Investigation and examination of a degraded Egyptian painted limestone relief from Tell Hebua (Sinai)

Eid Mertah[1]*, Moamen Othman[2], Mohamed Abdelrahman[3], Mohamed Fatoh[4] and S. Connor[5]
[1] Conservator of archaeological materials, Conservation Centre, Egyptian Museum of Cairo, Ministry of Antiquities, Egypt
[2] Director of conservation Centre, Egyptian Museum of Cairo, Ministry of Antiquities, Egypt
[3] Director of Scientific Research, Projects Sector, Ministry of Antiquities, Egypt
[4] Chief of stone Conservators, Conservation Department, Egyptian Museum of Cairo, Ministry of Antiquities, Egypt
[5] Research Fellow at The Metropolitan Museum of Art, New York
**** eid.mertah@yahoo.com***

Abstract

This paper presents a study bas-relief from the New Kingdom (1550-1070 BC), which was found in Sinai in 2009 and came the Egyptian Museum, Cairo, in a quite challenging condition. The interest of this piece lies in the danger that the salt causes to the block's surface, and particularly to the pigments of its decoration. The block is sculpted on two opposite sides, which both need to be consolidated, in order to be safely displayed in the museum's galleries. The authors describe the investigation carried out to identify the types of salts and to select the possible techniques to remove them and preserve the surface and pigments.

Keywords: limestone relief, Sinai, salt weathering, crystallized salts, stabilization.

1. History

The piece which is the object of this study is made of limestone. The decoration is on two opposing sides. Its dimensions are: Height. 107; Width. 114; Thickness. 27 cm. It is currently in display in the gallery in the Egyptian Museum, Cairo, with the inventory number JE 100014 (= SR 4/15988).

The block was found in a New Kingdom military site, discovered in North-West Sinai on April 22, 2009, Tell Hebua II,[1] the ancient "khetem of Tjaru"[2], about 4 km from the city of al-Qantara East, on the East Bank of the Suez Canal, about 50 km north of Ismailia.

Recent excavation led by Mohamed Abd El-Maksoud for the Supreme Council of Antiquities revealed an impressive defence system, consisting of a series of mud brick fortresses, protecting temples, administrative buildings and domestic structures, dating back from the New Kingdom to the Late Period (ca. 1550-332 BC). These fortified cities were intended to protect Egypt's North-Eastern border.

The site of Tell Hebua II, which seems to have been used for military purposes essentially in the New Kingdom, continued to be occupied in later times. Indeed, the excavators found this relief, together with several other temple blocks decorated and inscribed, reused in the casing of later tombs set within earlier structures. According to the continuity of the ornamentation and the orientation of their inscriptions, these blocks most probably belonged to a tripartite sanctuary, the foundations of which could not be identified so far. These blocks attest two phases of decoration: the first one during the reign of Thutmosis II (1482-1480 BC) and a second during that of Ramesses II (1279-1213 BC).

The decoration of the studied relief presents a particular interest, since it displays offering scenes on either of its opposing sides, sculpted at two different times: on one side, carved in raised relief[3], Thutmosis II receives life from the god of war Montu, while on the other side, which is carved in sunken relief, Ramesses II makes an offering of bread to the god of earth Geb. Very few representations of Thutmosis II are known so far, which makes this relief, of very high quality, a precious testimony of his reign. Furthermore, this block is evidence of the restoration and reuse of stone structures during the reign of Ramesses II in the fortress and its temple, two centuries after its building.

Due to the quality of its reliefs and its poor state of preservation, the piece was brought to the Egyptian Museum, shortly after its discovery.

2. Conservation state

The block JE 100014 was not found in its original setting, but reused as the closing of the entrance to a tomb cut into the rock. Since it was then buried under soil and surrounded by mud, it was in relatively wet and closed environment

Figure 1: Slab JE 100014 in its current display in the Egyptian Museum – face 1 [left image] (offering scene of Ramesses II) and face 2 [right image] (offering scene of Thutmosis II).

Figure 2: Slab JE 100014 when discovered as closing for the entrance of a tomb


Figure 3: [left image] Crystallized salts in the upper area of the Ramesses II's side, [right image] Crystallized salts in the lower area of the same side.

for more than two thousand years. The photographs taken at the time of its discovery still show a good state of preservation of the upper side of the piece, which was that of Thutmosis II's offering scene.[4] According to the available records, and to the information provided by Gharib Sonbol, chief of the restoration team during the excavation, the lower face of the block, showing Ramesses II, had already suffered salt damage when the block was discovered. The removal of the limestone block from its wet atmosphere to a much dryer one, in the Egyptian Museum, probably intensified this process of salt damage since salts were moving to the surface of the block as drying occurred, and therefore accelerated the deterioration of its sculpted and painted decoration.

The majority of the painted areas became weak and needed urgent consolidation. In many zones, crystallized salts have appeared below the layer of colour, which might lead to its loss in the future. This situation is particularly visible on the side which contains the scene of Ramesses II (which was placed face down, when the piece was reused as a slab for closing

Figure 4: The circle shows the area where Microballoons filler was used to complete the missing parts of the pigment layer. This intervention should be reduced in order to become more discreet and suitable for the rest the surface.

the tomb). On that side indeed, crystallized salts are not limited to the painted layer, but also invade the whole surface, especially in the upper and lower areas, where the inscription is carved.

Tests and analyses were carried out on the painting (visual examination, examination using magnifying glasses and optical light microscope, portable X-ray fluorescence [PXRF], Fourier transform infrared spectroscopy [FTIR] Analysis). They revealed that the painting was previously restored; partly at least on the archaeological site itself, according to the information provided by the restoration team. As the analysis demonstrated *(see below, Fig. 7)*, it appeared that Paraloid B72 had been used in the consolidation process, and that microspheres known also as microballoons filler (i.e. a glass

Figure 5: Spots where Digital light microscope images were taken on the side of the block which shows the offering scene of Ramesses II.

Figure 7: Side of the offering scene of Thutmosis III, on the slab JE 100014. The photo shows the areas where Digital light microscope images were taken.

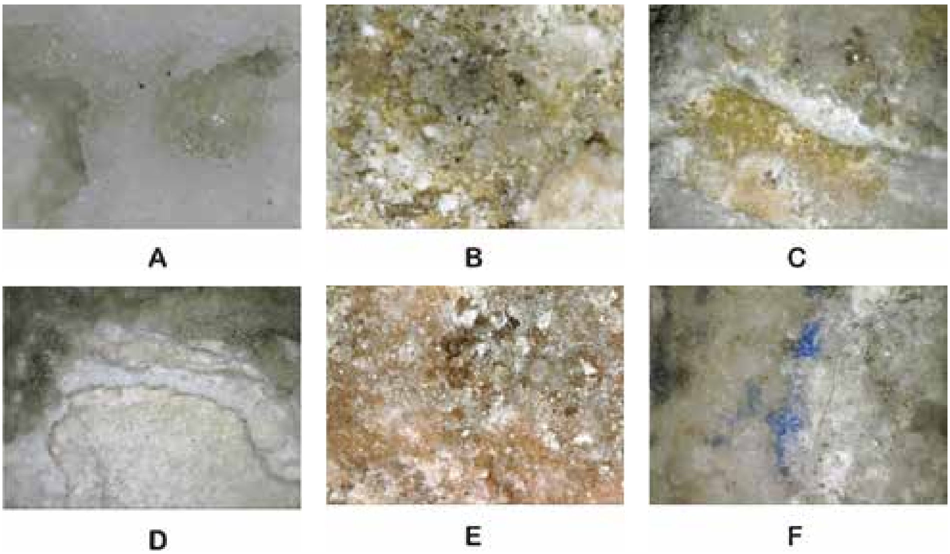


Figure 6: Digital light microscope images on Ramesses II's side of the slab. Images A and B show the crystallized salts on the surface of the relief. C and D show the crystallized salts above and below the pigments, which already led to the fall of some parts of the colour's layer. On image E the crystallized salts are captured inside the red colour, while F consists in a photograph of the crystallized salts above the blue colour. [A, B, E] 250x; [C, D, F] 50x.

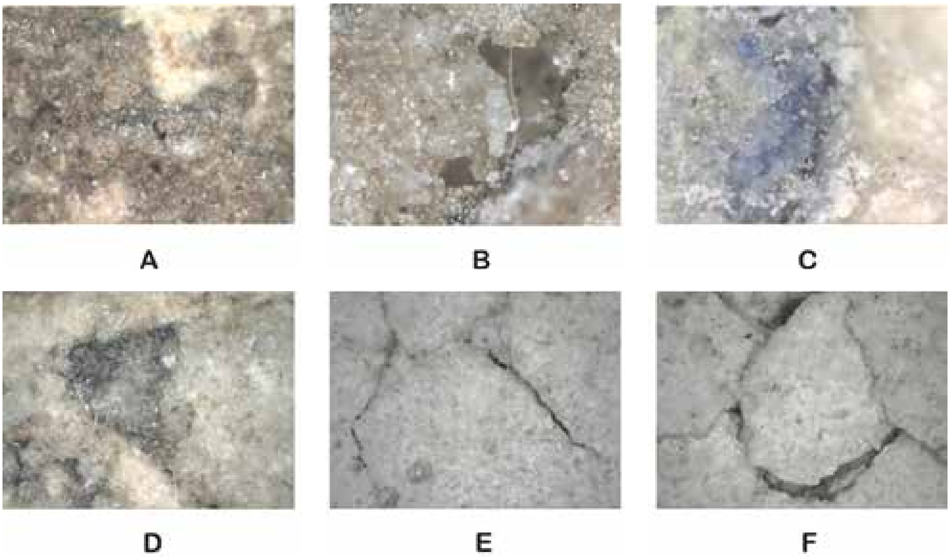


Figure 8: Digital light microscope images taken on the Thutmosis II's side. A shows the crystallized salts inside the red colour; B shows the crystallized salts above and below the pigments, which led to the fall of some parts of the colour's layer; on that photograph, we can see the flacking between the painted layer and the original surface. The crystallized salts inside the blue colour are visible on image C, while on D are shown the crystallized salts inside the eye of the figure of the king. E and F show the cracks and the micro-cracks on the surface of the relief. [A, C, D, E, F] 50x; [B] 250x.

fibre based on Silica [Si]) was also used to complete some parts, probably after the relief entered the Egyptian Museum.

The block needs a re-restoration, a stabilization of its fragile areas and a study of the possible ways to remove crystallized salts from the weak parts, and to preserve the painted layer.

In the framework of our study, different techniques, described in the following parts, have been used to identify the causes of rapid deterioration, salt weathering, which may have partially occurred in the external environment where the relief was lying before its discovery, but which has continued, since the relief has been installed in a poorly controlled interior environment, in the galleries of the Egyptian Museum.

3. Analytical Procedure

This section discusses the results of the different analyses and investigation techniques carried out to identify the salts emerging from the block and damaging its surface, and the nature and the state of preservation of the pigments on the decorated surface.

3.1. Optical light microscope (O.L.M.)

A portative optical light microscope was used in order to reveal details such as the porosity, grain morphology and micro-cracks. A series of twelve spots (six on each side) were analysed *(see fig. 5 and 7)*. The used device (Dino-Lite Digital Microscope) allows taking high quality photos (from 50 to 250x), even without direct contact with the surface of the object – the fragile state of preservation of the relief JE 100014 required a distance of a few millimetres to be kept. This first examination allowed determination of the different lithotypes of the block: it provided information about the damaged layers, such as the sequence of layers, the particle size, as well as the colour and texture of these layers. It also showed the cracks and the micro-cracks on the surface of the relief.

Furthermore, the microscope examination revealed that the salts are not only above the layer of colour, but also under it and inside it and thus putting it in particular danger *(see fig. 6 and 8)*.

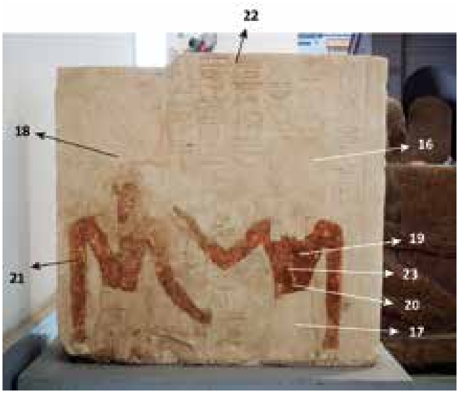
3.2. Portable X-Ray Fluorescence [PXRF]

X-Ray Fluorescence is widely used in the field of archaeometry due to its non-destructive properties, its high sensitivity and its applicability to a wide range of situations. The Egyptian Museum's lab owns a portable device (Elio Device SN 177), which we used to determine the specific elements that are present within the pigments and in the stone block itself (including the salts).

We selected a series of twenty-two points (fifteen on the Ramesside size and eight on the Thutmoside one) in order to cover all the different areas of the surface of the block, including the different painted layers, as well as the various parts covered with salt.

The analysis revealed a widely spread crystallization of chlorine salts on Ramesses II's side of the slab, and what appears to be calcium sulphate salts on the other side, due to the presence of sulphur *(see table 1)*. Both types of salt are also present within the red pigment (made of hematite, *see Table 2*), as well as in the blue and green pigments (both acquired from copper firing process, *see Tables 3 and 4*).

On the side (1), depicting Ramesses II (see figure 9-10), two analyses were made (14 and 15) on what seemed to be white colour. This revealed itself to be, through the PXRF, not to be a pigment but the microballoons used during the previous restoration (see above).



Figures 9 and 10: Slab JE 100014, with numbers showing the areas where PXRF analysis was carried out – face 1 [Fig. 9] (offering scene of Ramesses II) and face 2 [Fig. 10] (offering scene of Thutmosis II).

3.3. Fourier Transform Infrared Spectroscopy [FTIR] analysis

A sample of the red colour which had already fallen from the surface of the block was sent to the laboratory of the Ministry of Antiquities for a FTIR analysis, which allowed identifying an adhesive applied on the pigment layer, in order to fix it during the previous restoration: Paraloid B72.

4. Preliminary conclusion and salt-reduction treatment

This article discusses the investigation carried out on a limestone relief found in

	No.	Elements	Results
(1) Side with Ramesses II's offering scene	1	Ca, Cl	The stone itself is limestone (calcium carbonate). As revealed by the analysis, the side (1) suffers from a widely spread crystallization of chlorine salts on the surface. The side (2), however, contains sulphur, and may therefore contain calcium sulphate salts.
	2	Ca, Cl	
	3	Ca, Cl	
	4	Ca, Cl	
	5	Ca, Cl	
(2) Side with Thutmosis II's offering scene	16	Ca, S	
	17	Ca, S	
	18	Ca, S	

Table 1: Results of the [PXRF] analysis on the stone itself

	No.	Elements	Results
(1) Side with Ramesses II's offering scene	9	Ca, Cl, Si, Fe, S	The PXRF revealed the presence of Iron (Fe) inside all the red pigment, which means that it consisted of red hematite (iron oxide hematite Fe_2O_3). The presence of chlorine and calcium sulphate is due to the crystallization of salts inside the pigments (as well as under and above them).
	10	Ca, Cl, Si, Fe, S	
	11	Ca, Cl, Si, Fe, S	
(2) Side with Thutmosis II's offering scene	19	Ca, Cl, Fe, S	
	20	Ca, Cl, Fe, S	
	21	Ca, Cl, Si, Fe, S	
	23	Ca, Cl, Fe	

Table 2: Results of the [PXRF] analysis on the red colour

	No.	Elements	Results
(1) Side with Ramesses II's offering scene	6	Ca, Cl, Si, Cu, S	The presence of chlorine and calcium sulphate inside the green pigment is due, like in the case of the red one, to the crystallization of salts (see above). However, the colour was here acquired from copper.
	7	Ca, Cl, Si, Cu, S	
	8	Ca, Cl, Si, Cu, S	

Table 3: Results of the [PXRF] analysis on the Green colour (only on side 1)

	No.	Elements	Results
(1) Side with Ramesses II's offering scene	12	Ca, Cl, Si, S, Cu	The elements are similar to those observed previously. Indeed, green and blue colours are both acquired from a firing process of copper. The presence of chlorine and calcium sulphate provides again the nature of the crystallized salt inside the pigment.
	13	Ca, Cl, Si, S, Cu	
(2) Side with Thutmosis II's offering scene	22	Ca, Cl, Si, S, Cu	

Table 4: Results of the [PXRF] analysis on the Blue colour

a wet environment ten years ago, currently in display in the Egyptian Museum, Cairo (inv. JE 100014). This block has been subject to different deterioration processes, and needs urgent consolidation and restoration. Atmosphere variations during the years following the block's removal from its original environment caused salt crystallization and numerous internal and external stresses.

Our team carried out various techniques of analysis, in order to establish the different causes of damage and to identify the most suitable methods of restoration. First of all, before carrying out any conservation work, the block was carefully examined on all its sides. Each of the alterations and degradations was mapped, documented and registered in the conservation records.

A first investigation with the Optical light microscope (O.L.M.) allowed identification of the nature of the stone and the different lithotypes present in the block, and drawing out a map of all cracks and micro-cracks. It revealed the presence of salts not only above, but also inside and beneath the layers of colour, on the decorated surface of the reliefs.

An examination with a Portable X-Ray Fluorescence [PXRF] tool established the nature of the different elements from which the stone and pigments were composed. The whole surface of the block and its painted decoration were found to suffer from a crystallization of chlorine and calcium sulphate salts.

Finally, a Fourier Transform Infrared Spectroscopy [FTIR] analysis applied on a sample of red pigment revealed the presence of adhesive Paraloid B72, applied on the pigment layer in order to fix it during a previous restoration.

These different methods demonstrate that the weathered surfaces of the block have undergone continual warming and cooling cycles, due to the semi-dry atmosphere of Tell Hebua. The surfaces now exposed are enduring physical disintegration, as assessed from macroscopic visual analysis. The block suffers from several deterioration of its structural coherence: cracks, microcracks, cavities, loosing of material, resulting of needles of salts between grains, and accumulation of different kinds of dirt.

We are currently in the process of identifying the nature of the salts and their

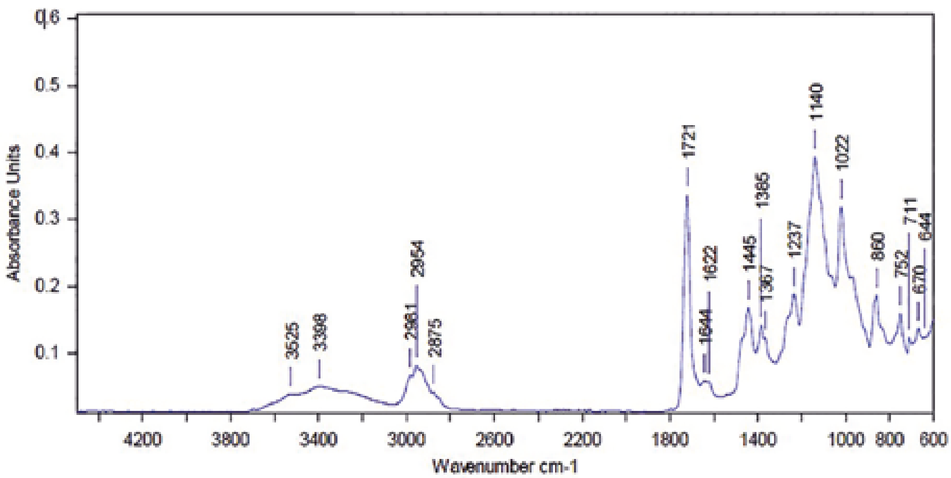


Figure 11: Spectrum FTIR of the sample of red pigment

degree of solubility, in order to choose the most appropriate method for removing them to prevent further desintegration of the stone due to their active presence. Some salts revealed themselves to be of calcium sulphate, which is very soluble and will be easily removable, but some other salts might be of unsoluble calcite, which would therefore require a mechanical cleaning. The chlorides identified on the side of Ramesses II (see table 1), they may show a variable level of solubility (either high solubility, if they consist of calcium or copper chlorides, or low solubility in the case of sodium chloride), and therefore require further investigation.[5]

Before any new restoration, we will first proceed to some de-restoration of the piece. The microballoon filler, applied at the arrival of the block in the museum, should be reduced to a smaller area, in order to produce a more suitable and sympathetic aesthetic appearance. In other situations, a de-restoration, although desirable, will probably be difficult: indeed, the presence of the materials used in early restoration treatment will have an impact on the ways of undertaking future consolidation work and must be taken into account. The Paraloid B72 applied on all the painted surfaces forms a film, covering large areas, which prevents the salts reaching the surface of the block during their migration. This creates a detachment between the stone and the painted layer, which is likely to continue to increase.

Due to the friable nature of the stone, and the fragility of the pigments[6] each consolidation and conservation intervention will be performed according to the needs of each of the individual problematic zones, after thoroughly testing all possible procedures.

In order to prevent further degradation of the relief, some precautions will be necessary to keep it on display in the Egyptian Museum. Controlling, to the maximum of possibilities, the relative humidity and temperature in the gallery would help prevent further salt damage; this is of course quite difficult in the current conditions of display, but will hopefully be improved in the near future.

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[2] Concerning the name of the site in the antiquity and the nature of frontier fortresses, see Somaglino C., “Les ‘portes’ de l’Égypte de l’Ancien Empire à l’Époque Saïte”, Égypte, Afrique & Orient 59 (2010), p. 10; Id., Du magasin au poste-frontière dans l’Égypte ancien-

ne : étude lexicographique du vocable khetem, (unpublished Phd dissertation, Paris IV University, under the direction of D. Valbelle, 2010, forthcoming in the Ifao series.

[3] On the side of Thutmosis II, the figures and the hieroglyphs of are all in raised relief, except for a few signs in the middle of the inscription, which are in sunken relief. These signs, which give the name of "Montu, lord of Thebes", were most probably originally in raised relief too, but were erased during the iconoclastic phase of the Amarnian period (1353-1334 BC), and then restored, necessarily in sunken relief, probably in the time of Ramesses II, when the king commissioned a new ornamentation of the temple. Cf. Abdel Maksoud M. and Valbelle D. 2011 (cf. supra).

[4] Our thanks go to Gharib Sonbol, who directed the team of restoration on the site during the excavation, and who kindly provided us information about the context of discovery and the state of preservation of the block in 2009, and allowed us to use the photos taken during the mission, in this article. Thanks are also due to Bianca Madden, for her coments and kind revision of English writing.

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[6] For similar cases and valuable sources of inspiration for salt treatment, see: Mirabootalebi R., "Conservation of A Highly Degraded Egyptian Limestone Stele", e-conservation Journal 3 (2015), available online 06 November 2015 (http://www.e-conservation.org/issue-3/52-Egyptian-Limestone-Stele); Doehne E., "Salt Weathering: A Selective Review", Geological Society Special Publication. Natural Stone, Weathering Phenomena, Conservation Strategies and Case Studies 205 (2002), p. 51-64.