December 22, 2021

Maths, Physics & Chemistry

Unveiling the secrets of ancient Egyptian ink

by Marine Cotte[1] I Beamline scientist; Thomas Christiansen[2] I Egyptologist; Sine Larsen[3] I Professor

[1]: European Synchrotron Radiation Facility, Grenoble, and CNRS, Paris, France
[2]: Egyptology Section, Department of Cross-Cultural and Regional Studies, University of Copenhagen (alumnus), Denmark
[3]: Department of Chemistry, University of Copenhagen, Denmark

This Break was edited by Olivier Kirchhoffer, Scientific Editor - TheScienceBreaker

At the dawn of recorded history, ancient Egyptians already used different colors of inks to highlight important messages on papyri. We studied the composition of 12 red and black inks on ancient Egyptian papyri (c. 100–200 CE) and were able to detect different lead-containing compounds in both red and black inks, revealing that lead was used as a dryer rather than a pigment.

Image credits: The Papyrus Carlsberg Collection, University of Copenhagen.

The earliest examples of preserving human thoughts by applying ink on a flexible and durable material, papyrus, were found in ancient Egypt at the dawn of recorded history (c. 3200 BCE). Egyptians used black ink for writing body text, while red ink was often used to highlight headings, instructions or keywords. During the past decade, many scientific studies have been conducted to shine a light on the invention and history of ink in ancient Egypt and more generally in Mediterranean cultures, including ancient Greece and Rome. However, many of them are limited to very little physical samples as supporting evidence.

In this study, we used the light produced at the European Synchrotron (a 844m-circumference ring generating extremely brilliant X-ray beams), to investigate the composition of red and black inks inscribed on papyri, from the only large-scale institutional library known to have survived from ancient Egypt: the Tebtunis temple library. This research project was exceptional, not only due to the provenance of the papyri, but also because the analysis included as many as 12 ancient Egyptian papyrus fragments (dating to c. 100–200 CE), all inscribed with both red and black inks.

Because of the unique and precious nature of the papyri, the analyses were performed without inflicting any damage to the material. The experiments were mainly conducted at the beamline ID 21 and combined several synchrotron techniques, which provided various pieces of information on the chemical composition of the inks. Analyses were carried out over several areas of the papyri, to differentiate between the signals coming from the inks and the papyri themselves. These areas ranged from the millimetre to the sub-micrometre scale and revealed the very heterogeneous composition of the inks.

We found that in 11 of the 12 analysed red inks, the colour is due to ochre, a naturally occurring iron-based mineral. Remarkably, lead was detected in 10 of these 11 red inks, besides also being detected in three carbon-based black inks. Instead of being present as the traditional “red lead” or “lead white” pigments, which were widely used since Antiquity, lead was found in complex mixtures and was associated with phosphate, sulphate and carboxylate ions to form salts. The distribution of these elements was even more surprising. We discovered that ochre is present as coarse particles that remain on the surface of the papyri, while the lead compounds are found to diffuse into the papyrus cells. This creates a ‘coffee-ring effect’ around the ink lines – just as if the hieroglyphic signs were outlined – which suggests that lead may have been present in a finely ground and maybe even in a soluble state. It also suggests that when Egyptians applied the ink to the papyrus, large ochre particles stayed in place, whilst smaller lead particles diffused in the papyri.

These results suggest that lead was probably added to the ink mixture, not as a colorant but as a dryer, which ensured that the ink stuck to the papyrus. This entails that the inks were made according to a complex recipe and we therefore hypothesize that there existed workshops in ancient Egypt, which specialized in manufacturing inks. Connections were made between these ancient ink recipes and paint practices developed many centuries later during the Renaissance. In 15th century Europe, when artists rediscovered the technique of oil painting, a challenge facing them was how to dry the oil within a reasonable amount of time. These artists realised that some lead compounds could be used as efficient dryers.

Were lead sulphates and phosphates initially present in ink or did they form during ink alteration? Their origin remains an open-ended question. Assuming they were part of the original ink, understanding their role in the writing process is the motivation of ongoing research. Lead was also found associated with chloride in white salt crystals forming at the surface of some red inks. The soil in which the papyri were found had a high content of salt, which can explain the formation of these crystals. This result calls for further studies of the degradation of lead compounds, which will facilitate future strategies of conservation and preservation of cultural heritage objects.