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CHEMICAL AND MINERALOGICAL STUDY OF NABATAEAN PAINTED POTTERY FROM PETRA, JORDAN

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Nabataean pottery is distinguished by the thinness of its walls, which were sometimes only 1.5 mm thick. It was a pinkish/red color, often decorated by hand with dark brown flower and leaf designs. The typical (egg-shell) shallow open bowls productions were very difficult to make on the potter's wheel, demonstrating how skilled their craftsmen were. Nabataean painted pottery from Petra Jordan were examined in order to determine the mineralogical characteristics of the raw pigment materials used for their production and to elucidate the ceramic manufacturing technologies employed. Optical microscopy, X-ray diffraction analysis (XRD) and scanning electron microscopy (SEM-EDS) were the analytical techniques used. The initial examination of the ceramic shreds in optical microscopy showed all samples to be identical in their paint and paste textures. The mineralogical composition of the paste (unpainted outer surface) is typical of a clay poor in calcium and fired at moderate-high temperature in an oxidizing atmosphere. The paste is composed of quartz, plagioclase, potassium feldspar, hematite, dolomite, and calcite. The latter two phases might be attributed to post-depositional contamination, since examination with both optical and scanning electron microscopes show fine carbonate particles deposited in the pores and cracks of the shred. The paint on the inner surface of the vessel, on the other hand is composed of hematite as a major phase with only some quartz and plagioclase

KEYWORDS: Petra, Nabataean, painted pottery, Archaeometry, pigments, clay, SEM-EDS.

INTRODUCTION

The study of pottery artifacts is helpful in the development of theories on the socio-economic circumstance and the cultural development of the societies that shaped or acquired pottery. The study of pottery may also allow inferences to be drawn about a cultures daily life, religion, social relationships, and attitudes towards neighbors, attitudes to their own world and even the way the culture understood the universe. The Nabataeans were nomads, they had little use for pottery and used water skins and wooden bowls, as a result, Nabataean pottery does not generally exist before 100 B.C. They began to produce their own pottery, both common-ware pottery for everyday use and very fine thin pottery for the wealthy, religious usage. It has been stated that pottery is a very sensitive product of human inventive power. Nabataean pottery is one of the most fascinating products of ancient technology in Jordan. This kind of pottery, especially the later type, was shaped and manufactured in huge quantities, and large mounds of broken Nabataean pottery could be found easily in Petra today. (Ortonetal *et al.*, 993)

Petra was a major center of pottery production, as attested by the discovery of large kilns at al-Zurrab and at Wadi Musa indicating that Petra itself was a center of production. The quality of this pottery declined from the late 3rd century A.D. onwards, maybe as a result of larger scale production (Tuttle, 2008).

Some archaeologists believes that the discovery came about by accident, when clay bowls or mud-lined baskets were placed too close to the cooking fire and were baked as a result, others guess that religious figures made of clay left-over or sacrificed in the fire, and found hardened in the ashes, could have tipped-off early peoples, still others think that early humans could have discovered that fire pits dug in clay were more efficient than those dug directly out of sand or soil due to the clay being baked, and transferred the technology to creating pots (Amr, 1987).

It's not only served in everyday needs of its user, but also serves as an indication of progress or lack of progress in a given culture. The distinctive Nabataean pottery was the key that unlocked the door to the reconstruction of their history.

Historical Overview

Nabataean Petra was founded 300 B.C.; the city start to expand and to be in development with later Roman administration of the city starting at A.D. 106; Byzantine invasion continued up to the 7th century A.D. (Maroke, 2003). In the first millennium B.C., the Edomite rose to importance, during the 7th Century B.C., they built settlements, some of which were fortified in the mountains. The most notable of these are Umm al-Biyara and Tawilan, high above the Petra Basin. Subject to Assyria, Babylonia and then Persia, Edom became the center of an Arab state: "The Nabataean Kingdom" (Wardam, 2007). The Nabataeans were nomads, they had little use for pottery and used water skins and wooden bowls, as a result, Nabataean pottery does not generally exist before 100 B.C. They began to produce their own pottery, both common-ware pottery for everyday use and very fine thin pottery for the wealthy, religious usage. It has been stated that pottery is a very sensitive product of human inventive power. In the Nabataean history, there were several Golden Ages, During the First Golden age (100 B.C. - 100 A.D.) the Nabataeans were ruled by democratically elected rulers. In that era, they developed great cities, architecture, and a worldwide system of trade. This was their economic Golden Age; later on, some attempts appeared to reunite the Nabataean Kingdom, but they failed for several reasons – most important was the Roman invasion for Petra and the new cities and political power that changed the importance of Petra, and also the trade routes were not in use which were changed several times.

The golden age (Healey 2001) for the Nabataean building activity was the second half of the first century B.C. and the first and early second centuries A.D., especially the long reign of Aretas IV: "lover of his people". Some archaeologists stated that "Aretas IV sent ambassadors to Rome where they and their king were commemorated in a grand marble inscription on the Capitoline (Bowersock, 2003).

In this period the Nabataeans' kingdom reached the zenith of its prosperity and started to achieve monumentality in its architecture, with buildings such as Al-Khazneh, the Theater, and Qasr Al-Bent. After all, the Nabataeans were an economic power, not political or military. It had profound influence over the world during its time.

In 106 A.D, the Nabataeans surrendered to Trajan; the Roman general at this time, Petra became part of the Roman Province of Arabia. After the transfer of the Roman Empire Capital to Byzantium in 330 A.D. under Constantine, Petra became the seat of a bishopric and by the 5th century A.D., Petra was the administrative center of the Byzantine province of "Palaestina Territa".

Although Petra's wealth had gradually declined because of the redirection of trading goods via sea routes (518 A.D.) and the greater traffic on the northern land routes that passed through Palmyra, it remained a wealthy and important center and a provincial capital.

Characteristics of Nabatean Pottery

Pottery was originally studied and recognized as Nabataean during the first systematic excavations in Petra, which were conducted in 1929 (Horsfield and Conway, 1930). The association of this unique style of painted and unpainted versions of "Egg-Shell" pottery with the Nabataeans, made it possible to classify many of their sites that were until that time unidentifiable due to the lack of inscriptions or references in the classical literature (Glueck, 1959).

Nabataean pottery is recognized by the thinness of its walls, which were sometimes only 1.5 mm thick. It was a pinkish/red color, decorated often by hand with dark brown flower and leaf designs. The painted ware had an interior decoration based on simple burning palmetto and feather motifs in a light red paint figure 1. The pottery became with time coarser, designs more stylish, intensive use of the brush, until it went out of production by the end of the Roman period. Hammond quotes R.J Charleston as saying that: —*The especial value of Nabataean pottery lies in its painting* certainly this was one of the out-standing characteristics of Nabataean ware, not all the Nabataean pottery was of this genre, there was some that was coarser and less decorative (Hammond 1973). Another characteristic of the Nabataean pottery is that it's extremely thin. The typical "Egg-Shell" Pottery, were mostly shallow open bowls were very difficult to be produced on the potter's wheel, demonstrating how skilled their craftsmen were. A kiln was recently excavated at Wadi Musa indicating that Petra itself was a center of production. The quality of this pottery declined from the late 3rd century A.D. onwards, maybe as a result of a larger scale production. Its development as being of "Egg-Shell" thickness and at the peak of its development similar to the finest porcelain, one might think that it was extremely fragile, but actually it was quite " durable" (Ward-Perkins, 1992). Nabataeans normal ware pottery was simple and comparable to the pottery used by the civilizations around them, Its distinctive characteristic was the use of red clay that gave it a bright red color, Nabataean pottery was well made, with little decorations, this was not true for their fine, thin-wares. Nabataean fine thin ware pottery was all made locally, and some was plain, but the majority was painted (Bedal

2000). Nabataean fine thin-ware could be the finest ceramics produced in the Middle East up to that time. It has been suggested by some that their taste in fine pottery came from pieces they might have imported from China (Hammond, 1973).

Figure 1. Nabataean painted ceramic shreds.

Nabataean Pottery (Previous Studies and Excavations)

George Horsfield and Agnes Conway in their excavation have found a large quantity of fine red ware with some painting and called it "Eggshell Pottery". They believed it was in common use by the people, and not only for religious services. They dated it 100 B.C.-100 A.D. (Horsfield 1930). Iliff (1934) described and re-presented some types of Nabataean pottery from Negev in Palestine, particularly at Auja, Al-Khalasa, Kurnub, and Tall Al-Sabi. Most of the pieces were fragments but represented different typical Nabataean patterns.

In 1959, Hammond published an article about pattern families in Nabataean painted ware. He studied the decorated motifs of the painted ware, classified them in different groups and presented them with illustrations (Hammond 1973). After three years, Hammond published another article about the classification of Nabataean fine ware in which he classified the ware into major groups according to forms.

Different studies were carried out of the painted Nabataean pottery from Oboda Temple, including the chronology of the painted ware by Negev (1986). One of the first strong attempts to establish a chronology of Nabataean pottery was that of Parr (1970). His article on a sequence of pottery from Petra gave a clear idea about the stratigraphy of the excavation and developed a chronology of the pottery using dated coins. His study contained 138 illustrations of the pottery according to the different phases of the excavation.

Nabil Khairy studied the objects exposed in the excavation at Petra, particularly the form of the ware and surface treatment. Most of the material came from stratified deposits and represented one step further in developing the chronology of Nabataean pottery (Khairy, 1990).

Zayadine (1982) wrote about the excavation work which he conducted in Petra 1979-1981. He discussed the pottery, and especially the oil lamps. Khairieh Amr made a neutron activation analysis study of the pottery from Petra (Amr, 1987). Francois Villeneuve (1990) studied the pottery from the oil factory at Khirbet Al-Dhariah and evidence of dating derives from bronze coins. The pottery of the factory was dated to the period A.D.100-15. Hijazi (1999) studied the provenance of Nabataean pottery excavated from Khirbet Edh-Dharih in southern Jordan.

Experimental

Several samples of painted pottery and raw pigments were submitted to investigation to better understand the technology of the fine Nabataean painted ceramics from Petra, Jordan. The initial examination of the ceramic sherds in optical microscopy showed all samples to be identical in their paint and paste textures. Figure 2 shows the typical textures of these samples. Therefore, only one sample (NRP.T2 locus 908 # 38) was selected for in-depth analytical study. Four samples of raw pigments were submitted to X-ray powder diffraction to determine their mineralogical composition for comparison with the artifacts.

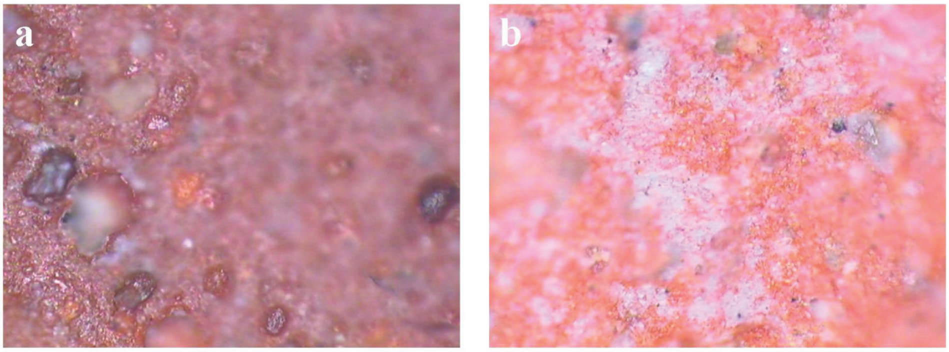

Figure 2. Optical micrographs of the Nabatean painted pottery, sample NRP.T2 locus 908 # 38: (a) inner red-painted surface and (b) outer unpainted surface. Note the course texture of the paint with the large and dark red grains of hematite and the transparent or milky quartz inclusions; the fine texture with fine carbonates and some quartz inclusions of the pinkish ceramic paste. Photograph dimensions:554x415µm.

A Mititoyo Ultraplan FS-110, in reflection mode with a magnification range of 100-1000X, was used for optical microscopy. Scanning electron microscopy observations were made using a Hitachi S-4700 (equipped with an EDAX EDS system) field emission scanning electron microscope. Samples coated with Au-Pd were studied at working distances of 12-14 mm and an accelerating voltage of 15kV. X-ray diffraction patterns were obtained for both raw pigments and painted ceramics using a Rigaku D/MAX-IIB X-ray diffractometer with CuKa radiation. Scans were taken for a 2q range between 2° to 65°, with scan speed of 2 °/min and a step size of 0.01°.

Results and Discussion

One of the most common properties used for the classification of the archaeological ceramic samples is the color of their body. This color is an indicator for firing temperatures, oxidizing or reducing conditions in the kiln and composition of raw materials (Kreimeyer; 1987; Molera *et al.,* 1998). The body color of painted ceramic ranges from reddish yellow (7.5YR 6/6), pink (7.5YR 7/4), to light yellowish brown (10YR 6/4), very pale brown (10YR 7/3 to 7/4).

1. Raw Pigments

Four samples numbered 6, 7, 10, and 12 were analyzed. Samples 6 & 7 are of dark red color, 10 is an orange red sample, and 12 is brown. X-ray powder diffraction patterns for these samples are shown in Figure 3. Samples 6 & 7 are composed of well crystallized hematite (a-Fe2O3) and quartz. These are high quality red pigments that only need screening to remove some of the quartz. Sample 10 contains quartz as a major phase with much less hematite, which is poorly crystallized. The pattern also shows

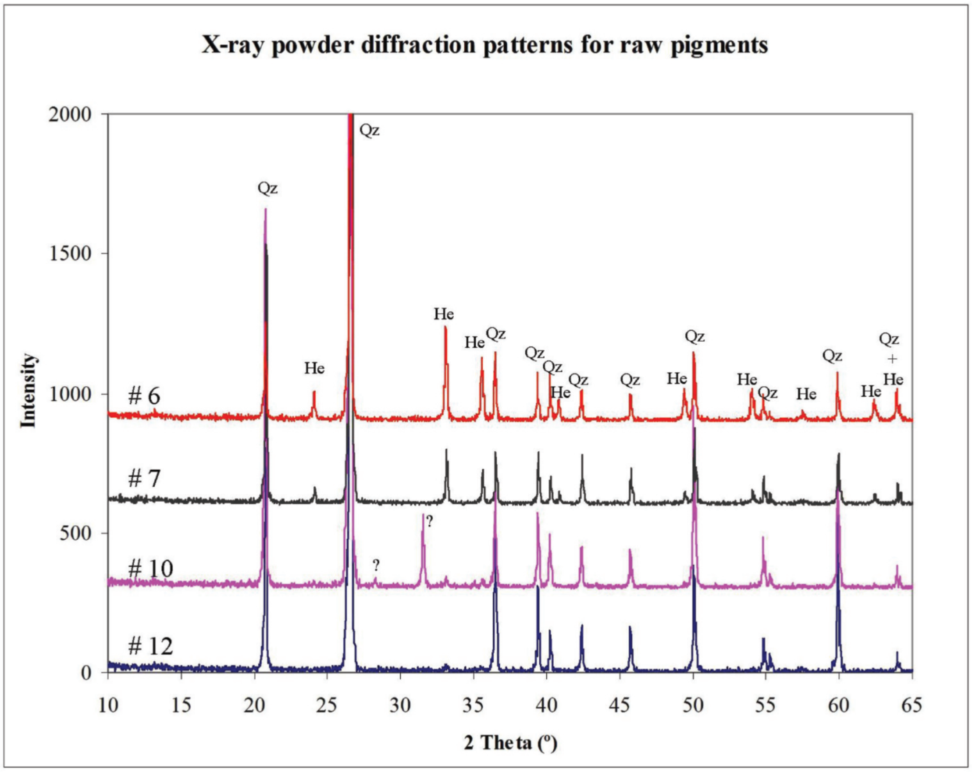

Figure 3. X-ray powder diffraction (XRPD) patterns of raw pigments from Petra. Samples # 6 & 7 are high quality (well crystallized) hematite pigments associated only with quartz as impurity. Samples # 10 & 12 are low quality pigments: both contain large amount of quartz and little hematite. # 10 contains an unidentified phase and # 12 contains also some goethite.

an unidentified phase. Sample 12 is even of much lower quality (which is almost a sandstone) that contain a lot of quartz and very little poorly crystallized hematite and a little goethite (a-FeO.OH).

2. *Painted Pottery*

Sample NRP.T2 locus 908 # 38 was analyzed with XRD, SEM and EDS. Figure 4 shows the XRD patterns obtained for both sides of the sample. These analyses were conducted directly on the sample and without any scratching or grinding. The mineralogical composition of the paste (unpainted outer surface) is typical of a clay poor in calcium and fired at moderate high temperature in an oxidizing atmosphere. The paste is composed of quartz, plagioclase, potassium feldspar, hematite, dolomite, and calcite. The latter two phases might be attributed to post-depositional contamination, since examination with both optical and scanning electron microscopes show fine carbonate particles deposited in the pores and cracks of the sherd. The paint on the inner surface of the vessel, on the other hand is composed of hematite as a major phase with only some quartz and plagioclase (Figure 3). This figure also shows that hematite is well crystallized, which is consistent with the optical micrograph on Figure 1 showing the large grains of hematite. It is also worth noting the somewhat high background (hump) centered at 2 θ = 22-23. This feature is commonly attributed to silica-rich amorphous meta-phases and glasses.

The presence of hematite as pigment in

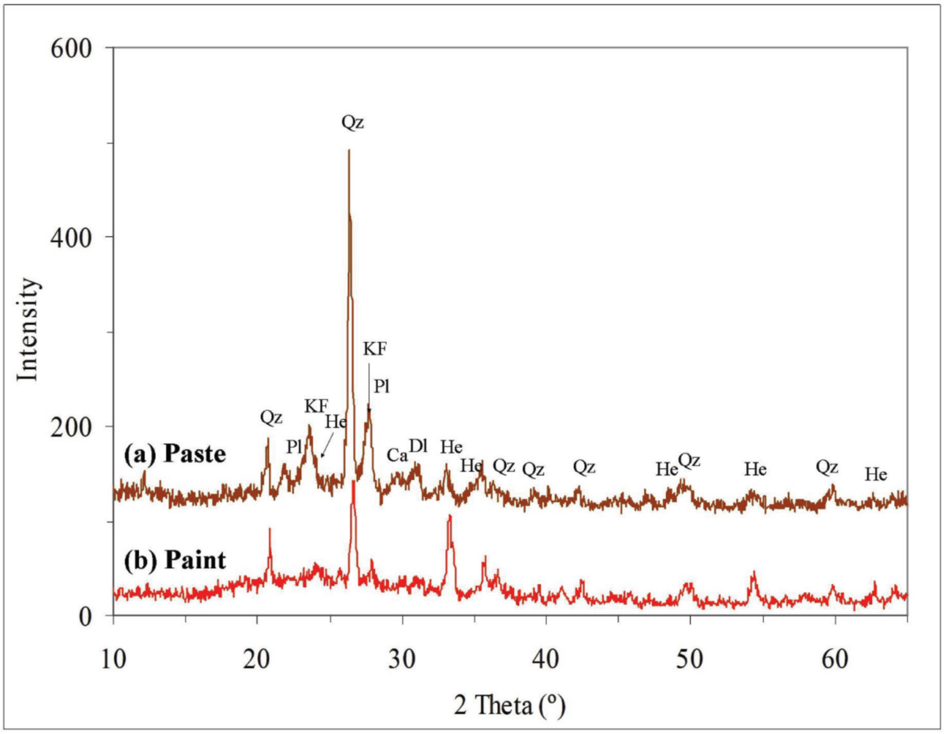

Figure 4. X-ray diffraction (XRD) patterns for both sides of the painted pottery sample NRP.T2 locus 908 # 38 from Petra: (a) unpainted outer surface (paste); (b) painted inner surface. Note the typical mineralogical composition of the ceramic paste: quartz (Qz), plagioclase (Pl), potassium feldspar (KF), hematite (He), dolomite (Dl), and calcite (Ca). The red paint is composed of hematite as a major phase with some quartz and plagioclase (probably from the paste underneath). Note also that hematite pigment is well crystallized and the high background hump centered around 2 θ = 22-23° that corresponds to an amorphous phase (see text).

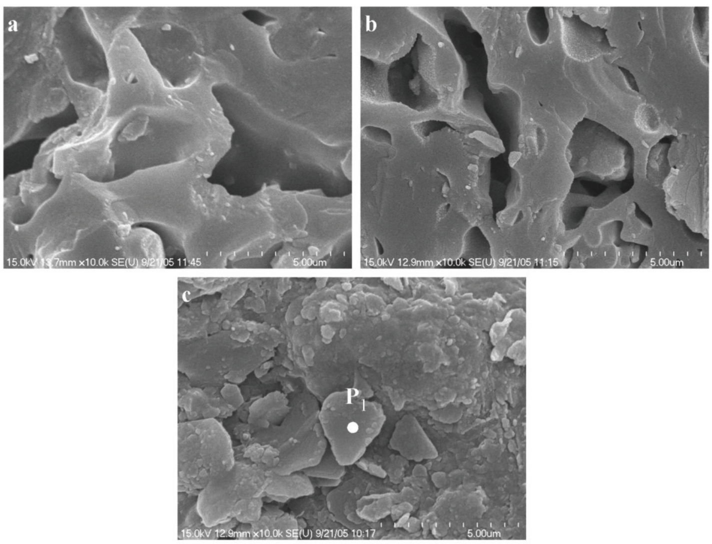

Figure 5. Secondary electron images obtained with field emission scanning electron microscopy (FE-SEM) for the Nabataean painted pottery, sample NRP.T2 locus 908 # 38: (a) unpainted outer surface; (b) ceramic core matrix; (c) red paint on inner surface of the vessel. Note the porous texture of the paste in (a) & (b) compared to the sealed surface in (c) which is composed of hexagonal crystals (hematite) cemented with some amorphous material (see text).

the paint was also confirmed by SEM observation. Figure 5 shows micrographs taken for the unpainted outer surface (paste), ceramic core, and painted inner surface, respectively. Micrographs (a) and (b) show the porous structure of the paste, whereas micrograph (c) shows some sealed surface with large hexagonal crystals cemented by some amorphous phase. Further analysis with EDS (Figure 6) shows high level of Fe in the paint layer, but also high level of K and Al. The latter elements are usually associated in some clay materials such as illite, which decomposes upon firing at moderate-to-high temperatures and can assure, through sintering, the adherence of the pigment to the ceramic surface.

Conclusion

The red color of the Nabataean painted ceramics is basically due to the presence of well-crystallized hematite in high concentration. The adhesion of the paint can be assured by the addition of some clay, which can serve as binder for the pigment, after decomposition and sintering. The presence of some quartz inclusions in the paint layer is also beneficial, since it gives texture, support, and hardness to this paint layer.

The study of painted and unpainted shreds showed that similar raw materials, characterized as calcareous clays, have been used by potters throughout their operation. These clay materials were poor in calcium and fired at moderate-high temperature in an oxidizing atmosphere. The paste is composed of quartz, plagioclase, potassium feldspar, hematite, dolomite, and calcite. The latter two phases might be attributed to post-depositional contamination, since examination with both optical and scanning electron microscopes show fine carbonate particles deposited in the pores and cracks of the shred. However, small differences in the production technology which has been used by the two workshops have been recognized, especially in the body preparation and in the clay to temper proportions.

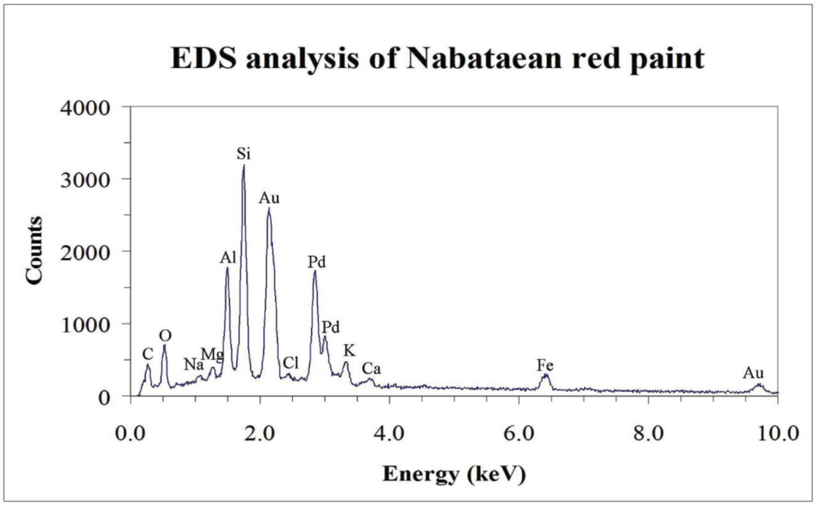

Figure 6. Qualitative chemical analysis, with energy dispersive spectroscopy (EDS), of a hexagonal crystal in the red paint (point P1 in Figure 4c). Au & Pd from gold-palladium coating and C from contamination with hydrocarbons. The detection of high levels of K & Al may indicate the use of a clay (for example, illite) as a binder for the Fe-rich paint.

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