ESRF	**Experiment title:** DEGRADATION PROCESSES IN DEAD SEA SCROLLS IMAGED BY FTIR AND X-RAY MICROSCOPIES	**Experiment number**: EC89
Beamline: ID21	**Date of experiment**: from: 02 Nov 2006 to: 07 Nov 2006	**Date of report**: 27.02.2010
Shifts: 15	**Local contact(s)**: **Marine Cotte**	*Received at ESRF:*

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Report:

Work published in:

[1] Murphy, B., Cotte, M., Mueller, M., Balla, M. and Gunneweg, J. *Degradation of Parchment and Ink of the Dead Sea scrolls investigated using Synchrotron-based X-ray and Infrared Microscopy* in Gunneweg, J., A. Adriaens and Dik, J. *Holistic Qumran*, Trans-disciplinary Research of Qumran and the Dead Sea scrolls, NIAS-Lorentz Workshop, Leiden University, STDJ-Series-87, Brill, 2010, 77-98, 2010

Extracted from above paper

Introduction:

Since the early nineteen fifties, a continuous process of conservation of the Dead Sea scrolls and fragments of them has taken place under the supervision of the Israel Antiquities Authority. Nevertheless, the scrolls have become darker and more brittle by the day. Therefore, at this stage, the degradation of parchment in general and that of the Dead Sea scrolls in particular continues to present intriguing questions regarding restoration, preservation and conservation. Given the enormous importance of the texts on the Dead Sea scrolls as cultural heritage, answers should be given very soon before the material becomes illegible and eventually destroyed. Representative Pieces of the Dead Sea parchment were used in these experiments. All pieces came from 4Q992: Three pieces are discussed in more detail in this report one containing an ink dot; parchment in an extreme state of degradation and a fresh piece of goat parchment measured as a reference sample.

The experiments were carried out at the X-ray microscopy beamline ID21 and on its Infrared facility, at the European synchrotron radiation facility in France. As it was intended to investigate the samples in absorption mode thin cross sections were required. Samples of parchment were cut into small pieces and were then prepared by embedding them in a fluid resin that hardened over 24 hours. Each resin block of about 0.5 x 1.0 cm^2 containing one sample was then cut with a microtome so that one obtained cross-sections of 10 µm, 6µm and 4 µm respectively. The cuts of cross-sections were placed between two sheets of parafilm to facilitate handling of the samples. One must take care that the resin, in its fluid state, may have interacted with the sample; in particular, it might have diluted some of the ink on the parchment. The suspected ink scrapings were in powder form and they mixed with potassium bromide and pressed into pellets for the Fourier Transform Infrared experiments.

Summary:

Modern synchrotron-based Infrared (figure 1) and X-ray microscopy (figure 2) techniques have shed some light on the nature of degradation in the parchment of the Dead Sea scroll found in Qumran. Returning to the aims, we state the following conclusions:

1. It is likely that a bone glue based ink binder was used. The decay of the calcium phosphate (bone ash) signal further away from the ink spot into the bulk of the parchment suggests that the ink permeated into the parchment.
2. Though we could not identify the tanning process, we could verify that it provides an effective preservation. The organic components of the parchment are still present. However, structural degradation is observed: the homogeneous, compact appearance of fresh parchment is changed into a more porous structure. Calcium carbonate may have been used to lime- whiten the Dead Sea scroll parchment, sometimes even on both sides. In particular, large agglomerates are still present under the ink.
3. The ink apparently destroyed the parchment in its immediate vicinity, as no organic matter could be found in the parchment regions penetrated by ink, and holes are visible underneath them. The neighbouring regions also show signs of organic denaturing.

We hope that these indicators will be useful for the preservation of the Dead Sea scrolls and other ancient parchments. Keeping the scrolls in a temperate dry environment will decelerate the chemical processes harmful for the parchment and reduce the diffusivity of attacking radicals.

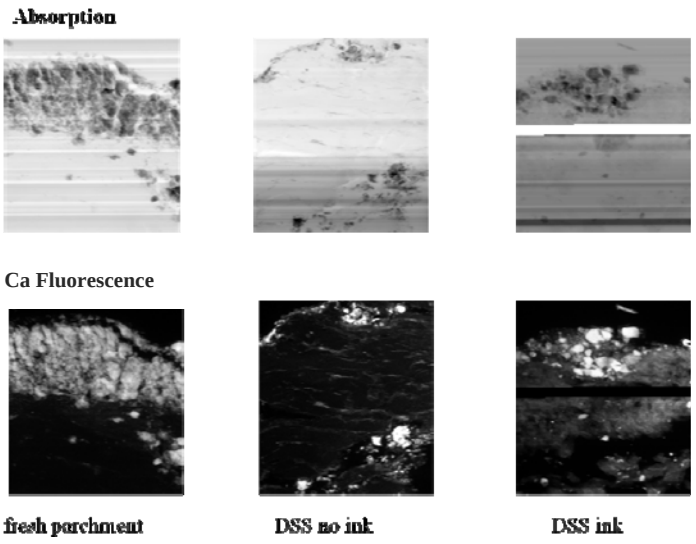

Figure 1: For comparison absorption and calcium fluorescence maps of fresh parchment (QUM 1, QUM 3, QUM 4; 90 x 100 µm^2), Dead Sea parchment with no ink and Dead Sea parchment with ink are shown. The increasing degree of degradation can be seen in each case.

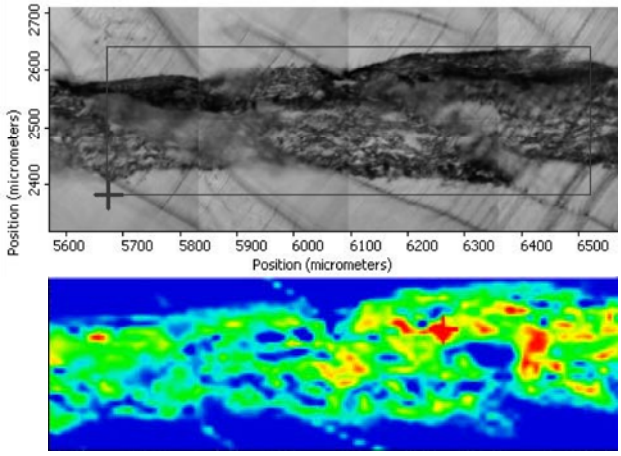

Figure 2: Microscope image of a thin section of QUM 7 (top) and amide II band intensity (bottom). FT-IR map size is 860 × 270 µm^2 with 10 µm step size in the two directions. The ink dot is located on top of the section in the centre (horizontal position: 6100 µm) with a hole well visible underneath the ink area.