DIAGNOSIS OF DARKENING GREEN PIGMENT ON ANCIENT PAPYRUS

by Dr Hussam El Din Abdel Hamid M.M.*)

Introduction:

In the field of paper conservation, few authors have discussed the problem of the destructive effect of some pigments and inks on the cellulose of paper (Fenger et al., 1982; Fackelman, 1983; Banik et al., 1982; and Banik et al., 1988). In the present work, the object is ancient papyrus. And the phenomenon is the change in green colour of the pigment on papyrus (more darkening).

Materials and Methods:

The material of interest in the actual article is a piece of coloured ancient Egyptian papyrus. It is exhibited in the manuscript section of the Egyptian Museum, which lies in the centre of Cairo City. This papyrus is registered under museum number 2512. The papyrus has suffered a darkening effect mainly in the green pigment areas. The whole piece of papyrus is stuck on a cardboard backing and exhibited inside a wood frame with glass face (see the photos included at the end of the article).

Non-destructive technique used for sampling:

The technique has been used described by Anna Teetsoo**). The method includes the usage of a drop of a suitable dilution and density of flexible collodion solution in amyl acetate, to cover the surface to be sampled. After the drying of the collodion

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*) Conservation Department - Faculty of Archaeology - Cairo University

**) Undated and unpublished report.

drop (in a few minutes), the formed film can be easily peeled off manually. The film will bear a very thin layer of the surface. The sample film is transfered in a clean, dry test tube to the lab. to be analysed for the detection of Cu and Fe elements. The results are tabulated.

Non-destructive technique used for testing (pH) of papyrus surface:

The measurement is carried out by contacting the universal pH. paper to the papyrus surface through a very small drop of water. Then the results are tabulated.

Results in tables:

Table (1) the results of analysis by AAS*) of darkened areas.

Serial No.	Element exist in (PPm)	
	Cu	Fe
(1)	0.640	0.461
(2)	2.200	0.301
(3)	0.228	0.249

Table (2) the results of measuring the surface pH of papyrus.

Sample Code	(pH) degree	Acidity in Code
(A)	3	++++
(B)	3.8	++
(C)	3.5	+++

*) The analysis by AAS for the papyrus surface samples was carried out in the micro-analysis centre - Faculty of Science - Cairo University

Discussion:

The results in Table (1) indicate the presence of (Cu) element in higher concentration beside the presence of iron traces. This result indicates the presence of copper pigment. This is mainly malachite(basic copper carbonate) $CuCO_3 . Cu(OH)_2$. Malachite pigment occurs naturally in Sinai and was used by the ancient Egyptian from the pre-dynastic period (Locas, 1962).

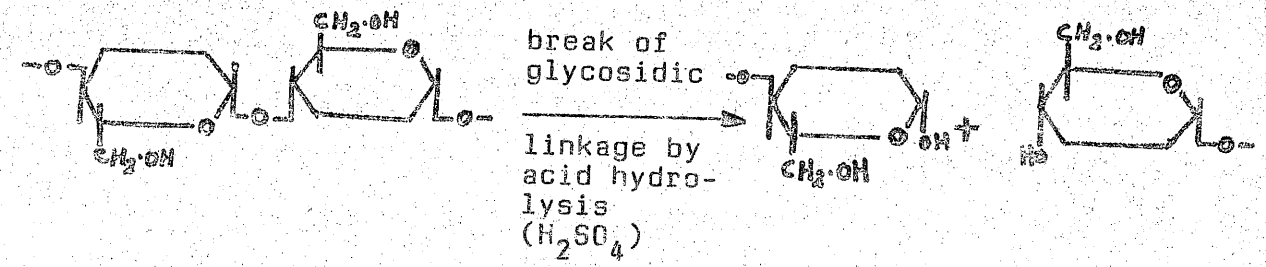
The results in Table (2) indicate the presence of high acidity pH ranges (3.5-4). On the other hand, according to the unpublished report*) of the air pollution unit. The Tahrier square in which the Egyptian Museum is located, there is a polluted zone containing acid gases such as SO_2 and NO_2. In the Tahrier square there are tremendous traffic movements of all kinds of transports especially big buses, which occupy a large area in front of the museum, as a huge terminal station. See photos (8-13). The acid gases pollutants are very harmful to all historical materials including ancient papyrus as museum collection. Moreover, the presence of (Cu) and (Fe) in the form of salts or oxides in papyrus - according to results in Table (1): can act as catalyst in the transformation of SO_2 gas to H_2SO_4 acid in papyrus material - as explained by the following equation:

$$SO_2 \xrightarrow[\text{sun light + Cu \& Fe oxides}]{/o/} SO_3 \xrightarrow[\text{R.H. more than 50\%}]{+H_2O} H_2SO_4$$

$$\text{Fe \& Cu oxides} + /o/ + H_2O$$

*) After Dr. Nasralla chief of the Unit of Air Pollution - the National Research Centre (Dokki/Cairo)

The formed sulphuric acid hydrolyses cellulose of papyrus and causes its degradation by breaking through 1, 4 glycosidic linkages of cellulose (which is stable under neutral condition). According to the following equation:



- Long chain of cellulose

- shorter chain of hydrocellulose

The rate of hydrolysis increases by the increase of acidity. The other acidic gas pollutant is NO_2. It oxidizes the cellulose of papyrus to transform it to the acidic oxycellulose, which is dissolved in alkalies as NaOH due to the formation of the sodium salt. This means that, the oxidized cellulose is succiptible for degradation by alkaline conditions. Finally the cardboard backing of papyrus, beside its conducting (Fe) impurities to papyrus material, it conducts also acidity in the form of organic acids (alifatic and aromatic) as a result of cardboard-lignin auto-oxidation. The conclusion, we have multi-sources of acidity, which reacting with papyrus materials and also with the onto malachite pigment. The pigment consequently transformed to different salts of these acids, which have different colours according to the salt type or the acid type as shown in the following equations:

Malachite (Copper carbonate) $CuCO_3$

- H_2SO_3 → 1 - Copper sulphate
- Benzoic acid → 2 - Copper benzcate
- Acetic acid → 3 - Copper acetate
- Nitric acid → 4 - Copper nitrate

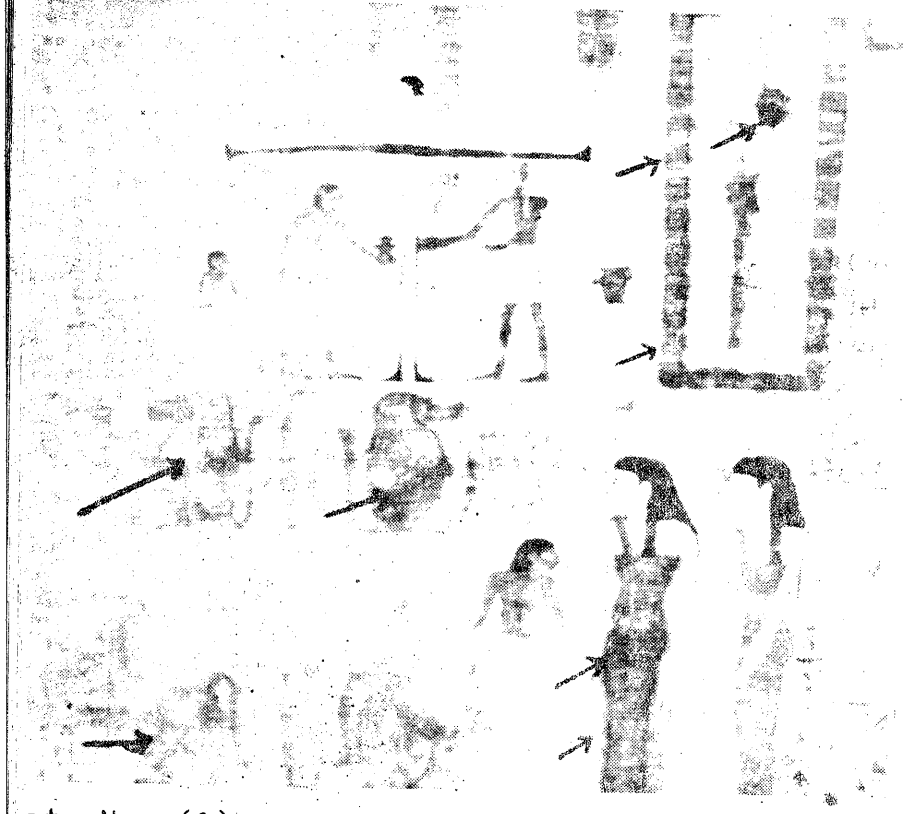
So. the acidity is the main factor in the change of malachite colour in the form of paling or darkening effects as in our case. And also acidity is main factor responsible for deterioration of papyrus material as shown in the accompanied photos (٤-٧).

Recommendation for saving such a case of papyrus and as general direction to save the historical collection in the Egyptian Museum in Cairo as follows:

1. Elimination of the pollution source to the Egyptian Museum, i.e. to move the terminal bus station, and in general all the traffic movement away from the museum location, and to substitute it with green land cultivated with flowers and ornamented with copies of the ancient Egyptian sculptures.

2. Concerning the internal condition of the museum environment, it must stabilize the relative humidity inside the building up to no more than 50% with a constant temperature of 20°C. The museum must be supplied with specific filters for light and air pollution especially that of SO_2 and NO_2.

3. For treatment of the explained case of papyrus, we propose the usage of the non-aqueous deacidifier/sizer mixture consists of Barium hydroxide (2%) + Hydroxyl-propyl-cellulose 2% in methyl alcohol (Hermans et al., 1988).



oto No. (1):
lustrates the change in the green pigment indicated by arrows.

oto No. (2):

same as photo No. (1)

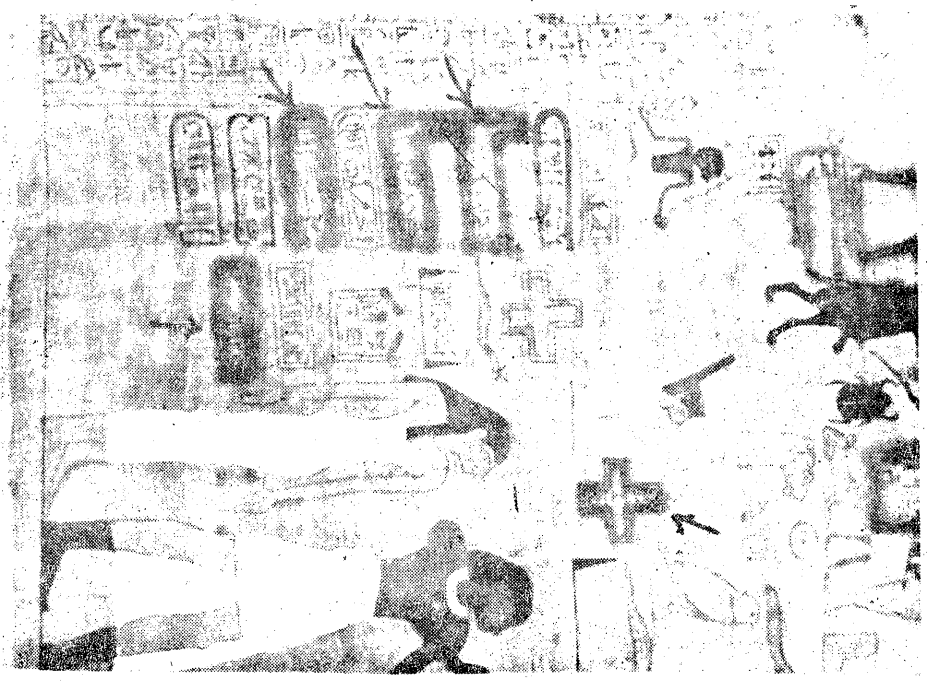


Photo No. (3)
Illustrates Focus picture on the burning symptom in the pigment areas (indicated by arrows).

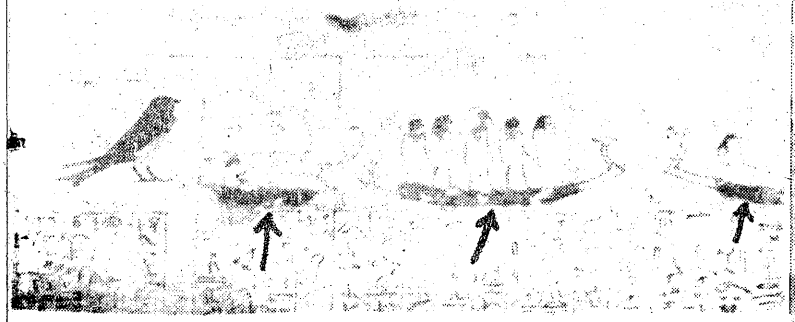


Photo No. (4)
- Both photos (4 & 5) illustrate the decaying symptoms on the pigment areas

Photo No. (5)

Photo No. (6)

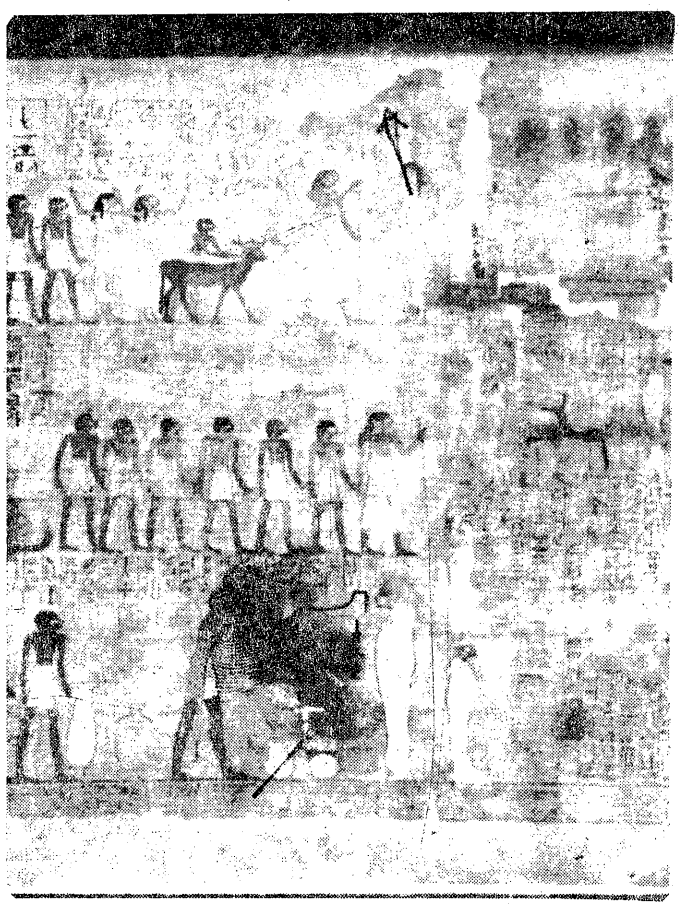


Photo No. (7)

- The same as in photos (4 & 5) - (decaying symptom)

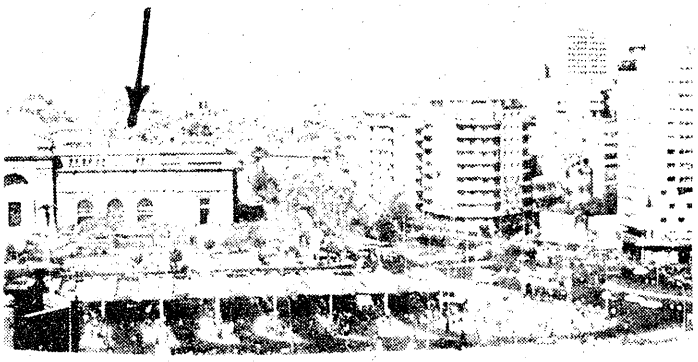


Photo No. (8)

Photo No. (9)

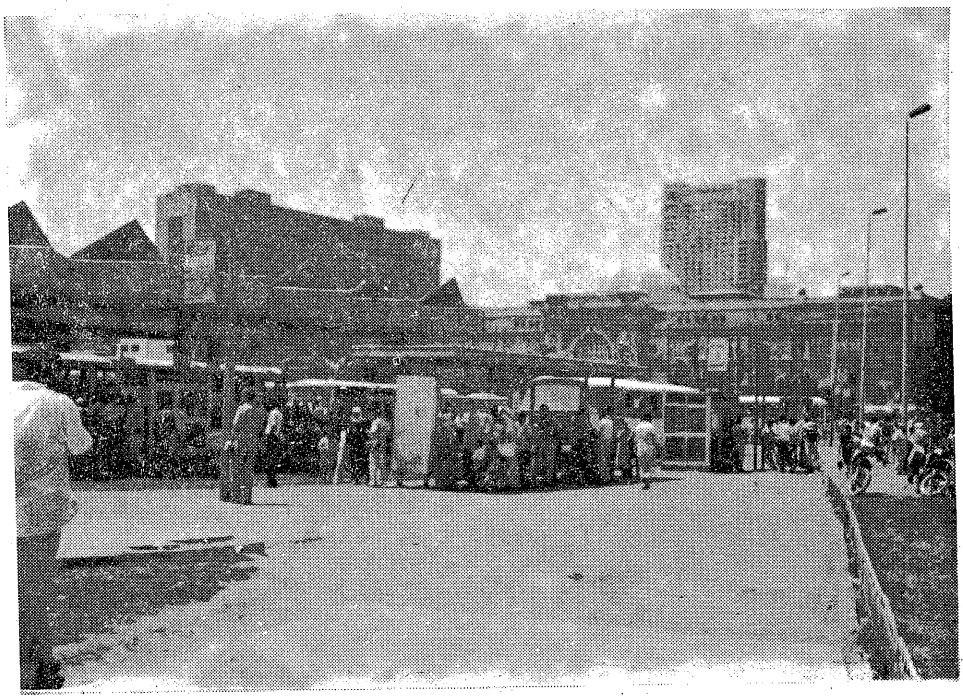


Photo No. (10)

Photo No. (11)

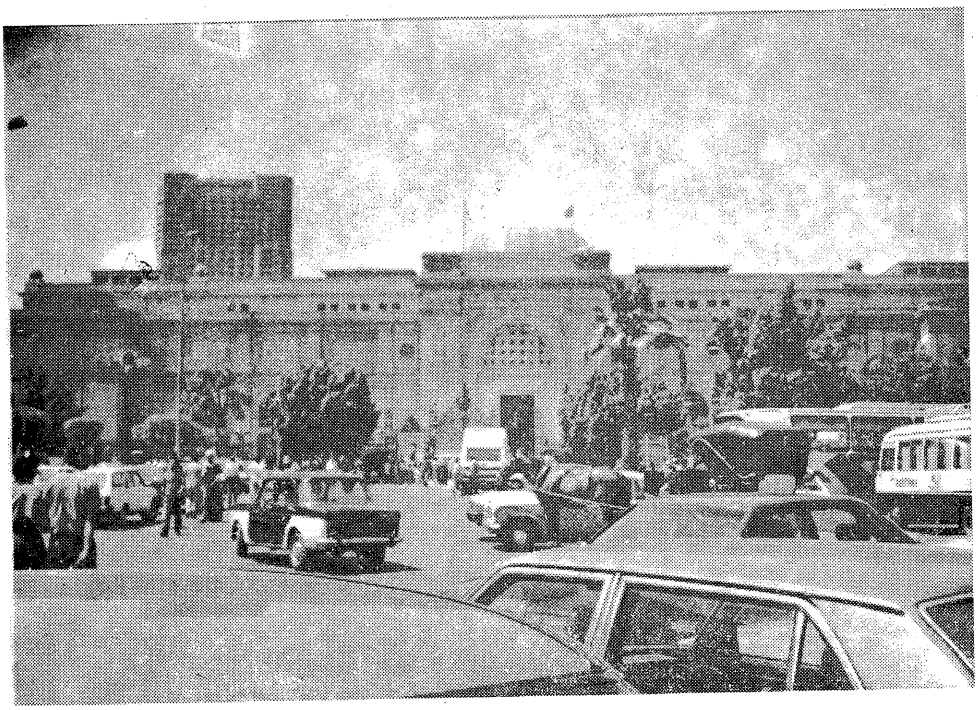


Photo No. (12)

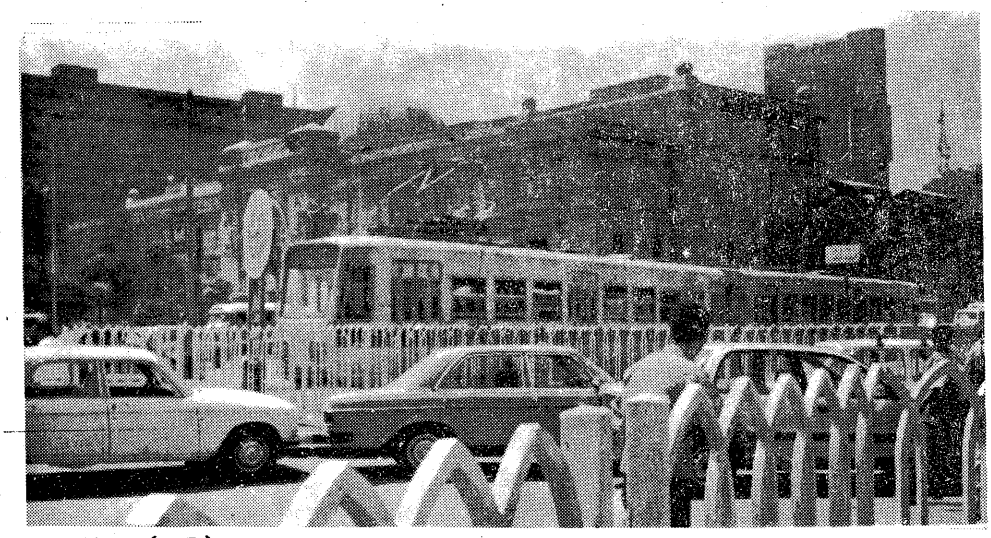


Photo No. (13)