



THE DETERIORATION PROBLEMS OF THE WALL RELIEFS OF KOMIR TEMPLE, ESNA, EGYPT

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ABSTRACT

The supreme council of antiquities in co-operation with the French mission discovered the Ptolemaic temple of Komir in 1979 in Esna, Upper Egypt. The Ptolemaic temple of Komir was built of regional sandstone and preciously decorated with reliefs and inscriptions. Investigation of the condition of the sites, together with physical, chemical, and mechanical tests of their material revealed that, it is collapsed and only partly preserved and it disposes of some still buried rooms. The Komir temple is exposed to different deteriorations processes caused by internal and external stresses due to the mineral composition of the building materials, climate factors, salts crystallization and groundwater. In this study, the deterioration problems of the wall reliefs were investigated for the aim of its conservation. For this purpose, the building was documented by drawings and photographs. The chemical, physical and structural characterization were performed by means of X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF) and observation of thin section by transmitted light optical microscopy (LOM), polarized microscope, Scanning Electron Microscope (SEM) attached with EDX and thermogravimetric (DTA &TGA). The physical and mechanical properties were done. The results showed that, sandstone is mainly composed of quartz, albite, orthoclase, microcline and dolomite. The density and porosity values of deteriorated sandstone are 1.52 g/cm³ and 25%. Results also showed that the deterioration of stone materials is due to the aggressive action of the environmental agents. Soluble salts, such as chlorides and sulphates were found in efflorescence samples. These results and information allowed the identification of the types of salts and deterioration features may be used in the future for conservation purposes.

KEYWORDS: Sunk reliefs, Komir temple, Ground water, Salt weathering, Excavation.

1. INTRODUCTION

The Komir temple is one of the most important sites in the third Nome of Upper Egypt and it is located in Komir village. This village is on the west bank of the Nile, 15km. south of Esna, Upper Egypt. Komir temple is dated back to the Ptolemaic period and dedicated to Anoukis and Nephthys. Until now the archaeologists can't decide the exactly date of the temple because of unfinished excavation completely. The temple was completely constructed from local sandstone called "Nubian Sandstone" which was cut from the quarry of Gebel El-Silsila, in south of Esna. It is one of the most prominent sites intensively used for quarrying since the MK "is the river gorge" at the Gebel El-Silsileh, some 70 km north of Aswan (Dietrich & Rosemarie 2001). The remains of Komir temple show fine reliefs and inscriptions stone which are very fragile and highly endangered by climatic and human influences. Parts of the site are not yet completely excavated. The aim of this study was to study the building materials of the temple and characterize the deterioration mechanisms that effect the wall reliefs, moreover suggestion the suitable procedures for restoring plan of the temple.

ARCHAEOLOGICAL HISTORY OF KOMIR TEMPLE AND ITS RELIVES

In 1941 the temple of Komir had been discovered. The history of beginning excavation there goes to back 1941, when an inhabitant of Komir village came upon large inscribed sandstone blocks while digging for sebackh in his house, these formed part of a wall, 2.40m long and 1.20m wide. On October 1956, seven small mud-brick houses were purchased for the sum and 12 iron bars were pounded into the ground to mark the limits of the area, then the site came under control of the Egyptian Antiquities department. First scientific excavation was done in 1976 by the Egyptian Antiquities department. Most

of the modern houses were removed and revealing some blocks of sandstone wall bearing the cartouches of Antonius Pius, thus indicating the date of the place approximately. The next excavation phase started in 1979, M. Es-Sagher and V. Dominique completed the excavation in Komir and they discovered nearly 600m represented the back foundation part of the temple. It is noticed that, presence of extension for the discovered part of the temple under the adjacent houses. At the end of this excavation period the temple site showed the same excavation status as today. The general description of the discovered part of the temple as may be seen from the plan (figure 1a). The temple in its present state forms a rectangle of 20m, E-W by 15m, N.S, its orientation being perpendicular to the Nile. Its entrance is to the east. The main parts of the temple are; 1- a hypostyle hall, with no extant columns, only partly excavated, the rest still being under the houses to the east of the temple (figure 1b). 2- The inner hypostyle hall or the outer vestibule, this hall measures 7.60m NS × 3.04m EW. 3- The second Vestibule hall, this hall has some dimensions as the previous one, its northern wall is completely destroyed, but it seems that it contained a stairway leading to the roof of the temple. The southern wall wasn't cleared because of the village houses. The western wall lies under the road left for the inhabitants of the village. 4-The Sanctuary; this is a rectangular chamber lying east to west and measuring 4.30×3.20m. It has a central chamber with two rooms (Es-Saghir and. Dominique 1979). The wall paintings of the Komir temple were carved with sunken and raised reliefs represented the king of Upper Egypt, Antoninus Pinus, facing north, wearing the white crown and a short skirt introduces the offerings to a god or goddess African, Asiatic, and figures of the personified cities and tribes subdued by the Emperor (Fig.2). They are bound together with papyrus stalks in a symbolic

depiction of the Emperor's victories , they include African, Asiatic as well as Mediterranean territories, long symmetrical texts of hymns addressed to Anukis and Nephthys, papyrus and lotus swamp.

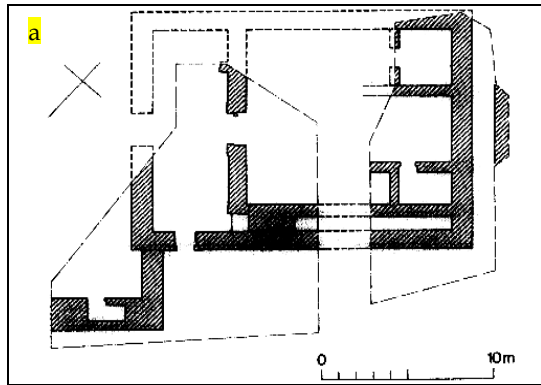


Figure 1a,b a: View of the excavated part of the temple (Es-Saghir and Dominique 1979) b: Extension for the discovered part of the temple under the adjacent houses of Komir village



Figure 2 wall painting at Komir temple represented the king Antoninus Pinus introduces the offerings to a goddess.

2. FIELD OBSERVATIONS AND DEGRADATION CAUSES

During the inspection of the Komir temple, different kind of alterations and degradation phenomena were evidenced, such as missing parts, erosion of stone surfaces, exfoliation, wind corrosion, flaking, crumbling to splitting, cracking of the stone surface, macro, micro destruction of walls by wasp nests and saliva, wide deep cracks, disintegration of many parts, dissolution, salt efflorescence, accumulates of dirt, flakes, pits, joints, fissures, accumulation of white and black

rusts, biological attacks and effects of human exploitations were found in the surface of stone blocks (figure 3a-j). The stone surface of the temple became blackish in appearance due to deposits of dust, dirt and dried vegetation and micro vegetation. Due to these deposits the aesthetic beauty of the reliefs is seriously affected. A lot of deterioration factors play an important role in the degradation of reliefs at Komir temple. The most cited affecting the site is a moisture source

(ground water) resulting from dramatic rise of the water level. The main reason for the water rise is the location of the Komir village. It occupies an ancient mound now becomes located two meters under the level of the surrounding cultivated land and it is located to the east of the modern El-Ramady Canal and opposite the village of Esh-Sharawan on the east side of the Nile. In addition to the village situated two meters under the level of the Nile. Also the main reason for the water rise is the seepage from land reclamation areas, sewage water from cultivated lands and waste water from homes located two or more meters above the level of the temple. This water rich in chloride and total dissolved solids reacts with the lower parts of the engraved stone blocks and partly buried parts causing several damages and cracks. Also water sometimes penetrates those cracks and causes the surface layer to peel off, detachment of the superficial layers of reliefs and may even cause large stone blocks to fall off. The temple is subjected to the severe action due to the climate. Komir village lies at the bank of the Nile valley in a desert environment. According to the bio-climatic provinces of Egypt, the area is hyper-arid with mild winters and hot summers (Said 1962). Average annual rainfall of 1 mm, mainly in winter, in some years 4–6 mm are recorded, in some years there is no rain at all. The evaporation rates are lowest in January (2.5mm/day) and highest in June (9.4mm/day). The maximum temperatures is 45°C in summer, 15° C in winter, the monthly average of air temperature ranges between 12–32°C. The maximum relative humidity (RH) during winters sometimes exceeding 60% and reaching a maximum of 78% in the early morning and it reaches 30% in August. In the desert situation of the temple heavy wind is very common and the average wind velocity ranges between 3.7 and 12km/h. The extensive changes in air temperature favors the crystallization/re-crystallization cycles of salts, which led to the loss of stone material

as the relief in the form of small pits, cohesion between grains and caused the current detachment of individual grains. Poorly adhesive deposits of salt aggregates lead to discoloration of stone surface, salt efflorescence, blistering, disintegration and formation of many salt encrustations on the reliefs (Mahmoud et al 2010; Ismail, 2001) . Salt weathering is one of the principle deterioration factors in Komir temple, these salts can be observed directly as efflorescence and appear at the surface of the wall painting at Komir temple. Sandstone containing iron oxides which leave disfiguring reddish -brownish stains as shown in (figure 3f). These stains are weakness zones and can cause several alteration features in rock reliefs because these minerals can be dissolved, transported to and then leached from the surface of the temple walls and these nodules would be more susceptible to deterioration than grains of quartz the main constituent mineral. The wall paintings in Komir temple suffered serious damages, due to shock environment. After the discovering of this reliefs, they were leaved without any treatment until now exposing to the environmental shock. The hesitating of sub-surface water, salts, the direct sunshine and the micro-organisms that resulted in the outside surface layers caused weakness of stone and let a lot of clay particles and a lot of foreign materials on the surfaces which disfigured, discoloration of stone surface and hid their reliefs. In addition to the natural weathering causes there are many human deterioration impacts like the former use of the temple as a quarry for building stones from the inhabitants of the village. Alterations that hint to fires inside the temple are frequent. On the walls there are many relics of soot from burn weeds and waste by inhabitants. The surfaces are black and react more to heat impacts as shown in (Fig.3j).

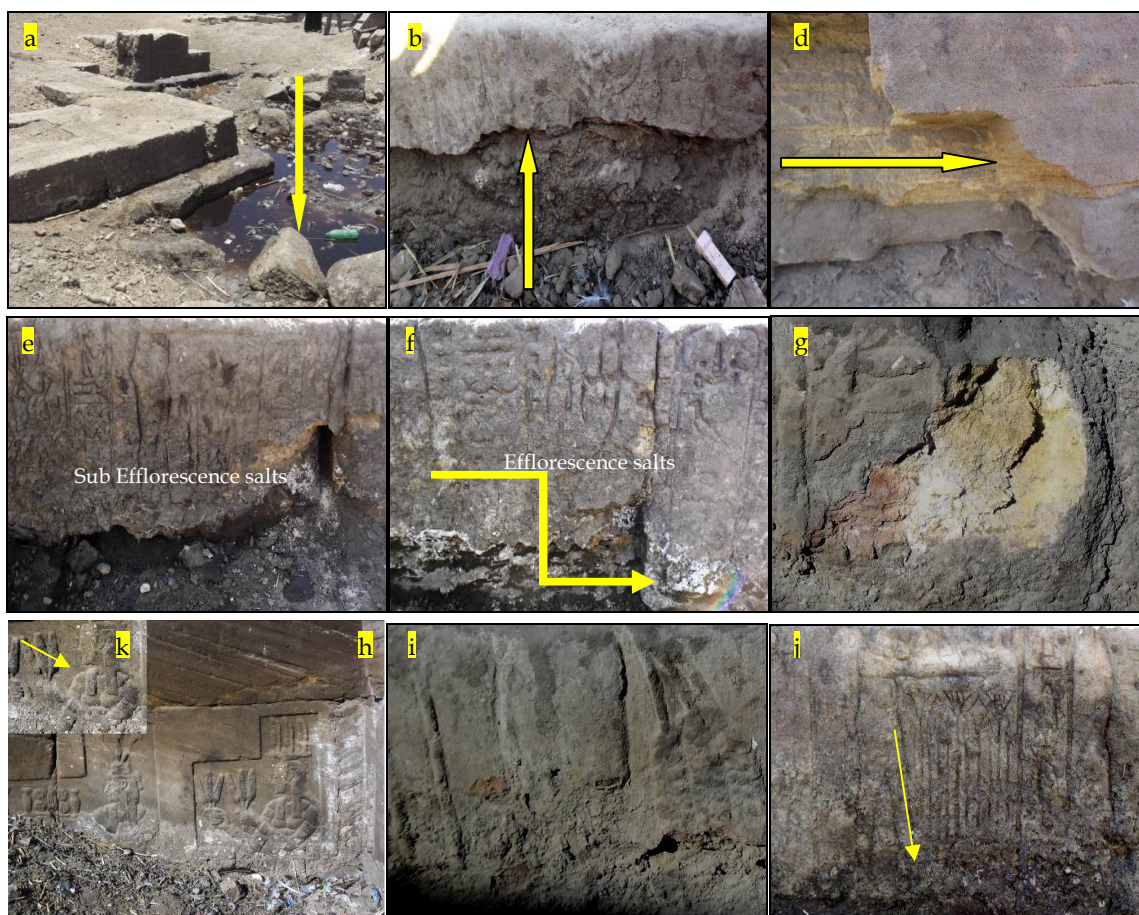


Figure 3a-j weathering forms of the reliefs at Komir temple **a** rising in sub-surface water at the temple **b** peel off the surface layer **c** detachment of the superficial layers of relives **d,e** Efflorescence to light-colored crust tracing the surface and sub efflorescence salts **f** iron oxides which leave disfiguring reddish -brownish stains **g** Light-colored crust changing the surface **h** pitting and obliteration of relives and dark-colored crust tracing the surface **i** micro cracks, cavities, clay particles pits and destruction of walls by wasp nests and saliva, **j** the impact of fire at wall painting.

3. METHODS AND MATERIALS

Some representative well preserved and degraded stone materials were sampled from wall of Komir temple and its relief directly exposed to the action of meteorological agents. The samples were taken from the crusts and areas that had no aesthetic value for future reconstruction or from deteriorated areas. Furthermore, samples of degradation induced by soluble salts were taken from different surfaces. Samples were collected by scraping the surfaces and by chiseling. Salts efflorescence were sampled by brush. Samples of deferent dimensions were taken

from each block. One blocks of un-graved sandstone from Komir temples were used. The number of samples, their dimension and tests carried out on them are listed as follow: 10 samples of 3.5×3.5×3.5 cm for bulk density, water absorption and porosity and 6 samples of 3.5×3.5×3.5 cm for measurement of compressive strength. The collected samples were analyzed and studied to identify the different weathering forms, their products such as salt profiles and salt types. The samples were defined by various techniques that follow:

Optical Light Microscopy (L.O.M (Examination)

The samples were observed by Light Leica DM 1000 stereoscopic microscope Optical Microscope (L.O.M), by using a with a Leica EC3 camera. Optical

microscopy (OM) was very useful for determining the different litho types present in monuments and for identifying the exact stratigraphy of the samples. It can

Petrographic examination

The minerals characteristics, texture, cement materials and diagenetic features of sandstone samples were further examined by using a polarized optical microscope.

Scanning electron microscope (SEM-EDX)

The SEM images of crusts and salt samples and microprobe analyses were performed by (SEM JEOL JSM 6400) to identify textural and mineralogical changes of the rock and altered rock surfaces. The samples

X-ray diffraction (XRD)

The mineralogical structure of samples was determined by X-Ray Diffraction (XRD), XRD analysis was performed by using a Philips X-ray PW 1840 diffractometer. The

Thermal analysis DTA and TGA

Thermo Gravimetric and Differential Thermo Analysis (TGA-DTA) were carried out to measure the clay minerals by detector type DTA- 60H and TGA- 60H, atmosphere: Nitrogen, gas flow: 20ml/min, Pan Name: Platinum, temp. Rate [°C/min]

Biodeterioration study of the engraved limestone

A survey of biodeterioration phenomena was performed in several sandstone blocks by squashed and crumbed (aggregated). For each sample, 1g was diluted with 9 ml of sterilized distilled water. Samples were shaken vigorously to form uniform solution of 10⁻¹ concentrations. The decimal serial dilutions (10⁻¹ to 10⁻⁵) were prepared using the method of (Ejifor & Okafor 1985). For the isolation of fungi, plate count method (Raper & Fennell, 1965)

Organisms/g compost= number of colonies/ (amount plated x 1/dilution).

The same method was used for the isolation of bacteria, by using nutrient agar medium (NA) instead of Czapek's. The inoculated plates were incubated at 37°C from 24 to 48h. The evaluation of

Colony forming units (CFU)/g = Number of colonies X 1/dilution.

provide information of the damaged layers, such as the sequence of layers, the particle size, color and texture of those layers.

Petrographic thin sections were prepared and optically analyzed by using a Leitz polarizing microscope.

were coated with gold and 10 kV voltages were used, coupled with an energy dispersive X-ray spectrometer (EDX) system, detector model 6587.

patterns were run with Ni-filtered, Cu K α radiation ($\lambda = 1.54056 \text{ \AA}$) at 30 kV and 10 mA. The scanning was limited from $2\theta = 1$ to $2\theta = 80^\circ$ range.

10 up to 1000 with $\alpha\text{-Al}_2\text{O}_3$ as a reference material, sample weight: 2.549[mg]. The temperature, weight, change in wt., and the thermal behavior of each mineral were recorded on the chart.

was used as follows: a known volume of the diluted sample, from sample serial dilutions, was used to inoculate the used medium in plates. The plates contained Czapek's agar medium. The plates were incubated at 28 °C for 5-7 days during the developing fungi colonies were counted and identified according to [Domsch et al 1980].The microbial population in the original compost sample was then calculated using the following equation:

microorganism total concentration in each sample was determined by plate counting of serial dilutions according to the equation:

4. RESULTS

L.O.M. Examination

Examination of sandstone samples by optical microscope reveals that, the Komir sandstone mainly consists of polycrystalline quartz grains, occasionally alternating with monocrystalline quartz. The Komir sandstone shows more sandy varieties, less cemented and consequently with a higher porosity. The color of the sandstone varies from grey to yellowish brown depends on the amount of iron oxides (probably Goethite ($\text{FeO}\cdot\text{OH}$) which occur as thin coating around the grains.

Also examination of the sandstone by L.O.M. reveals that, the samples suffer from several deterioration of its structural coherence, the photograph shows cavities, disintegration and chosen of quartz grains. Optical microscopic investigation of the surface crust reveals the presence of gypsum, soot particles and dust from the environment and human deterioration (Fig. 4a-h).

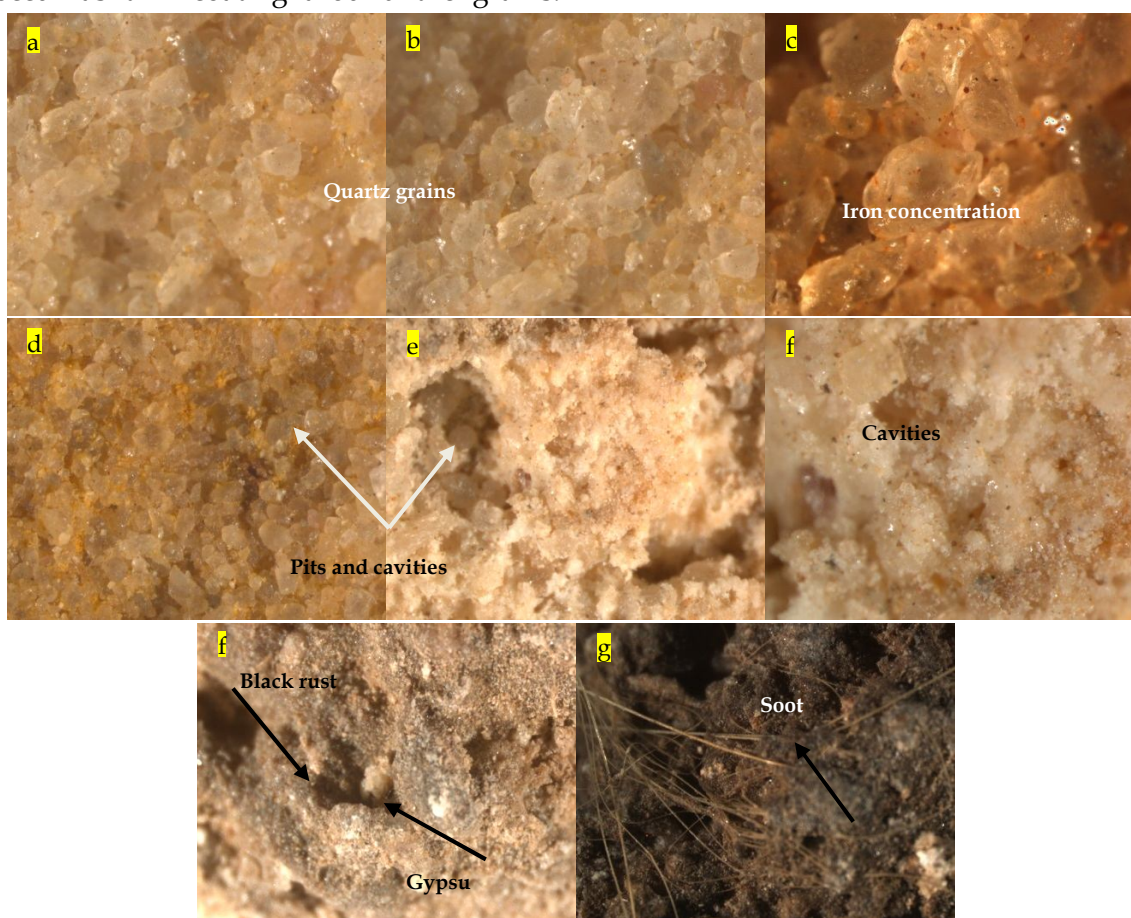


Figure 4a-f microscopically image of surface of Komir sandstone shows, disintegration and chosen of grains, cavities, micro cracks and iron concentration and detail of black surface crust taken with optical microscope.

Petrography investigation

Examination of thin sections of the sandstone samples under polarized light microscope (PLM) indicated that, it composed of quartz (main component); Quartz grains occur as turbid color, it displayed quartz crystals are angular to subrounded in shape and fine to medium

grained. It was affected by mechanical breakage and chemical process which produced micro-fractures and cleavages dissecting the quartz grains into several subindividual grains. They are surrounded by feldspars (partially altered to Sericite), with cement of calcareous and iron oxides.

In these samples small contents of calcite and gypsum were found. The sandstone used in Komir temple described as arcose arenites characterized by a brownish to

yellowish red color in general related to its stone properties (Fig. 5a-f).

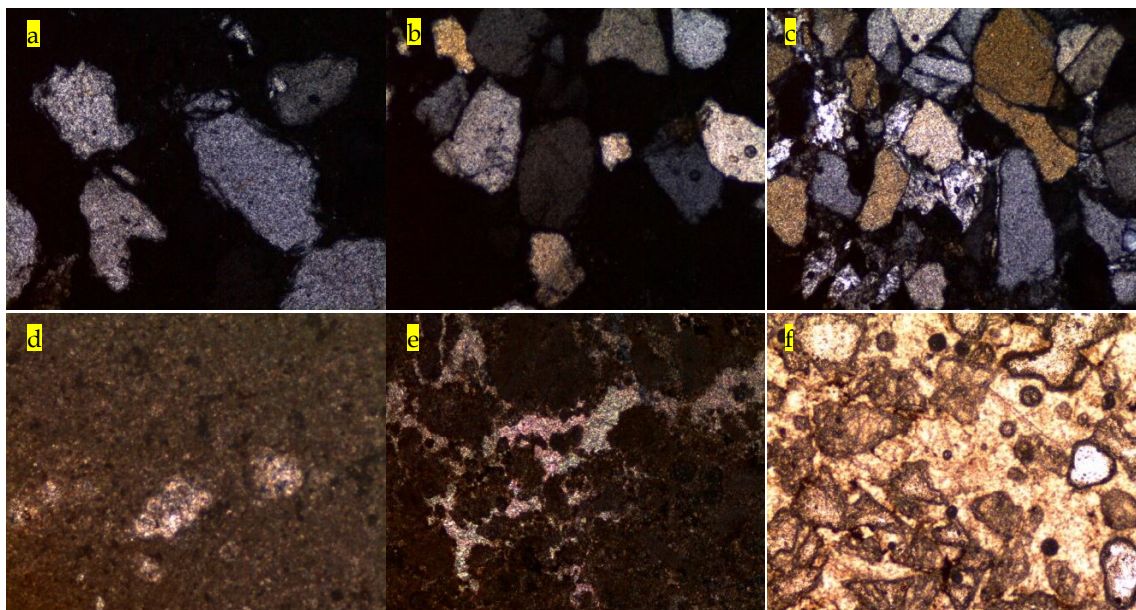


Figure 5a-f: Polarizing microscopy view of sandstone samples; **a,b**: samples taken from hypostyle hall shows quartz grains and feldspars (X40), **c,d** samples taken from the inner hypostyle hall shows quartz grains and feldspars with cement of calcareous and iron oxides as spots, **e,f** samples taken from the second Vestibule hall shows quartz grains and feldspars with ferruginous cement (X40).

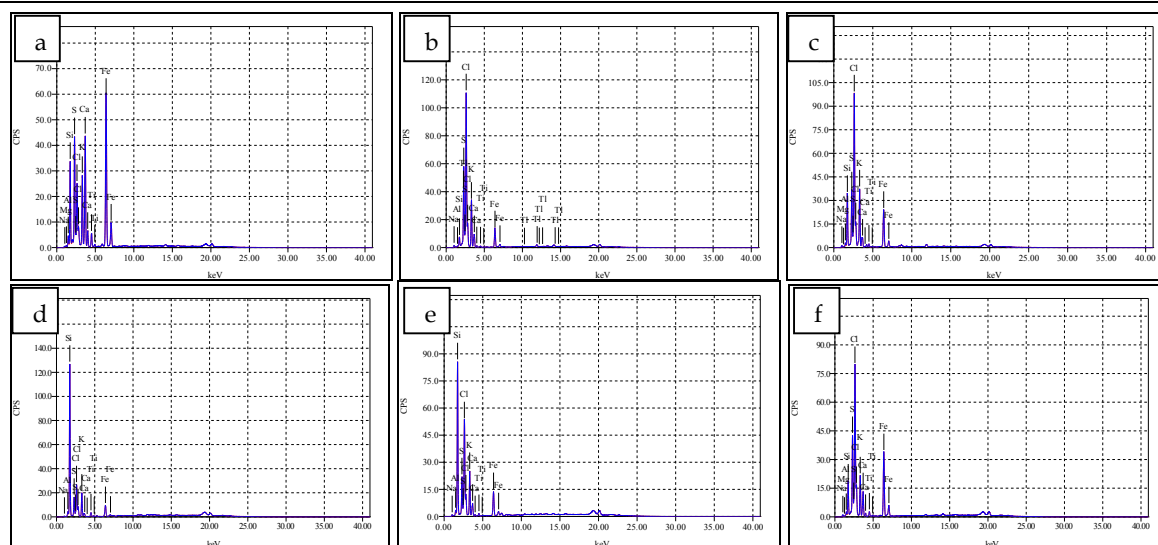
Bulk Elemental Analysis by EDX

The EDX micro analytical methods were performed to identify the sandstone and soluble salts affecting the stone and to evaluate their different components. The investigations results are shown in (table 1) and (figure 6). An EDX micro analysis of the samples indicated that, the elemental arrangement for the sandstone rock samples collected from Komir temple can be put in a decreasing order according to their concentration as follow: Si (24.60%), Cl (20.95%), K(17.45%), Na (12.97%), S(7.88%), Ca (7.27%), Fe (4.63%), Al(2.36), Ti(0.92%), Mg (0.80%). The obtained results help understanding the weathering mechanisms affecting the temple. The main building materials used in the temple is sandstone contained Si as the major element. The high concentration of chlorine (Cl) (20.95%) and sodium (Na) (12.97%) attributed to the crystallization of halite salt

on the wall reliefs. The analysis also revealed a high concentration of sulfate S (7.88%) and calcium Ca (7.27%) ions which may be attributed to the crystallization of gypsum and anhydrite salts on the wall reliefs. In addition, the high amount of potassium (K)(17.45%) and Aluminum Al(2.36) attributed to ph-silicate group. The low ratio of magnesium ions Mg (0.80%) was detected by EDX analysis attributed to Epsomite salt $[MgSO_4 \cdot 7(H_2O)]$. The source of magnesium may be from groundwater contamination and dissolution of dolomite or leaching from clay sediments from Esna shale (Kamally, 2012). EDXS analysis indicated small quantities of titanium in sandstone. The presence of titanium in sandstone due to atmospheric pollution and it plays an important role in deterioration.

Table1: Samples Quantitative EDXS microanalysis of the studied sandstone samples and salts

| Sample | Na | Mg | Al | Si | S | Cl | K | Ca | Ti | Fe |
|--------|-------|------|------|-------|-------|-------|-------|-------|------|-------|
| A1 | 6.66 | 2.75 | 5.26 | 18.96 | 10.12 | 6.88 | 13.82 | 21.70 | 2.05 | 11.76 |
| A2 | 20.10 | --- | 0.10 | 3.02 | 9.77 | 33.82 | 24.32 | 6.02 | 0.29 | 2.51 |
| A3 | 16.34 | 1.13 | 1.96 | 15.70 | 6.78 | 28.30 | 22.10 | 3.08 | 0.76 | 3.80 |
| A4 | 6.70 | --- | 3.04 | 59.31 | 5.19 | 10.32 | 12.52 | 0.74 | 0.97 | 1.18 |
| A5 | 10.39 | --- | 2.03 | 40.47 | 5.69 | 19.12 | 16.14 | 3.63 | 0.42 | 2.07 |
| A6 | 17.67 | 0.93 | 1.81 | 10.15 | 9.78 | 27.28 | 15.85 | 8.46 | 1.04 | 7.00 |

**Figure 6a-f: EDX analysis pattern of the studied sandstone samples and salts from Komir temple.**

Scanning electron microscope (SEM)

Based scanning electron microscope (SEM) observations (Fig. 7a-p), the rock are very weak and have low compactness and durability. SEM image of samples shows a dense coat of halite crystals (Fig.7a) which covers the pores of the stone. Halite was identified in SEM micrographs as large euhedral cubic (Fig. 7b) aggregates (Fig.7c), prism and needles (Fig.7d, e). SEM micrograph indicated that most of the pores were affected by the crystallization of the salt and that a crystal growing in smaller pores (up to several microns) which is capable of exerting sufficient pressure to start or propagate a crack. Gypsum crystals grow within the pores as thin plates and tiny white dots causing many deep pits (Fig. 7g,h). The gypsum salts indicating the existence of sulfur ion, exist as a result of environmental pollution or microbiological activities, especially

with the presence of aggressive alternative cycles of drying and wetting (El-Gohary, 2010). Clay minerals crystals are visible with patches of irregular surface in formed by quartz intergrowth possibly due to deterioration factors (Fig.7i). Bumpy surfaces and disintegration of the sandstone were detected. Moreover, the sandstone shows many micro-weathering phenomena such as micro-pitting, micro-cracking and covering the stone surfaces with dirties cracks, pores and cleavage plane enlarging the cleavages and dissected it into several flakes as shown in (Fig.7j:l). Micro-exfoliation and dissolution of cements occur in the samples (figure7m,n) which leads to an increasing in porosity and loss of cohesion of the stone as shown in (figure7m, n). Quartz crystals seriously deformed and lost its original shape (Fig.7o). It must be

mentioned that weathering attacked strongly the rock formations which started from the surface and continuing inward thus losing the mineral fabric. Scanning

electron micrographs show growth of mite (phylum: Arthropods) between grains (Fig. 7p).

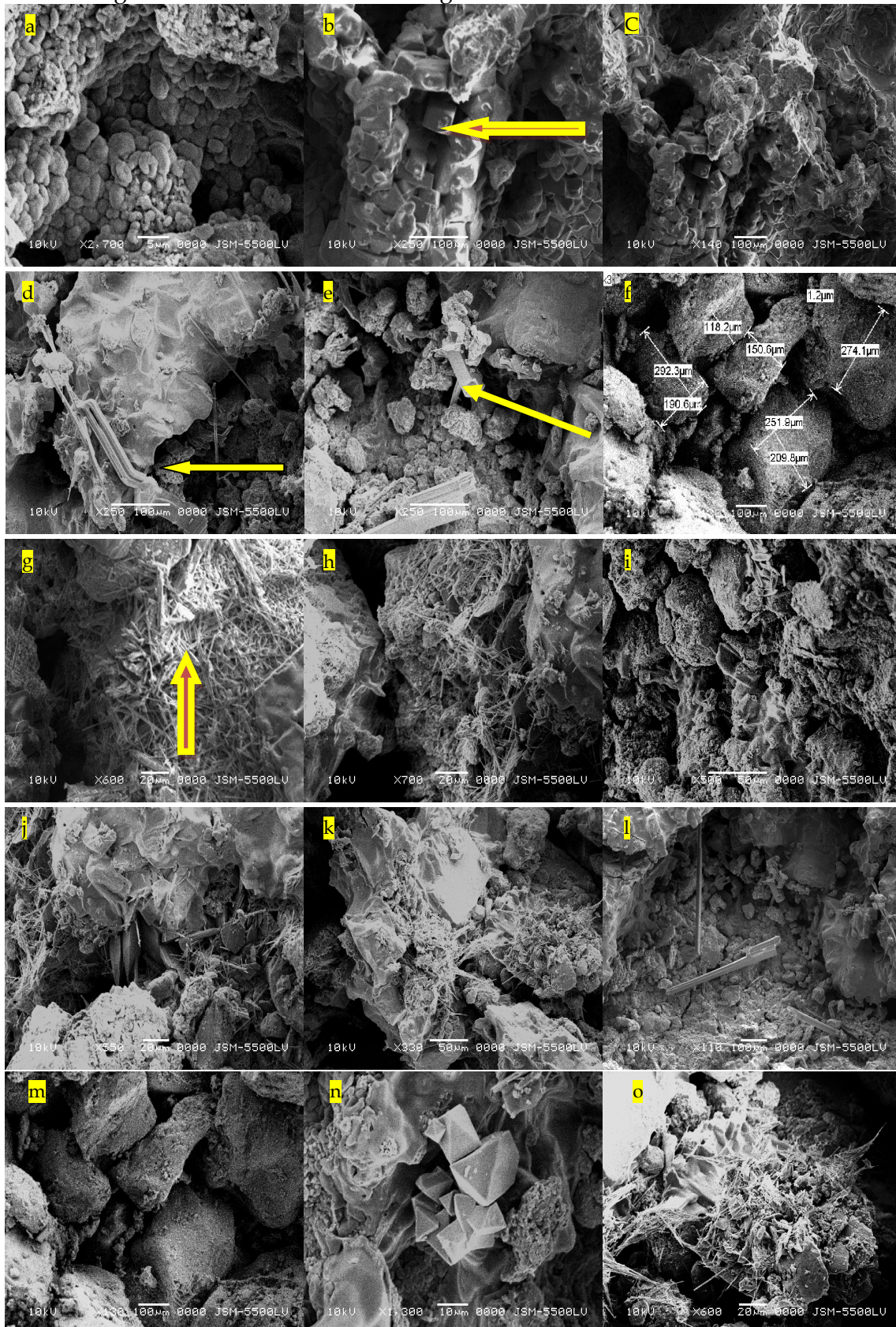


Figure 7 SEM microscopy view of sandstone samples **a** dense coat of halite crystals, **b** large euhedral cubic aggregates **c** sodium chloride as aggregates **d,e** prism and hair grains, **f** grain size of quartz of komir temple **g,h** loss of cohesion of the surface quartz grains due to secondary gypsum growth. **i**, clay minerals with patches of irregular surface **j:l** micro-pitting, and micro-cracking and cleavage plane **m,n** micro-exfoliation and loss of cohesion of the stone, **o** deformed of quartz grains p growth of mite.

Mineralogical Analysis by XRD

Mineralogical investigations were carried out by XRD for defining the different crystalline phases of samples. All results are shown in (table2) and (figure8). The results of the study show that the sandstone of Komir temple consists of quartz SiO₂, Feldspar (Orthoclase and Microcline) Kaolinite Al₂(OH)₄Si₂O₅, Calcite CaCO₃, montmorillonite NaO.3(Al,Mg)₂Si₄O₁₀(OH)₂.6H₂O, and gypsum CaSO₄.2H₂O. These results confirmed that the building stone used in the temple is Nubian sandstone according to (Saleh et al 1993). It is

obvious that all samples contain soluble chloride and sulphate. It is known that much damage to the porous materials such as sandstone is caused by the mechanical stress induced by the crystallization cycles of salts (Gauri and Stone, 1982). The contamination of the sandstone with soluble salts, mainly sodium chloride and calcium sulphate (Gypsum and Anhydrite) bears a considerable risk for the preservation.

Table 2: Mineralogical composition of the sandstone and salts of Komir temple

| Component /Sample | Sample (A1) | Sample (A2) | Sample (A3) | Sample (A4) | Sample (A5) | Sample (A6) | Sample (A7) | Sample (A8) |
|-------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Halite | 55.4 | 60.13 | 57.63 | 6.99 | 54.61 | 41.28 | 62.15 | 50 |
| Quartz | 24.88 | 4.75 | 39.76 | 89.86 | 24.1 | 11.17 | 20.88 | 39.6 |
| Calcite | 15.23 | 12.20 | _____ | 3.22 | _____ | 14.06 | 9.57 | 13.3 |
| Albite | 3.36 | _____ | _____ | _____ | _____ | 12.82 | _____ | 10.2 |
| Monto. | 1.33 | 6.25 | _____ | _____ | _____ | _____ | _____ | _____ |
| Gypsum | _____ | 13.35 | _____ | _____ | 3.36 | 20.82 | _____ | 6.7 |
| Anhydrite | _____ | 3.42 | _____ | _____ | _____ | _____ | _____ | _____ |
| Orthoclase | _____ | _____ | 2.51 | _____ | 6.01 | _____ | _____ | _____ |
| Microcline | _____ | _____ | _____ | _____ | 4.91 | _____ | 7.39 | _____ |
| Kaolinite | _____ | _____ | _____ | _____ | 3.27 | _____ | _____ | _____ |

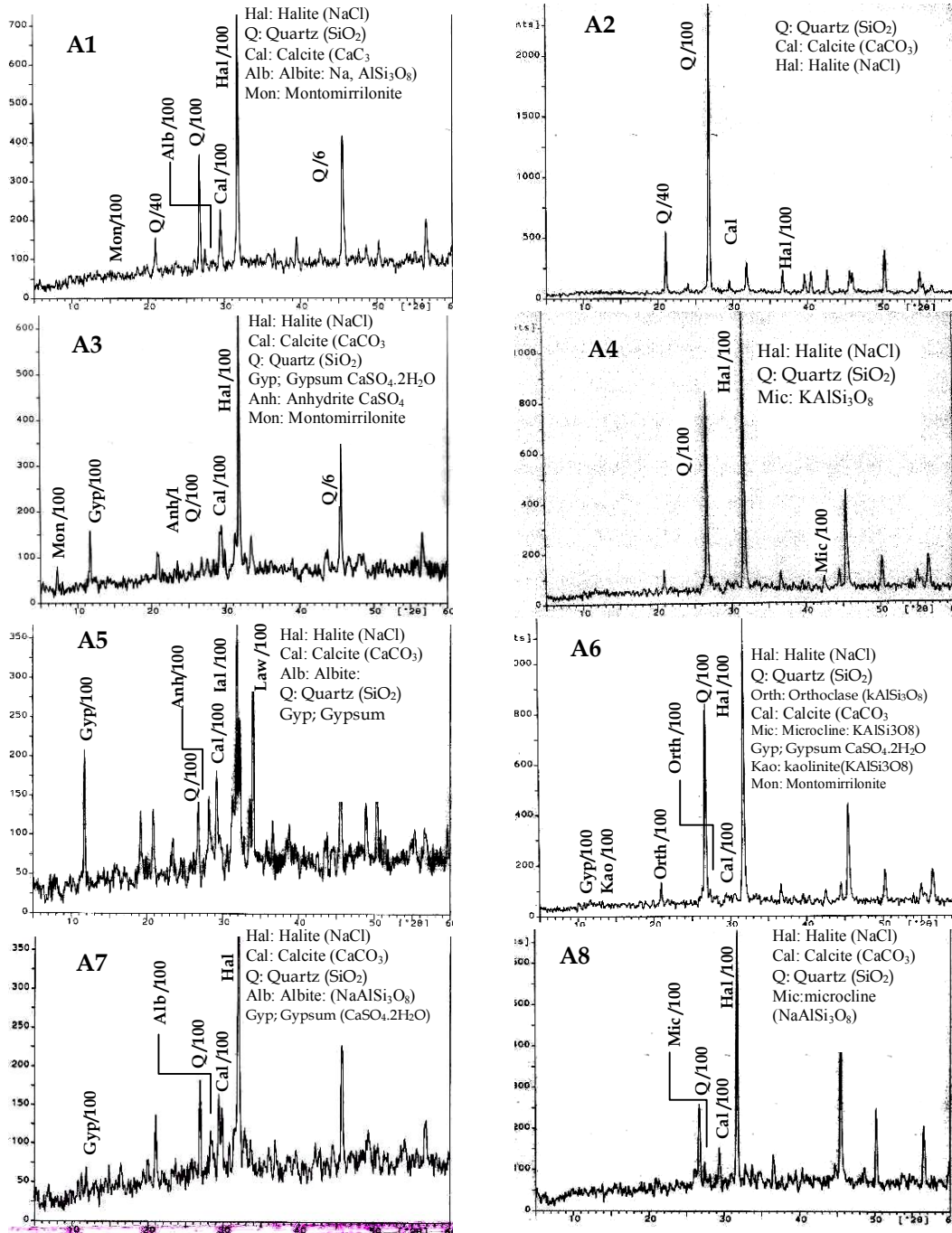


Figure 8 XRD pattern of the studied sandstone samples and salts from Komir temple

Thermal analysis

The DTA - TGA data show the clay fraction of sandstone consists of Smectite and Kaolinite. The total loss in weight due to heating is 14.790% (0.377mg). Smectite exhibits three peaks on DTA curve, the first is a large endothermic peak at temperature 100-110°C due to the enter layer water of Smectite was lost, the 2nd is endothermic at temperature 500°C due to rapid loss of

hydroxyl group (OH), the 3rd peak is exothermic at temperature 870-900°C due to decomposition of the structure. Kaolinite exhibits two peaks, the first one is a medium endothermic peak at 525°C due to loss of hydroxyl group and the 2nd is a very small exothermic reaction at temp.915°C due to the structural change of the mineral. Calcite gives medium

endothermic peak at temperature 762°C, Gypsum gives a double endothermic peak, the 1st small endothermic peak at 108°C due to a loss of 1.5 molecules of water to give Hemi-hydrate, the 2nd at temperature 182°C related to loss $\frac{1}{2}$ molecules of water to give anhydrate. Quartz exhibits a small peak at temperature 675°C due to transformation of α -Quartz to β - Quartz. The heating cycle are graphically recorded as shown in (Fig.9). This declares the great problem of hydric expansion and shrinkage due to absorption and loss of water. Hydric expansion is one of the most important reasons for deterioration of sandstone. The aggregation/disaggregation or swelling/shrinking of

the clay particles occur when these particles interact with water causing a whole series of identifiable pathologies in building stone. The swelling types of clay minerals were linked with their crystallographic structure and bonding properties, especially in the case of interlayer spaces (Colas et al 2011). Osmotic swelling occurs for all clay mineral types in response to an electrolyte concentration increase in the double diffuse layer on clay mineral surfaces. Different clays react differently to hydric expansion while the textural anisotropy of clay bearing stones appears to play a critical role on swelling- shrinking related damage.

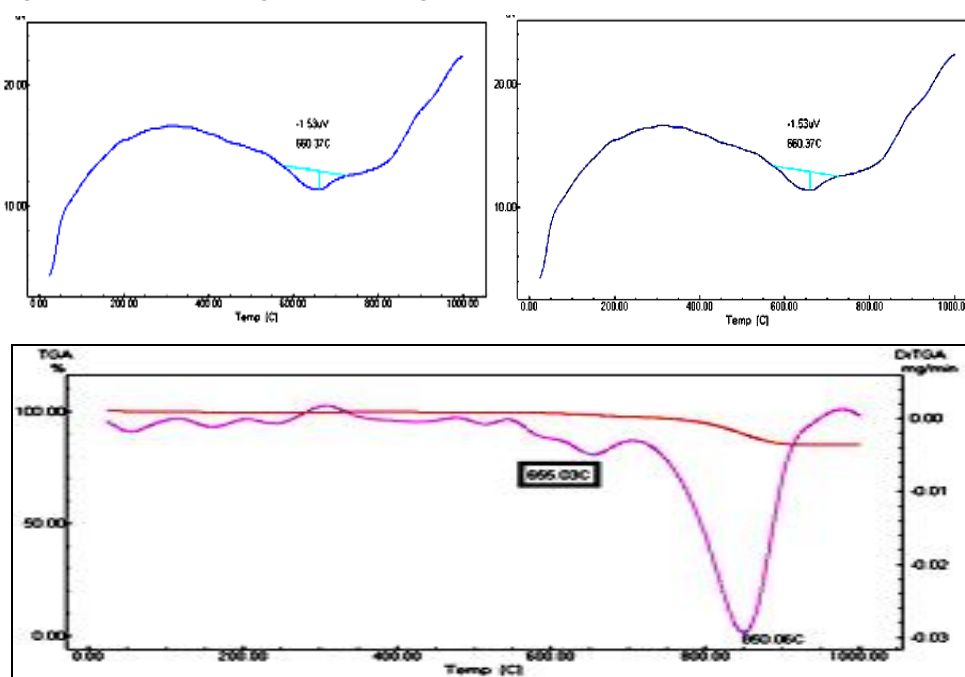


Figure 9 A,B show diagram of DTA of sandstone sample revealed that the sample consisted of montmorillonite and its peaks recorded at 118- 237°C and 822-877°C besides peaks of calcite

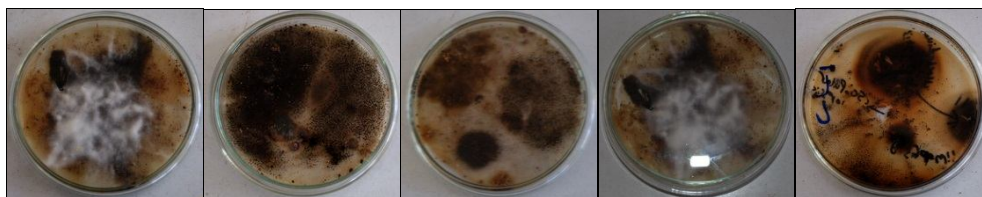
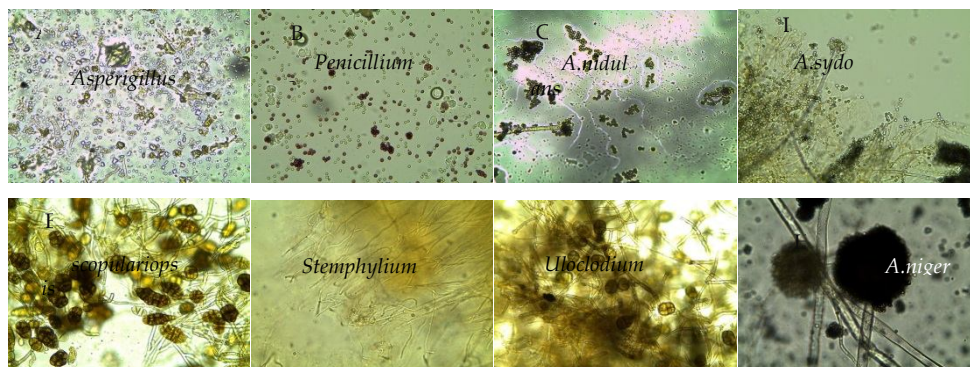
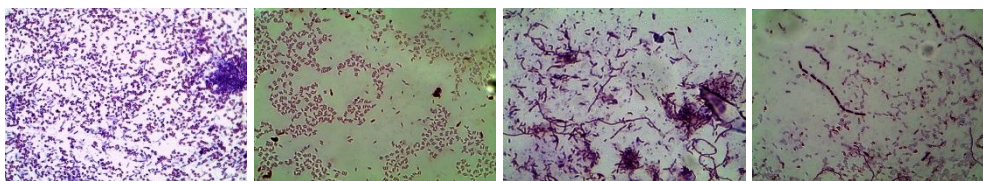
Identification of microorganisms

During the present investigation 12 fungal floras were identified that caused deterioration of the wall relieves (Table 3). The fungal species *Aspergillus nidulans*, *Aspergillus niger*, *Aspergillus sydowii*, *Aspergillus terreus*, *Aspergillus flavus*,

Alternaria alternate, *Uloclodium botrytis*, *Stemphylium herbarum*, *Scopulariopsis*, *Cladosporium oxysporum*, *Fusarium sp.*, *Penicillium sp.*(figure10,11). Also it *Bacillus sp.*, of bacteria were identified (figure12).

Table 3: Various types of microbiological growths found over wall painting at Komir temple.

| No. of sample | Bacteria CFU/g | Fungi CFU/g | Microorganisms |
|---------------|----------------|-------------|--|
| A1 | ----- | 1100 | <i>Aspergillus nidulans</i> - <i>Aspergillus niger</i> - <i>Aspergillus sydowii</i> - <i>Alternaria alternata</i> - <i>Uloclodium botrytis</i> - <i>Stemphylium herbarum</i> - <i>Scopulariopsis</i> . |
| A2 | 150 | 11 | <i>Aspergillus niger</i> - <i>Aspergillus sydowii</i> - <i>Aspergillus flavus</i> - <i>Aspergillus terreus</i> - <i>Penicillium sp.</i> -gram positive Bacilli- spore forming Bacilli. |
| A3 | 190 | ---- | <i>Bacillus sp.</i> |
| A4 | 250 | 3 | Sterile mycelia- <i>Bacillus sp.</i> - spore forming Bacilli. |

**Figure10 a-e Different colonies of isolated fungi from Komir temple.****Figure 11a-h. Light microscope photos of isolated fungi from komir temple: A *Asperigillus terreus* B *Penicillium Sp.*, C *A.nidulans*, D *A.sydowii*, E *scopulariopsis*, F *Stemphylium herbarum* , G *Uloclodium botrytis*, H *A.niger*.****Figure 12a-d. Light microscope photos of isolated Bacteria from komir temple infection Bacillus Sp.****Determined of physical and mechanical properties of sandstone:**

The specimens used for physical and mechanical properties were cubic in shape with 4cm edge and estimated from (ASTM C97). The porosity of the sandstones was measured stone estimated from (ASTM C97) it was found to be 18 -25%. The bulk density was obtained to be 1.5-1.87 gm./cm³. The compressive strength of the

sandstone was estimated in which the dry and wet. The measurement was made on the smooth surface of 12 sandstone cubic samples (3.5×3.5×3.5 cm), compressive strengths varied 20-25 kg/cm² for dry strength, 11-13 kg/cm² for wet samples. The (dry) strength was thus classified from low strength to medium strength.

Discussion

Field observations and lab analysis indicated that, there are many types of damages that wall painting can undergo in the Komir temple. All building and decoration materials of Komir temple have been investigated concerning the contamination with soluble salts. Soluble salts represent one of the most important causes of stone decay that may precipitate on the external surface ("efflorescence's") or in proximity of the surface ("sub-efflorescence's") [Brai et al 2010]. The degradation induced by soluble salts on wall painting in Komir temple was studied by sampling efflorescence's from different places and studied by XRD and XRF. Samples confirmed the presence of chlorides and sulphates species in the form of the following crystalline phase "anhydrate and dehydrate calcium sulphate, CaSO_4 and $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ (gypsum)" and sodium chloride (NaCl). Also scanning electron microscope examination confirmed the existence of Halite and Gypsum as the kind of salts in Nubian sandstone. The source of these salts is ground water which carried into masonry by rising damp in the absence of damp coursing. Also Ground water carried

these salts into the pores of the sandstone during burial leaving them behind when the water evaporates. After excavation, these salts crystallized at or just below the surface of the wall painting in Komir temple causing damage caused by the mechanical stress induced by the crystallization cycles of salts (Gauri 1982), which weakens bonding between the grains in the sandstone and causes the spalling, flaking, powdering, sugaring and current detachment of individual grains and pushing surface layer of stone. The contamination of the sandstone with soluble salts, mainly sodium chloride bears a considerable risk for the preservation (Saleh et al 1992). Sodium chloride thus migrates to higher areas and re-crystallizes under volume expansion. Moisture can convert the halite salt from the solid state to the solution and during the day when temperature become high, the water will evaporate and the salt crystallize, this lead to crusting, white blooms and a lot of stress which lead to micro crack, blistering, delamination, scaling, disintegration and separation of some parts from rock inscription as shown in (figure 13a,b) (Maureen et al 2003).

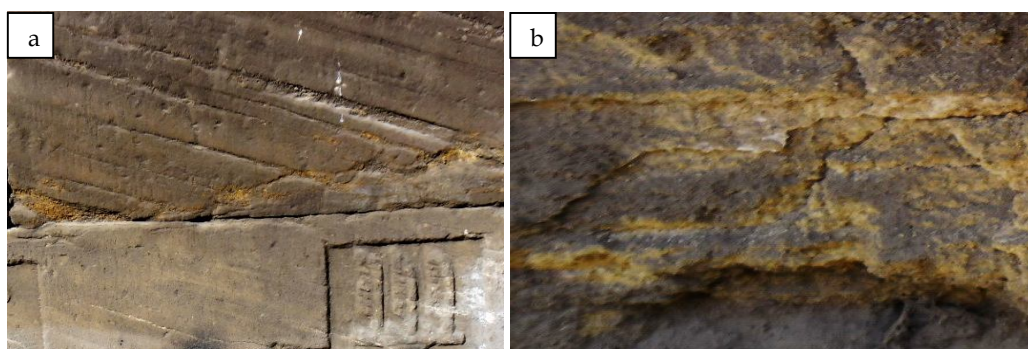


Figure 13: Salt induced deterioration of sand stone at Komir temple (a) Incipient Flaking, (b) scaling parallel to bedding.

Gypsum crystallizes on the surface of the wall paintings of Komir temple. Gypsum crusts are commonly found on calcite cemented sandstones. In contrast to calcareous stone, the mechanism of crust formation on sandstone is different, because both sulfate and calcium must originate from external sources. Therefore,

the formation of gypsum crusts on non-calcareous stones cannot be considered the result of chemical deterioration of the substrate. Nonetheless, the low solubility of gypsum favors its accumulation in the pore space of these materials. Very often, the pore space close to the surface is completely filled with gypsum deposits

(Charola et al. 2007). A characteristic feature at a later stage of the damage process is the complete destruction of the original internal fabric which is replaced by secondary gypsum supported fabric. The gypsum crystals growing on the original thin black surface layer resulted from the subsequent development of a leak above this area. The problem is more complicated by the existence of clay minerals which the lab analysis indicated it in the samples. The moisture retention by the clays will tend to accumulate salts in these layers so that the scaling pattern of a thin surface flake may result in the formation of thicker layers spalling off, the properly called delamination (Michael et al 2001).

L.O.M photograph indicated presence of soot particles at the grains of Quartz. It is a result of fires inside the temple. Fire has both physical and chemical implications for stone decay. Post-fire deterioration of sandstone is strongly conditioned by fracture networks and soot cover inherited from the fire. The exploitation of fractures

can lead to spalling during salt weathering cycles, this takes place as granular disaggregation steadily widens cracks and salts concentrate and crystallize in areas of inherited weakness. Soot cover can have a profound effect on subsequent performance. It reduces surface permeability and can be hydrophobic in character, limiting salt ingress and suppressing decay in the short term (McCabe et al 2010). The biological degradation of reliefs had been studied and 12 fungal floras were identified, also *Bacillus* sp., of bacteria were identified. The results of the present investigation proved that excessive moisture in building materials supports microbial growth and the aesthetic beauty of the reliefs was seriously affected due to these deposits. From a scientific point of view these depositions are very harmful for the health of the stone surface because these microorganisms secrete an acid that dissolves the sandstone (Torraca, 1981).

CONCLUSION AND RECOMMENDATIONS OF TREATMENT

The previous study clarifies that the wall painting at Komir temple had been exposed to aggressive deterioration factors mainly due to environmental conditions and different sources of moisture (i.e. groundwater and domestic waste water) containing high level of different harmful ions. Therefore, the following recommendations should be taken for protecting the wall painting such as:

There are many problems need a lot of scientific work before satisfying conservation plan will be established as Preventive Conservation. Preventive conservation measures of more immediate effect are usually concerned with keeping water out of the stone and with controlling the relative humidity and temperature of the air around the stone [Price, 1993]. The main purpose of relative humidity control is to prevent salt damage which can be carried out by reducing the subsurface water level under the Komir temple by

treatment the reasons for rising (i.e. converting Ramady Canal to covered drainage system and conversion the system of farmland irrigation in the surrounded area to drip irrigation, that reduce the rate of water leaks into the walls of the temple.

The amount of trash, dust and debris must be raised from the floor of the temple.

The parts of the wall painting which was buried should be discovered according to the pictures and maps that had been made by M. Es-Sagher and V. Dominique 1979 and completing excavation to discover the another parts of the temple.

The surrounding houses should be removed according to the law as they do not give any chance for the aesthetic appreciation of the temple in addition to give chance to complete the new excavation.

Vegetation removal should be carried out by mechanical removal for roots and rhizomes and chemical removal by using

chemical pesticides as pesticide Glyphosate pesticide or Fuluazifop-p-butyl.

Wall Paintings should be covered with suitable methods in order to avoid any damage that can occur during the excavation or raised the debris.

After Preventive Conservation, conservation interventions have to be individually planned and conservation materials should be tested before to ensure their efficiency and have to be well adapted to the material parameters of the building in order to avoid further damages (Leisen et al 2008).

During field observation, highly endangered areas have been detected. Here emergency measures should be carried out immediately in order to prevent the loss of original material and relives. Emergency interventions are preliminary measures like gluing pieces or pre-consolidate. A partial pre-consolidation should be carried out only on the crumbed and separated weak surface. According to experimental tests 5% Paraloid B.48 by spray methods is the best consolidant material to apply in this environment. Primary fixation of separated crusts from reliefs can be done by using emulsion of primal AC33. Injection of crumbed and separated areas of the relives aims to stabilize this rendering and their attachment to the underlying support. A mixture of sand, lime, and white cement (2:1:1/2) with Primal AC33 can be used as glue to separated parts.

Friable and Unattractive dirt, Crusts, excrete of birds, microbial stains, unfavorable surface accumulations and different species of salt crusts should be removed by suitable scientific techniques. A wide range of techniques is available for cleaning stone, ranging from mechanical cleaning using manual and mechanical tools as scalpels, spatula, different types of brushes and sponge particles containing mineral grains of varying hardness at 100–200 kPa can be used to minimize abrasion of substrate and reduce dust levels. Also, water cleaning can be used safely to remove dirt from the surfaces of the relives, supplemented with non-ionic detergent

and steam or hot pressurized water cleaning (Mack and Grimmer 2003). Chemical cleaning can be done to remove what mechanical cleaning failed to remove from soot, stains and dirt by using organic solvents. Biocleaning treatment should be applied to remove the strongly thick black crust using bioremediation with *Desulfovibrio vulgaris* subsp. successfully removed black crust relives according to (Polo et al., 2010). Biocides must be used, not only to kill the growth in the relives, but also to be resistant to new strains.

Reduction of salts should be done. Desalination of relives from soluble salts as sodium chloride is usually attempted through the use different types of poultices, which may consist of clay, paper pulp, or cellulose ethers. In instances of calcium sulfate hydrate (Gypsum) and black rusts can be cleaned by using two poultices, the first one was absorbent poultices loaded with mixture of 10% sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$) + 5% ammonium carbonate with distilled water. After that, distilled water with ethyl Alcohol used to rinse treatment places to remove ammonium sulphate with severe susceptibility to water solubility. The second one employs the sodium salt of the ethylenediaminetetra-acetic acid, abbreviated as (EDTA) as active ingredient.

After removing the salts the walls become ready to consolidate, it should be consolidated not only for aesthetic reasons but also to ensure the correct conservation of the entire structure. Consolidation of weak parts, losing cohesion and adhesion of the sandstone relives using Silane based products aims to eliminate or reduce capillary absorption of water in driving rain and enhance durability of the stone material and the object as a whole. Laboratory research and experimental field work suggest that these consolidants are promising for treatment of sandstones because of increasing in compressive strength, modulus of rupture, and abrasion resistance. These improvements seem remarkable, given the relatively small amount of consolidant deposited. Viewed

in the context of other parameters-depth of penetration, stability of surface appearance, and retention of porosity [Klaus J.H, et al 1988].

On the other hand, filling the joints between the blocks of stones and completing the missing parts should be

carried out. Our experiments have proved that the best material for this target is mortar sand, lime, and white cement mixing in 15% Ediobond M56 with water by 3:1:0.5 sizes, respectively.

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