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LETTER

EGYPTIAN BLUE AND/OR ATACAMITE IN AN ANCIENT EGYPTIAN COFFIN

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Abstract

This work deals with the composition of the blue and green pigments used in the wooden sarcophagus studied by Abdelaal et al. and published in 2014 in this journal. From the published data, a degradation of the originally used Egyptian blue pigment is proposed. The presence of chlorine in the pigment deduced from SEM-EDS analyses and the greenish hue observed point to the formation of a certain amount of atacamite (or one of its polymorphs, paratacamite or clionoatacamite) because of the Egyptian blue degradation process named copper chloride cancer.

Keywords: *Egyptian blue; Cuprorivaite; Atacamite; Copper chloride cancer; Sarcophagus; Ancient Egypt;*

Introduction

After the reading of the article written by Abdelaal et al. [1] and published in this journal there are some doubts or questions related to the identification of the blue and green pigments used to decorate the Egyptian polychrome wooden sarcophagus of the Graeco-Roman period they analyzed. The main purpose of this short communication is to indicate that perhaps more information than the described by the authors could be obtained from their published data.

The authors carried out a study in order to identify the grounds, the binder, the pigments and the wooden used for the coffin. After the analytical study of the pigments, the authors proposed that the blue color was obtained by using the Egyptian blue pigment (chemically named cuprorivaite, $CaCuSi_4O_{10}$). On the other hand, the pigment used for the green color was Egyptian Green, a mixture of wollastonite, $CaSiO_3$, and a Cu-bearing amorphous phase. For the identification of the pigments, the chemical techniques used were Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM-EDS) and X-ray Diffraction (XRD).

Green color: consequence of a pigment degradation?

According to the authors, "*Egyptian blue was identified in the dark green pigmented areas*". It is interesting to note that according to the authors there were green areas where they could identify traces of a blue pigment. Although the authors identified Egyptian blue by XRD

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(see Figure 5 in Abdelaal et al.'s article), the presence of this pigment does not satisfactorily explain the greenish hue of the color ("*dark green*" according to the authors). The SEM-EDS spectrum (also in Figure 5) shows that the main elements present in the pigment are copper, calcium and silicon, but it is noticeable the presence of peaks corresponding to chlorine, which appear between the Si and the Ca peaks. The presence of chlorine would point to a chlorine-containing solid phase in the analyzed region and, considering the chemical reactivity of cuprorivaite, this solid phase could be atacamite, $Cu_2(OH)_3Cl(s)$, or one of its polymorphs, paratacamite or clinoatacamite. These are products of the degradation of the Egyptian blue when in contact with high-chloride concentration solutions [2,3] through the subsequent reaction:

$$2CaCuSi_4O_{10}(s) + 5H^+ + Cl^- \leftrightharpoons Cu_2(OH)_3Cl(s) + 2Ca^{2+} + 8SiO_2 + H_2O$$

Accepting the presence of atacamite, the composition of the "dark green" parts of the coffin would be a mixture of Egyptian blue and atacamite (perhaps mainly atacamite). Therefore, although Egyptian blue was originally applied to the coffin in order to obtain the blue color, it could have degraded to atacamite because of the contact with saline solutions. While the chemical result would be the presence of atacamite, the macroscopic result would be a green color.

One could then question why the authors do not see atacamite in the XRD spectrum. According to the authors, "*The X-ray pattern was taken from a blue part on* [sic] *a sample*". The absence of atacamite in the diffractogram could be actually due to the election of a 'blue part' for the analysis. This part would be less degraded and would have a lower percentage of atacamite. The XRD technique is not able to detect the presence of minor solid phases and, actually, even if the peaks of theses minor phases appeared in the diffractogram they could be almost hidden by the peaks of major phases. For example, small peaks in the diffractogram shown in Figure 5 could correspond to paratacamite [4,5].

On the other hand, the authors also show the results of the analysis of the green parts of the sarcophagus. However, after the reading of the article it is not clear how such 'green' parts look on the coffin, but Figure 1 of the article, with pictures of the sarcophagus, seems to show that there is a green hue in all the regions that could be painted in origin as blue or green. It is difficult to ascertain if the green color analyzed by the authors corresponds to the green parts associated to the Egyptian blue ("*dark green*") or there are other green parts in the coffin, not related to Egyptian blue. In any case, the authors concluded that the green pigment used was probably green frit. This is a bit surprising because it seems that the use of green frit disappeared before the Graeco-Roman period, when the green pigments used were green earth or mixtures of Egyptian blue and yellow pigments (goethite or orpiment) [6,7]. According to the authors, "*The green pigment sample from the wooden sarcophagus was identified with SEM-EDS, which showed the presence of elements as Cu, Ca, Si and Cl*". As in the case of the composition of the blue pigment, it seems that the pigment contained an amount of chlorine, probably even higher in this pigment than in the blue region if we compare the SEM-EDS spectra in Figures 5 and 6 (although SEM-EDS spectra might only give semi-quantitative results). Therefore, the results obtained for the green pigment also point to the formation of atacamite through the degradation of Egyptian blue or green frit [2].

The coexistence between Egyptian blue and atacamite on blue-green colors was already observed in sarcophagi from different periods. For example, Lee [8] found that the dull green color of the Amenemope sarcophagus (British Museum, EA 22941), from the Third Intermediate Period, consisted on a mixture of pale blue particles (perhaps Egyptian blue) and green particles of atacamite; and Mallinckrodt identified atacamite in a Ptolemaic anthropoid sarcophagus (San Diego Museum of Man, USA) [9].

Conclusion

From the data published by the Abdelaal et al. [1] it might be deduced that some of the Egyptian blue was already degraded through the process known as ‘copper chloride cancer’. The degradation of the Egyptian blue would have produced a change of the blue color to green, due to the formation of atacamite (or other polymorphs) because of the contact of the pigment with chloride. The main indications of this degradation process are (1) the green color of regions associated to Egyptian blue and (2) the presence of chlorine deduced from the SEM-EDS results presented in the article. The possible existence of a degradation process on the pigments must be taken into account in any restoration or conservation work, because such processes might hide the original color of the sarcophagi.

References

[1] Sh. Abdelaal, N. Mahmoud, V. Detalle, *A technical examination and the identification of the wood, pigments, grounds and binder of an ancient Egyptian sarcophagus*. **International Journal of Conservation Science, 5,** 2014, pp. 177-188.
[2] S. Schiegl, K.L. Weiner, A. El Goresy, *Discovery of copper chloride cancer in ancient Egyptian polychromic wall paintings and faience: a developing archaeological disaster.* **Naturwissenschaften, 76**, 1989, pp. 393-400.
[3] J. Gimenez, *Finding hidden chemistry in ancient Egyptian artifacts: pigment degradation taught in a chemical engineering course*. **Journal of Chemical Education, 92**, 2015, pp. 456-462.
[4] S. Švarcová, D. Hradil, J. Hradilová, *Micro-analytical evidence of origin and degradation of copper pigments found in Bohemian Gothic murals*. **Analytical and Bioanalytical Chemistry, 395**, 2009, pp. 2037-2050.
[5] A. Moussa, M.F. Ali, *Color alteration of ancient Egyptian blue faience.* **International Journal of Architectural Heritage: Conservation, Analysis, and Restoration, 7**, 2013, pp. 261-274.
[6] D.A. Scott, S. Warmlander, J. Mazurek, S. Quirke, *Examination of some pigments, grounds and media from Egyptian cartonnage fragments in the Petrie Museum, University College London*. **Journal of Archaeological Science, 36**, 2009, pp. 923-932.
[7] H.H.M. Mahmoud, *Investigations by Raman microscopy, ESEM and FTIR-ATR of wall paintings from Qasr el-Ghuieta temple, Kharga Oasis, Egypt.* **Heritage Science, 2**, 2014, pp. 18-29.
[8] L.R. Lee, **Investigation into degraded pigments on the Coffin of Amenemope. EA 22941.** British Museum Conservation Research Group CA1997/20, 1997.
[9] C.S. Mallinckrodt, *This old foot: identification of ancient and modern reuse in a Ptolemaic child sarcophagus,* **ANAGPIC Conference**, Los Angeles, CA, USA, 2013.

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