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# Insights from a Collaborative Study of Beeswax Paint from Romano-Egyptian Mummy Portraits







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A study was designed to investigate the composition of beeswax and pigments from mummy portraits with the aim of improving our existing knowledge of the encaustic painting technique. This collaborative endeavor was made possible by the APPEAR project, which fosters interdisciplinary research between scientists and conservators and has resulted in new research yielding a better understanding of the inherent complexities of studying beeswax paint media. Colored paint samples were taken from nine encaustic mummy portraits (with different provenances) from two Danish museums, Ny Carlsberg Glyptotek (ÆIN) and the National Museum of Denmark (AS). Two portraits were excavated in Hawara by Sir W. Flinders Petrie, another five were bought from art dealer Theodor Graf's collection and are suggested to come from er-Rubayat, and the provenience of the last two portraits has not yet been established but according to museum records they are assumed to also derive from er-Rubayat. Dating for the nine portraits varies; the oldest are assumed to be from 25–75 CE, the youngest 150–200 CE (fig. 9.1). The research presented here complements a previous study of binding media from the same portraits.<sup>1</sup>

The encaustic wax painting technique on some mummy portraits utilized heated and melted beeswax applied with

small metal instruments leaving behind characteristically shaped and raised tool marks. Previous researchers have distinguished between encaustic technique and a beeswax technique executed in a painterly style that appeared more blended, with subtle variations in color and less impasto.<sup>2</sup> This painterly beeswax technique has been described in the literature as “cold, modified, Punic or emulsified” and has caused misunderstanding of both the artist's intent and technique. Pliny's description of Punic wax has led to a belief among some scholars that the beeswax was (partially) saponified prior to its use in paints, allowing it to be applied cold, as an emulsion, and that various findings from analytical studies have been used to promote this idea.<sup>3</sup> Still, the nomenclature and characterization of beeswax paint media is a source of contention and confusion.<sup>4,5</sup> For example, the mummy portrait ÆIN 1425 was described as “wax used cold.”<sup>6</sup>

Typical beeswax is composed of 14% hydrocarbons, 35% palmitic wax esters, and 12% free fatty acids.<sup>7</sup> Researchers have analyzed beeswax and paint samples from a small number of portraits executed in a painterly style (assumed to be modified or “used cold”) and concluded that a reduction in wax esters compared to hydrocarbons, the presence or absence of free fatty acids, or the detection of

Ny Carlsberg Glyptotek						National Museum of Denmark			
Provenience	Er-Rubayat (Graf collection)			Hawara (Petrie)		Presumable er-Rubayat			
	680	681	682	683	684	1425	1426	3891	3892
									
Date	100–125 CE	125–150 CE	140–160 CE	125–150 CE	140–200 CE	25–75 CE	100–125 CE	150–200 CE	150–200 CE
Flesh tone	Lead white, iron oxides, carbon black, kaolinite, goethite, minor red lead	Iron oxides, lead white, kaolinite, carbon black, red lake	Iron oxides, lead white, Egyptian blue, carbon black, quartz	Iron oxides, lead white, carbon black, red lake, quartz	Iron oxides, lead white, carbon black, kaolinite	Iron oxides, lead white, Egyptian blue, carbon black, red lake, quartz	Iron oxides, lead white, Egyptian blue, carbon black	Iron oxides, lead pigment, carbon black, calcite, gypsum	Egyptian blue, iron oxides, lead white, carbon black
Background	Lead white, iron oxides, carbon black	Iron oxides, lead white, Egyptian blue, carbon black, quartz	Iron oxides, lead white, carbon black, kaolinite	Iron oxides, lead white, carbon black, kaolinite, calcite	Iron oxides, lead white, carbon black	Iron oxides, lead white, Egyptian blue, carbon black	Iron oxides, lead white, Egyptian blue, carbon black	Iron oxides, lead pigment, carbon black, calcite, gypsum	Iron oxides, lead white, gypsum
Chiton	Lead white, iron oxides, carbon black	Iron oxides, lead white, kaolinite, carbon black	Gypsum, red lake, bassanite, minor red lead, lead white	Blue: Indigo, gypsum, bassanite, lead white Red: iron oxides, lead pigments, carbon black	Iron oxides, lead white, carbon black, kaolinite, quartz	-	Lead white	Iron oxides, lead pigment, carbon black, calcite, gypsum	Iron oxides, lead white
Lips/red	Iron oxides, lead pigment, kaolinite	Iron oxides, lead white, red lake (lips), calcite	Iron oxides, lead white	Red lead, lead white, iron oxides, kaolinite	Iron oxides, lead white, carbon black	Vermilion, lead white, iron oxides, carbon black	Hematite	Iron oxides, lead pigment, carbon black, calcite, gypsum	Iron oxides, lead white, carbon black
Hair/black	Iron oxides, carbon black, lead white, red lake, kaolinite, quartz	Carbon black, iron oxides, lead white, quartz	Carbon black, iron oxides, lead white, quartz	Carbon black, iron oxides, lead white, quartz	Iron oxides, lead white, carbon black, kaolinite	Carbon black, iron oxides, lead white	Carbon black, red lake, lead white, iron oxides, quartz	Iron oxides, lead pigment, carbon black, calcite	Iron oxides, lead white, gypsum, carbon black
Gold imitation	-	-	Goethite	Goethite	-	-	-	-	-
Clavus	Bassanite, red lake, lead white	Gypsum, red lake, bassanite, lead white	-	Red lead, red lake (minor), lead white, gypsum	Bassanite, gypsum, lead white, red lake	Lead white, red lake, iron oxides	Gypsum (?), lead white (minor), red lake, iron oxides (minor)	Lead white, iron oxides	Lead white, red lake
Ground	-	Carbon black, iron oxides	-	Iron oxides, carbon black	-	Calcite, gypsum, carbon black	-	Iron oxides, gypsum (anhydrite), hematite	Iron oxides

**Figure 9.1** The nine analyzed portraits in this study, including their provenience and age. The table is a schematic overview of the present pigment identification results together with the results from former analyses done on the portraits as part of the APPEAR project (see note 11). Ny Carlsberg Glyptotek: Young Man, AIN 680; Young Man with Beard, AIN 681; Young Woman with Jewelry, AIN 682; Woman with Blue and Red Dress, AIN 683; Man with Receding Hairline, AIN 684; Portrait of a Man on Canvas, AIN 1425; Portrait of a Man, Red Shroud Mummy, AIN 1426. Photos: Ole Haupt

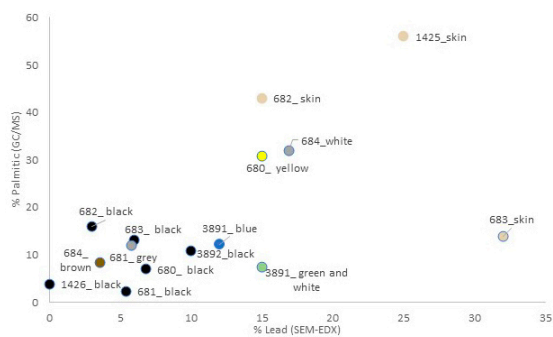
fatty acid metal soaps can be used to characterize “cold” applied wax or “modified beeswax.”<sup>8</sup> These conclusions seem inaccurate, as researchers within the APPEAR project have shown through the scientific analysis of over thirty wax-paint portraits that fatty acid soaps from beeswax-paint portraits are independent of painterly style.<sup>9</sup> Data

also showed that they had similar beeswax profiles—the hydrocarbons had either evaporated or lesser amounts remained, fatty acid and wax ester content were consistent depending on the pigment, and they could contain significant amounts of palmitic acid lead soaps. The study showed the impact of pigments on the formation of fatty



profile of old beeswax paint is modified when compared to fresh beeswax. Lead white paint will contain significantly more palmitic acid soap, while paint samples without lead white (or metal-forming pigments) do not form lead soaps, resulting in the evaporation of fatty acids from the paint matrix.

SEM-EDX and GC/MS results for percentages of lead and palmitic acid are shown in figure 9.3, where results for each sample are described as a color with its portrait number. The percentage of lead in the paint samples was calculated based on the estimated content and sum of a variable mixture of pigments using SEM-EDX. Therefore, both values may be affected by the inhomogeneity of the paint sample and application methodology employed. Preliminary results indicate that lighter-colored samples contain significantly higher percentages of lead and palmitic acid soap, while the opposite is true for darker-colored samples. For example, the flesh tones in the ÆIN 682 portrait contain approximately 15% lead and 43% palmitic acid, while ÆIN 682 black contains 3% lead and 16% palmitic acid.

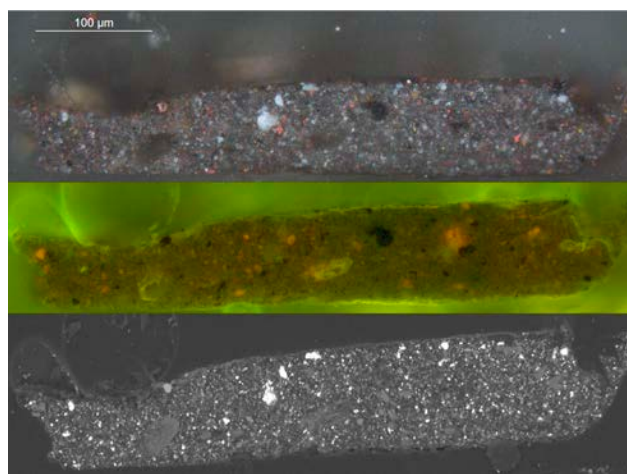


**Figure 9.3** GC/MS and SEM-EDX results showing palmitic acid and lead percentages. Colored circles (with their portrait numbers) indicate the light and dark beeswax paint colors.

It should be noted that several samples were outliers and did not follow the trend of increased lead and palmitic acid content, such as the flesh tones on ÆIN 683. The variability of our data could be due to several reasons. First, the inhomogeneity of the pigment particles was evident in the area/surface of the SEM-EDX scan. When polishing the cross sections, the pigment particle size was highly variable and the size of the particles at the surface of the cross section changed with subsequent polishing. This change could impact the results of the SEM-EDX scan on a given cross section and may indicate an area of inhomogeneity that is not representative of the lead

pigment content. Second, a small cross section sample does not always represent the lead content found in larger areas of the portrait. Third, it is well known in oil-paint studies that, due to the soaps' ability and tendency to migrate throughout the paint layers, lead soaps form concentrated inclusions in areas within the paint matrix.<sup>17</sup> This would result in variable amounts of palmitic acid detected in a small paint sample compared to an overall average in a larger paint area.

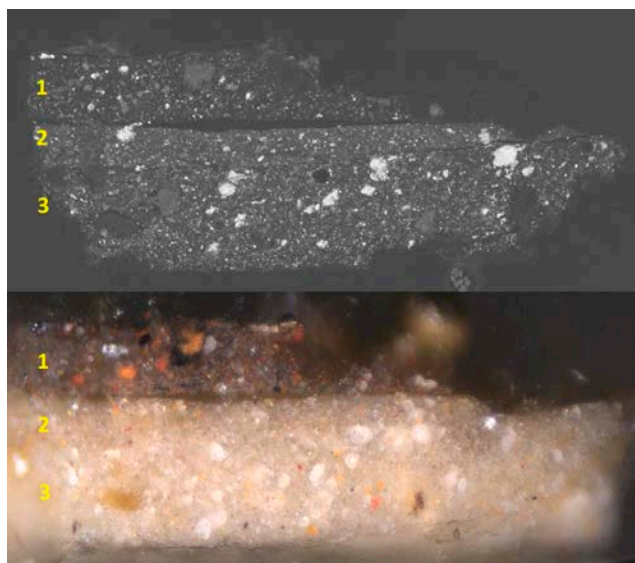
The following pigments were identified in the seven dark paint samples: carbon black, red/brown iron oxides, and, in one example, red lake. The SEM-EDX cross section scans provided information on the pigments used in the specific paint layers studied. Figure 9.4 shows an example of a cross section from a dark color, ÆIN 1426, and illustrates the complexity of pigments found in dark or black areas. The visible light image shows how the paint is composed of black, white, brown, red, and yellow pigments. There is a surprisingly high lead white content (seen as white particles in the SEM-EDX image) in many of the dark/black paint layers. The cross section also shows the presence of red lake pigment, a surprising addition to black paint. The red lake pigments can be observed as bright orange particles with or without ultraviolet radiation.



**Figure 9.4** An example of a black color cross section, Portrait of a Man, inv. no. 1426. Top: visible light; center: UV-fluorescence (note that the red lake pigments appear as bright orange particles); bottom: SEM-EDX image showing lead as bright white particles. Photo: Lin Rosa Spaabæk

The cross sections also gave interesting information on the stratigraphy of the wax paint, though most samples were diminutive and thus did not contain all the layers in the paint structure. However, a cross section shows the stratigraphy of black hair (layer no. 3) on top of two layers (nos. 1 and 2) of light gray background color from ÆIN 681 (fig. 9.5). The visible light image shows how both the light

and dark colors consist of red, yellow, black, and white pigments, and in most cases yellow iron oxide as well. Calcite and quartz were present in all dark-colored samples as well as lead white in surprisingly significant amounts when compared to the dark sections of the paint. It is noteworthy that we did not detect the red pigment minium in the darker areas, however, lead white was ubiquitous in all the samples analyzed and is the only pigment present in the paint samples capable of forming lead soaps.



**Figure 9.5** Cross section showing the stratigraphy of black hair (layer no. 1) above two layers of light gray background color (nos. 2 and 3). Mummy portrait of a bearded young man from er-Rubayat. Inv. no. ÆIN 681. Top: visible light; bottom: SEM-EDX image. Photo: Ole Haupt

Lead white, calcite, and quartz mixed with various hues of red and yellow iron oxides were observed in all six light-colored samples analyzed. The addition of Egyptian blue was also identified in two samples taken from light-colored flesh tones (see fig. 9.1). The pigments identified in this study of mummy portraits painted with beeswax-based paint revealed that the painters had an economical yet precise and conservative palette of pigments, and the results corroborate what other studies have so far reported.

## CONCLUSION

The SEM-EDX results revealed that both dark and light beeswax samples taken from nine beeswax-based mummy portraits contained variable amounts of lead white. Carbon black, with the addition of red/brown iron oxides and one example of red lake, was identified in the seven dark paint samples. Lead white, calcite, and quartz mixed with various

hues of red and yellow iron oxides were observed in light-colored paints.

Through a fortuitous collaboration, evidence is presented here that allows for a better understanding of how lead soaps form in ancient beeswax and why its presence should not be used as an indication of cold applied or Punic wax. GC/MS and SEM-EDX results were compared and preliminary results show that lead is positively correlated with the formation of palmitic acid soaps. This provides further evidence that the soaps present in beeswax paint can be attributed to lead metal complexes. Therefore, differences in beeswax chemical profiles should not be used to indicate a purposeful modification of the beeswax during the preparation of the beeswax paint. Rather, the beeswax chemical profiles are different from one another because of lead content, evaporation, pigments, wax ester hydrolysis, and subsequent soap formation. The hydrolysis of wax esters occurs over time and, when palmitic acid is released, it forms a palmitic acid lead soap. This explains the variation we see in the wax ester profile, and it is hoped that these results will inspire discussion and offer a clearer understanding of the ancient beeswax painting technique.

## ACKNOWLEDGMENTS

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## NOTES

1. Spaabæk and Mazurek 2020.
2. Ramer 1979.
3. Kühn 1960.
4. Sutherland, Sabino, and Pozzi 2020.
5. Stacey 2011, 1749.
6. Doxiadis 1995.

7. Jiménez et al. 2004.
8. White 1978.
9. Mazurek, Svoboda, and Schilling 2019.
10. Spaabæk and Mazurek 2020.
11. Mazurek, Svoboda, and Schilling 2019.
12. S-3400N scanning electron microscope from Hitachi combined with a Bruker XFlash 6I30.
13. The pigment identifications were done by various methods: internal reports by MOLAB, led by C. Miliani (FTIR, XRF, UV-vis, SEM-EDX, Raman) (see also Miliani et al. 2010); internal report by the Danish National Museums research department, by chemist M. Taube (XRF analyses) and M. C. Christensen (amino acid and FTIR analyses); internal reports by R. Newman, MFA, Boston (FTIR, Raman, SEM); internal report by D. Buti, CATS, National Gallery of Denmark (XRF); internal report by Julie Jaeger, teaching associate professor, KADK (SEM-EDX); Nini A. Reeler, chemist, University of Copenhagen (Raman) (see also Reeler 2013). The portraits have also been studied by various analytical photographic methods: visible-induced infrared luminescence (VIL), X-radiography, and ultraviolet radiation. Figure 9.1 shows a schematic overview of pigment identification.
14. van den Berg, van den Berg, and Boon 1999.
15. Casadio et al. 2019.
16. Schilling, Carson, and Khanjian 1998.
17. Plater et al. 2003.