DEGRADATION PROCESSES OF ANCIENT EGYPTIAN PIGMENTS

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A large number of written and illustrated papyri from Ancient Egypt have survived through the ages, providing numerous details about stories, practices, and everyday life in Egypt several millennia ago. We investigated a series of fragments of illustrated papyri from the collection of the Champollion museum (Vif, département de l'Isère, France), showing scenes from the Book of the Dead, a document essential to prepare for the afterlife. The colours still visible today come from the well-known Egyptian palette: red hematite, blue cuprorivaite (colouring material of Egyptian blue), green malachite, yellow orpiment, white lead white, and black carbon. These colours are believed to be still vivid today because of the inorganic nature of most of the pigments. Nevertheless, X-ray diffraction data proved the existence of degradation phases, unveiling a global degradation process affecting most of them [1].

The coloured regions are highly heterogenous, and are made from a mix of organic and inorganic compounds of variable microstructure and crystallinity, apposed on the papyrus support. Mixed Rietveld and Pawley refinement were carried out against the power diffraction data taken in the different coloured regions, granting access to quantitative and microstructural information for the crystalline phases. In addition, X-ray fluorescence and X-ray absorption were used synergistically to help us identify and characterize further the less crystalline and amorphous phases. Finally, X-ray diffraction computed tomography (XRD-CT) and 2D-mapping were also applied to investigate the distribution of the different phases and the interfaces between the coloured regions.

Thanks to this approach, we identified, apart from the original pigments, several sulfate-, chloride- and oxalate-based phases. As an example, malachite ($Cu_2CO_3(OH)_2$), which was used originally as a green pigment, transformed into atacamite ($Cu_2Cl(OH)_3$), and finally to moolooite ($Cu(C_2O_4)$,nH_2O) [2]. Furthermore, in regions where green and yellow were superposed, complex cross-degradation products appeared, like lavendulan $NaCaCu_5(AsO_4)_4Cl{\cdot}5H_2O$ or another copper arsenate $Na_2Cu_3(AsO_3OH)_4{\cdot}4H_2O$, following a particular stratigraphy. A better comprehension of the chemical reactions leading to the current degradation state should help to gain insights into the long-term behaviour of such materials and find appropriate conservation measures to transmit this unique Heritage from Ancient Egypt to future generations.

[1] Autran & al., Scientific Reports (2023), 13, 524.
[2] Castro & al., Analytical Chemistry (2008), 11, 80.