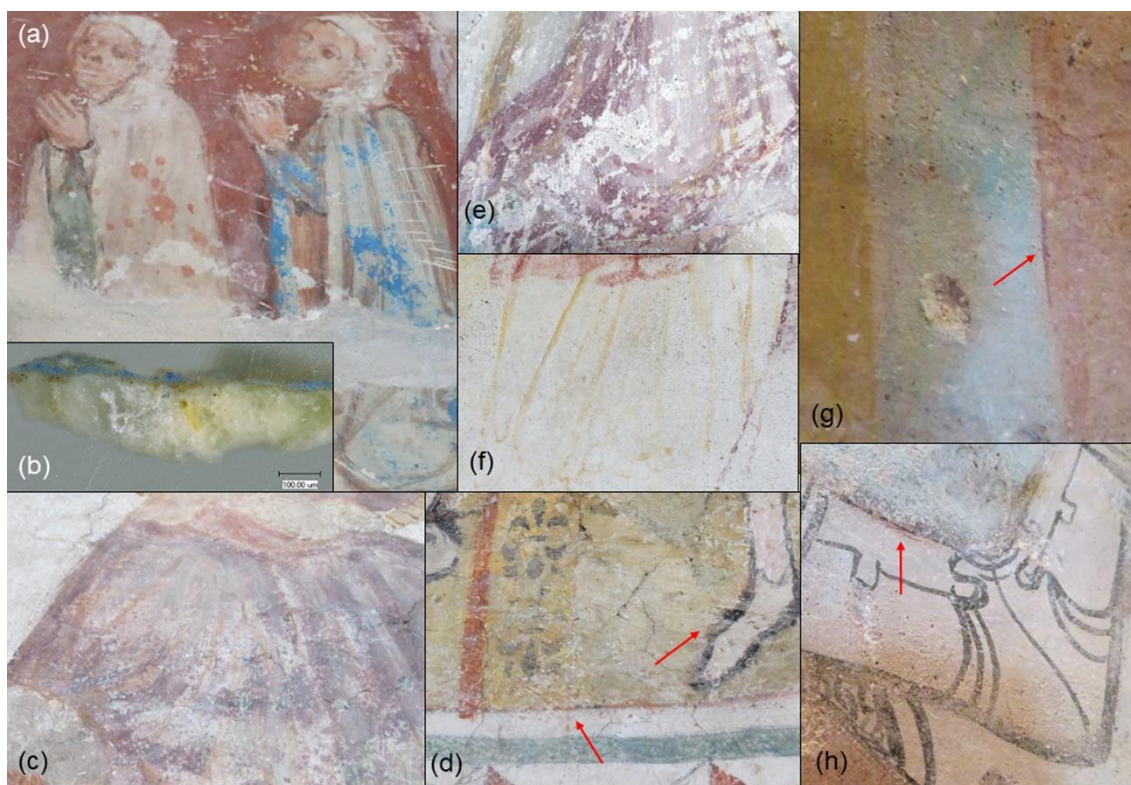


Figure 7. Underdrawing in red, observed on (a) a detail from Marz; (b) an OM image of a sample cross-section from Marz; details from (c) older and (d) younger pictorial registers in Rust, where also a pressed rope dipped in red (d) can be observed. Underdrawing in yellow was found: (e) St. Johann am Steinfeld and (f) Ofenbach. In Kobenz (g), red pressed rope (h) and red drawing were applied. The red arrows point towards the underdrawing lines.

Regarding underpaintings in the mural cycles of this study, the greyish color of blue backgrounds already observed by the naked eye, shows the general use of *veneda* under azurite (Figure 8a), following the Northern-European tradition [5–8]. On the contrary, in Marz (Figure 7a) and Kobenz (Figure 8e), the red background with some overlaid blue remains and indicates a possible loss of blue azurite applied on *morello*, consistent with the Italian Trecento painting [5–7,9]. Surprisingly, the cross-sections of related samples confirmed the use of the grey underpainting only in St Johann (Figure 8b) and the older register in Rust, where its color is very light grey, almost white (Figure 8c). In Marz, a red *morello* is clearly seen under the green color, probably malachite (Figure 8d).

As already observed by art historians [2–4], the modeling in Marz, St. Johann and the older pictorial register in Rust is stylistically quite similar (Figures 6a–e and 9). The figures are presented with rounded heads, small noses, and small eyes, emphasized with strong dark brown or/and black straight line, semi-circular upper eyelids and high eyebrows. A strong brownish shading under the eyelids, around the nose, and under the cheekbones is characteristic. The mouth is also small, performed with two brushstrokes; a longer straight one for the upper lip, and a rounded short one for the lower lip. The bodies are elongated and elegant, as was common for the time around 1400. The hands are small, with short fingers, separated with a thick brown line and also strongly shaded. The black final contour is wide and strong, but in many places it is lost. Despite a very similar pictorial language, diverse hands, active in these three locations, can be distinguished. There are significant differences in flesh tones: some are lighter and more pinkish, with much softer shading and a smoother color transition, while others are darker, with strong brown shading. This observation does not correspond to the general representation of lighter female and darker male carnations. In the darker ones, the face lines are thicker,

superficial, the color transition rougher, and highlights and shades applied with wide brushstrokes, showing lower quality and, thus, revealing the work of assistant(s). On the contrary, the lighter ones manifest much smoother modeling with thinner brushstrokes, indicating the hand of a skillful artist, probably the principal master. This duality can be observed in Marz, St. Johann, and Rust, pointing towards work of the same workshop in all three locations, but by different artists.

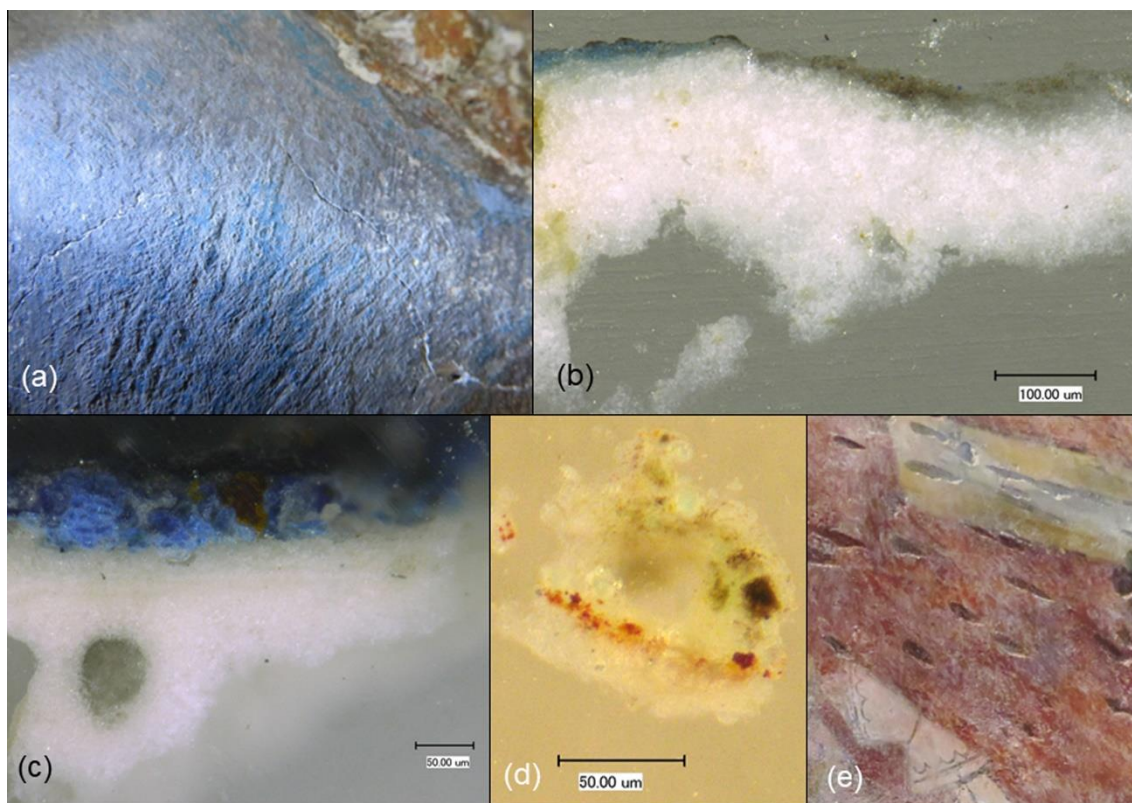


Figure 8. (a) Underpainting in grey observed in situ in St. Johann am Steinfelde and confirmed by (b) OM image of the sample cross-section; (c) OM image of the sample cross-section from Rust showing very light grey *veneda* under azurite; (d) OM image of the sample cross-section from Marz revealing *morello* under green color; (e) red background in Kobenz, probably originally under azurite.



Figure 9. Color modeling observed on details from (a) Marz, (b) St. Johann am Steinfelde, and (c) the older pictorial register in Rust.

The younger register in Rust is very much retouched, with very strong black contours which predominate in the composition (Figure 10a). The original color is largely lost, therefore, not much can be specified about the modeling. Nevertheless, it is clear that these

paintings were executed by a different artist compared to the older pictorial register. The heads are oval with a large upper scull part. The eyes are elongated and often almond-shaped, the eyebrows are high, straight, or semi-circular, large lips are separated with a strong black middle line and a short line under the lower lip. The hands are big with thick fingers, defined with a strong black final contour, while the bodies are long, trying to be elegant following the general taste of the time, but are rather clumsy and not proportional. It seems that the artist used cartoons, as was already stated by art historians [2,4]. Due to the color loss and overall retouching, the original color modeling cannot be evaluated. In Kobenz (Figure 10b), the figures are very elegant, with thin waists, dressed in contemporary clothes. Their hands are long, narrow, with thin fingers. The heads are elongated, with a high forehead, a long straight nose, and fleshy lips. The eyes are big, almond-shaped, and emphasized with strong half-circles for the upper and lower eyelid. Thin and half-circled eyebrows crown them. The modeling results are very different as in Rust, but this could be due to the heavy retouching already mentioned. Although the color modeling is mostly lost today, on some areas, the combination of thick and thin brushes that create soft color transitions can still be discerned.



Figure 10. Color modeling observed on details from (a) the younger pictorial register in Rust, (b) Kobenz, and (c) Ofenbach.

A great part of the color layers is lost also in Ofenbach (Figures 6f and 10c), mostly due to the outdoor location of these paintings. Some basic color layers are still conserved, but on many areas, especially in the lower part of the wall, the paintings have faded almost entirely. On the upper part, being the most protected against weather changes, some faces on the *Crucifixion* can still be perceived. The heads are rounder with small, pointed chins. Almond-shaped eyes are marked with upper and lower eyelids, which are much softer and less arched as in Kobenz. In addition, the eyebrows are long, straight, and rounded only at the exterior end. The nose is straight and sometimes too long, while fleshy lips are characterized by a rounded lower lip. The basic flesh tone is pinkish, similar to Kobenz, but it differs from it by some strong shading in brownish tones conserved in some areas. The hands are small, with thick fingers, separated with a strong brown final contour that frames the entire figures. The bodies are long, slim, but not as sophisticated as in Kobenz. Regarding these parameters, different artists must have worked on the younger pictorial register in Rust, in Kobenz, and in Ofenbach.

3.4. Painting Techniques

Already by the naked eye it can be discerned, that *a fresco* was the principal painting technique in all five mural cycles. The basic color layers are generally well preserved; the application of plasters was carried out by the system of *giornatas* (portions of fresh plaster to be painted in one day) [5–7,9]. Nevertheless, all paintings were finished *a secco* for the modeling and final contours. The proportion between *a fresco* and *a secco* varies from mural to mural, which resulted in a better or worse conservation state of the color layers. The paintings in Ofenbach are in the worst conservation state, principally due to their

exterior location, being exposed to extreme atmospheric changes such as temperature and humidity [5,7]. It seems, that the paintings in Marz, St. Johann and the older register in Rust were largely carried out *a fresco* with only a smaller portion painted on already dry mortar. XRD spectra show high calcite peaks (Figure 1a,c,d), which indicate plasters prepared with a high amount of lime to serve as a binder for uplaid pigments. The exceptions are azurite and malachite, which were painted *a secco* and in many cases fell off. Such is the case of the donor's vestments in Marz (Figure 7a) and was also confirmed in other localities on the basis of several sample cross-sections (Figure 4a,b, Figure 7b, and Figure 8c). On the other hand, the younger register in Rust, the paintings in Kobenz, and those in Ofenbach must have been carried out largely *a secco*. This can already be estimated from the XRD spectra that show very low calcite peaks, indicating a low amount of this inorganic binder (Figure 2a,c). Additionally, *intonaco* seems to have been applied in quite thin layers, as already observed in situ, and therefore, started to dry quickly. This caused the loss of almost the entire modeling of the faces, the application of shades and highlights, as well as the final contours. On some areas, remains of the upper color layers, glued to the lower *a fresco* painted surface, can still be observed. They indicate the use of an organic binder that must have degraded, causing color-layer loss. Unfortunately, the organic binders have not been studied so far. The combination of both principal painting techniques is supported also by cross-sections (Figure 2a,d, and Figure 5a). In Rust, a thick underlayer applied with wide brushstrokes over the entire surface can be observed under the color layers of this pictorial register. It indicates a possible application of lime wash; in this case, lime technique was used. While lacking samples, only a visual inspection was made, therefore this is only a hypothesis. The comparison of painting techniques among the mural cycles is presented in Table 2.

4. Conclusions

After comparing plasters, pigments, painting procedures and techniques of all the selected mural cycles, it is difficult to sustain the art historical hypothesis regarding workshop connections. The link between murals in Marz, St. Johann am Steinfelde, and the older paintings in Rust can be confirmed. All these murals show similar plaster composition with high amount of lime and low impurities as well as the following: the application of *intonaco* by the system of *giornatas*; the palette composed of natural inorganic pigments suitable for painting on a fresh mortar; deep, wide incisions and pouncing (linear and circular); strong wide brushstrokes for the underpainting; grey underpainting for blue azurite; and the predominance of *a fresco* technique over *a secco* technique. There are, however, some differences in the choice of underdrawing color, being red in Marz and Rust, but yellow in St. Johann. In addition, in Marz a red underpainting was encountered under the green color, which was not observed elsewhere. Therefore, different hands of the same workshop are suggested. This is supported also by the color modeling of the faces, hands, and figures, which is very similar, but reveals higher or lower artistic quality, hence, different painters.

On the other hand, the younger paintings in Rust and those in Kobenz and Ofenbach, do show some similarities, but more differences. In the case of Rust, no samples were taken, therefore conclusions can be drawn only based on visual inspection and are, hence, not complete. The plaster is of lower quality as in the first group, with less lime as binder and a lot of poorly cleaned aggregate, revealing low consistency of the support which tends to pulverize. This strongly influences the conservation of the painting layers, with the loss in Ofenbach being also the result of its outdoors location. Plasters were applied by *giornatas*, but in thin layers which dried fast and did not allow painting on a fresh mortar for a longer time. Therefore, a larger part was conducted on a dry mortar, which resulted in the loss of almost all the modeling layers. The pigment palette is similar to the first group, however, in Kobenz synthetic lead-pigments were also found, as well as another copper based green pigment, perhaps verdigris. Therefore, this is an important sign of another painter/workshop. As for the painting procedures, the incisions and pouncing were used only in Ofenbach, while in other two murals they were not found. The

preparatory drawing is red in Rust and Kobenz, but yellow in Ofenbach. Samples did not confirm the use of grey *veneda* under azurite, although the visual inspection in Rust and Ofenbach does suggest it. On the contrary, the backgrounds in Kobenz are red with some traces of blue; probably the sky was painted with azurite over *morello*, following the Italian Trecento tradition, not observed in the other two churches (but in Marz). Regarding the little that is conserved of modeling, in Kobenz, elegant figures and faces can be appreciated, while in Ofenbach the modeling seems rougher, with stronger shading and clumsier figures. In Rust, too many retouches from later conservation–restoration interventions do not allow a proper evaluation. The general forms of the figures and their faces follow the style around 1400. Some come close to those in Kobenz for their typology, but they are rough and not proportional. It seems unlikely that the Master of Kobenz, who shows high painting skills in the murals from Kobenz, would be the author of the younger pictorial register in Rust and those in Ofenbach. Even the workshop connection seems questionable. They might be works by his followers, but in each location another artist must have been active.

The present study cannot confirm the art-historical hypothesis of the linkage between the murals of both groups; however, at least for the first group a workshop connection can be established. The stylistic similarity of the second group is more likely the result of the general taste of around 1400 and not of the same workshop activity.

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