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INVESTIGATION OF ENVIRONMENTALLY DRIVEN DETERIORATION OF DIORITE STATUES IN MUT TEMPLE, EGYPT AND CONCEPTS FOR CONSERVATION

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ABSTRACT

Mut temple is located at the south of the great temple of Karnak. Most of parts at this temple belonged to the king Amenhotep III, who furnished it with hundreds of statues of the goddess Mut in her leonine shape of Sekhmet. Amenhotep set up these statues in diorite which had been used in many important ancient Egyptian monuments during the heights of ancient Egyptian civilization. These diorite statues were subjected to different kinds of physical, chemical and biological alteration as a consequence of their exposure to the direct action of aggressive atmospheric agents (temperature, humidity, wind, chemical weathering and salts pressure) so, They suffer from different deterioration phenomena such as missing parts, erosion of stone, presence of cracks and micro cracks, disintegration of some parts, crystallization of salts and dirt. A correct evaluation of degradation processes is needed in order to find the appropriate conservation and restoration treatments. For this purpose, an integrated study of the diorite samples in the Mut temple and the evaluation of their conservation conditions were carried out. Little systematic investigation has been done as polarizing microscope (PM), scanning electron microscope (SEM) attached with energy dispersive X-ray analysis (EDX), light optical microscope (LOM), X-ray diffraction (XRD), and chemical analysis of water to identify their components. Finally, discussed the important recommendations for the restoration, treatment and conservation of diorite statues were carried out.

KEYWORDS: *Mut temple, Diorite, Alteration, groundwater, Salts, Analysis, Conservation*

1. INTRODUCTION

Mut temple of goddess complex is located at the south of the great temple of Karnak, on the eastern bank of the Nile River of Luxor, which was once the ancient capitol, Thebes and is surrounded with mud bricks enclosure walls. Amenhotep III during his reign (XVIII dynasty, 14I1-1375 B. C.) had erected in southern Karnak this temple to the great Theban goddess Mut, (Velde, 2001), who figures in the Theban triad of Amon, Mut, and Khonsu, as the wife of Amon and mother of Khonsu-and within the temple he caused to be set up what may literally be described as a "for-est" of these statues of Sekhmet, "the mighty one," the terrible goddess of war and strife, who as the mother-goddess of the earlier Memphite triad had now seemingly become identified with Mut, the corres-ponding local Theban deity [Erman J. Junker]. Mut's temple was connected to Amun's at Karnak creating the largest temple complex in ancient Egypt, which joined by an avenue flanked on both sides by sphinxes with ram's heads that extends south to north between Al Karnak and Luxor temples (Fig. 1) for a length of about 3km and it is mostly damaged. It is centered by Isheru; sacred lake has a crescent shape, which may be fed by the largest underground spring that is preserved [Velde, 2002]. The Mut temple, half surrounded by its horseshoe –shaped sacred lake, contain 500 diorite statues of the lioness-headed goddess (Mut) Sekhmet lined up in rows around its temple [Hayes C. W1999), (Bard A.K1997) that Amenhotep set up these statues in diorite of (Sekhmet in such lavish fashion-in places in a double row, one behind the other, "crowded together so closely that they were in actual contact with each other in places, and presenting something of the appearance of a regiment drawn up in battle array. Most of these statues have unexpectedly fragmented. However, others in a good state of preservation. The aim of these article is to study the diorite Statues of Mut temple to identify its components, the causes of damage that affect these statues and led to several forms of deterioration. Moreover, suggestion the suitable procedures for restoring these statues.

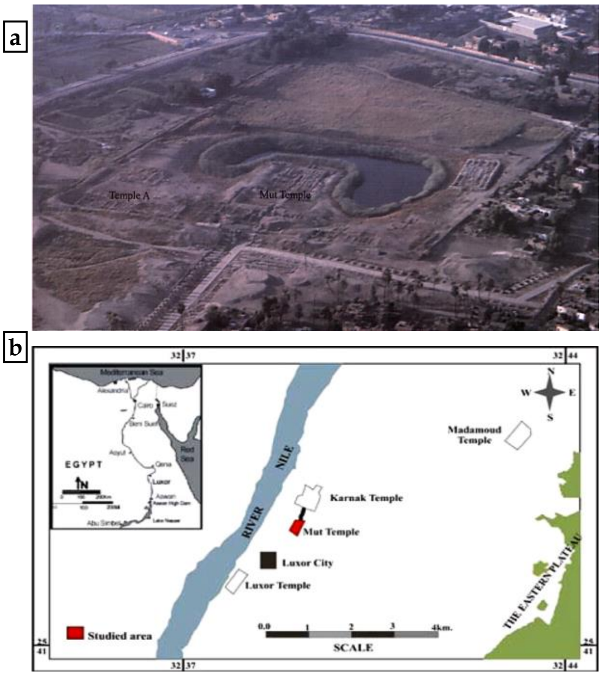

Figure 1 Mut temple location; a: An aerial view of the trapezoidal Mut precinct from the north. In the Mut temple with the sacred lake called the Isheru; b- Location map shows the goddess Mut temple in relation to Luxor and Al Karnak.

Figure 2 Series of Sekhmet diorite statues in Mut Temple

1.1 Conservation state of Diorite statues at Mut temple

These statues suffer from different deterioration phenomena such as mechanical exfoliation detachment of diorite surface, disintegration of grains, separation of some of these grains and separation of the scales of the surface layer (Fig. 3a, b) as a result of the detachment and loosing of the bonds that tie the grains of the surface area and those grains of the layer, (Helmi 1985). Missing parts, erosion of stone surfaces (Fig.3c, d), different type of cracks; macro, micro and wide deep cracks also were noticed (fig.3e). Crystallization of salts and accumulated dirt (Fig.3f,g), change in mineral composition (color & type of minerals), the stone surface of the statues became blackish in appearance due to deposits of dust, dirt, dried vegetation and micro vegetation (Fig.3h), some diorite statues are particularly damaged and the other fell into flakes and fissure (Fig.3i). Due to these deposits the aesthetic beauty of the statues is seriously affected, so the statues' inscription is difficult (Fig.3j), because the rear of the statue is badly degraded as shone in (Fig.3h). It was suggested that the damage was caused by intense heating and presumably rapid cooling with water, the arid climate of the region and continuous changes between day and night, and seasonal changes in temperatures especially in the south are considered very important participating factor in damage. The surface layers of diorite relief on the sunny sides often reach much higher temperature in July 40°C and relative humidity 50% in December, so the diorite stone can suffer from severe damage due to the cyclic thermal expansion in the range of 40°C and more. Repeated cooling and heating cause about 20% of irreversible deformation and is finally express as mechanical damage of diorite. The maximum temperature on the diorite surface due to solar radiation are indirectly related to the color of stone surface (Mauko et al 2006). (Winkler 1994) showed that, the surface temperature of diorite stone could be more than ten degrees higher than the air temperature, this might promote exfoliation, disintegration and cracking of the diorite. A more probable cause of this type of degradation is the infiltration of soluble salts into the rock pores and microcracks and crystallization of the salts therein. Salt weathering is one of the principle deterioration factors in Mut temple, these salts can be observed directly as efflorescence and appear at the surface of the statues. The most cited affecting the site is a moisture source (ground water) resulting from dramatic rise of the water level, great problems with the Mut temple that result from its proximity to the sacred lake and its intermittently high and low water levels. The ground water level under the Mut temple is less than 3m and the salinity minerals of this water have a negative impact upon the diorite statues above and under the ground surface (Richard, 2007). Biological effect of planet is one of the principle factors of the diorite statues at Mut temple resulting of rise of ground water (Fig.3k). The deterioration caused by plants is both mechanical and chemical. In this case the chemical action is influenced. The chemical action is due to the acidity of the root tips and the acidity and chelating properties of the exudates. Certain plants, for instance ivy, can also cause a change in stone color as a result of the release of organic compounds (Caniva, G., et al 1988). Stain due to bird extraction also is one of the deterioration factors, many bird's nests were observed at statues (Fig3l). Bird excrement accelerate the deterioration process of the stone.

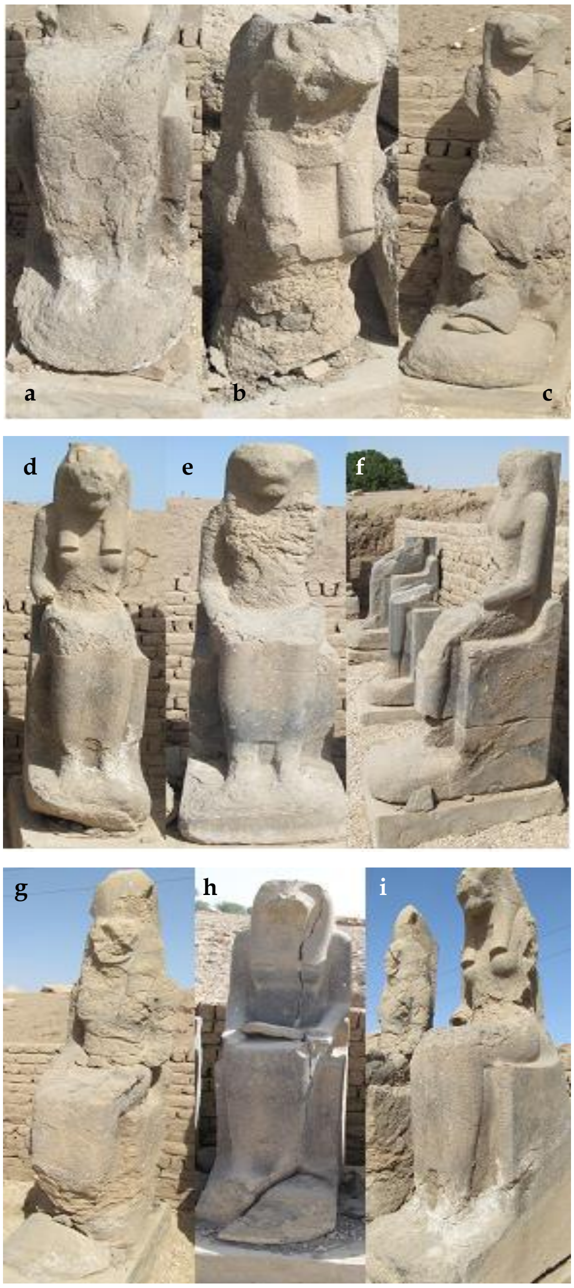

Figure 3 details of deterioration at the diorite statues at Mut temple.

2. EXPERIMENTAL

Samples

Diorite samples were taken from removing the fragments removed from Sekhmet statues and salts efflorescence was sampled by brush analyzed thorough various investigation techniques. Collected samples were analyzed and studied to identify the different weathering forms. In the case of the phototrophic microflora, sterile sampling collection have been picked with a sterile scalpel on black, dark green, brown patina, rosy discoloration and remains of birds. Taxonomic characterization has been carried out up to species using physiological and morphological methods. The analysis is based on non-destructive methods such as:

Stereomicroscope:

Collected diorite samples were studied using (Olympus SZ61) stereomicroscope with (Olympus E-330) digital camera to study alterations of stone surfaces. The photomicrographs recorded with various magnification degrees, up to maximum 4X.

Scanning Electron Microscope (SEM):

The Samples were investigated by scanning electron microscope (SEM). Samples for SEM were cut at 50mm with flat surfaces and coated with gold. Observations were done using JEOL JSM 6400 coupled with dispersive X ray spectrometry (EDX) analysis (Philips with Be window) detector and coupled with EDS PV6587) was used. Quantitative analysis used software EDS-Genesis with errors computed via ZAF correction. ZAF - for atomic number Z, Absorption A and Flourescence for F - uses fundamental factors to correct for the effects of atomic number (Liritzis, I., et al 2011) absorption and fluorescence. Analyses were performed at 25 keV with 35^{o} take-off angle. More reliable analyses are these for elements contained in concentrations >0.1%. An error of around 5 to 10% is accounted, for the major elements. Samples for EDX were grounded down to powder with grain size 50 - 100 μm.

Polarized Microscope (PM):

Thin sections were prepared from diorite fragments, each about 0.8cm in diameter. The minerals and texture of diorite samples were determined using Olympus BX51 TF Japan petrographic microscope attached with digital camera under magnification 20X up to 40X (Geology department, Faculty of Science, SVU University).

X ray diffraction (XRD):

X ray diffraction, for the analysis of powdered samples was employed to identify the mineralogical composition of the diorite. A Philips PW 1840 diffractometer equipped with an automatic slit was used. The following conditions were applied: CuK radiation, 40kV/25mA divergence and detector slits of 1.54056°, 1.54439° 2_ step size, and time for step of 1s. The XRD profiles were measured in 2θ goniometer steps for 0.300s.

Biodeterioration Study:

The microbiology analyses carried out in order to favor the growth of the cyanobacteria and fungi spices found in the samples, requested the use of liquid growth medium. One gram of various biodeteriorated/biodegradated diorite samples which were collected from Mut temple was powdered and diluted with 9 ml of sterilized distilled water. Samples were shaken vigorously to form uniform solution of 10-1N concentrations. The decimal serial dilutions (10-1 to 10-5N) were prepared using the method of (Ejifor & Okafor 1985). For the isolation of fungi, plate count method was used as (Repar & Fannel 1965] 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 that was melted and kept at 45°C. Czapek's medium comprised (gl-1): sodium nitrate 3.0; potassium dihydrogen phosphate 1.0; magnesium sulfate 0.5; potassium chloride 0.5; ferrous sulfate 0.01; glucose 10; agar 15. Chloramphenicol (0.05mg/ml) was used as bacteriostatic agent. The plates were incubated at 28ºC for 5-7 days during which the developing fungi colonies were counted and identified. The microbial population in the original sample was then calculated using the following equation: Organisms/g sample = 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 medium comprised (gl-1): beef extract 3.0; peotone 5.0; agar 15; pH = 7.0 (Seeley & Van Demark, 1981). The inoculated plates were incubated at 37°C from 24 to 48h. The evaluation of microorganism total concentration in each sample was determined by plate counting of serial dilutions according to the equation: Colony forming units: (CFU)/g = Number of colonies/dilution.

Chemical studies of groundwater:

Water samples from the Mut temple was analyzed in order to identify the soluble salts content. Water sample was taken from Sacred Lake when its level was high in summer in sterile bottle in order to avoid any local contamination or evaporation. The samples were analyzed for the major cations (K^+, Na^+, Mg^{++} and Ca^{++}) and the major anions (Cl^-, NO_3^- SO_4^{2-}, PO_4^-, CO_3^{2-}, N-NH_4) using chemical methods, as well as water temperature. In added to, PH and Ec were measured.

3. RESULTS

3.1 Mineralogy

XRD results indicate that most abundant phase in the diorite samples is quartz (37.82%), Plagioclase 'Albite' $NaAlSi_3O_8$, (26.945%), Calcite (8.753%), Biotite ($K(Fe, Mg)_3AlSi_3O_{10}(F, OH)_2$, (4.05), clay minerals (5.68%), Hematite Fe_2O_3 (3.62%) appear in smaller amounts. Also XRD analysis of the diorite from the temple showed NaCl concentration levels of (7.06%) (fig.4).These ratios indicate that an amount of NaCl accumulated in certain areas of the statues.

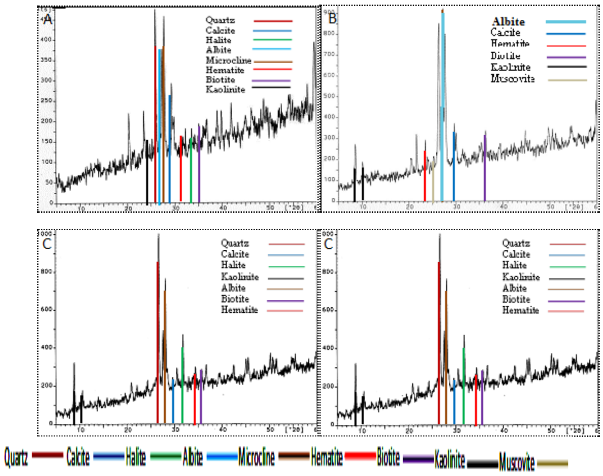

Figure 4 XRD patterns of the diorite samples from Mut temple.

3.2 Thin section analysis

General observation from the petrographic study for the samples revealed that, the rock under investigation is medium to coarse grained, dark grey in color and characterized by hypidiomorphic texture. It characterized by intra-crystal microcracks intercrystal boundary cracks and channels now revealed (Fig5a, c). In the thin section it dominantly composed of plagioclase feldspar, Quartz, potash feldspar, biotite and hornblende. Plagioclase is mainly represented by euhedral and subhedral, crystal of oligoclase and andesine. Plagioclase show different types of twining and frequently appeared cloudy due to conversion to clay minerals (Fig5d). Plagioclase is subject to slight to moderate alteration to sericite and kaolinite (Fig5e,f) Seriticised plagioclase occurred frequently and was itself split by micro-cracks which were iron stained. A rust coloured stain was found within intra-crystal microcracks in plagioclase and was associated with biotite crystals. Potash feldspar occur as microcline crystals showing cross hatching twinning and partly kaolinized and serietized (Fig.5b). Mafic minerals are represented by biotite and hornblende Biotite shows different degrees of deformation and alteration. Some biotite crystals show pending and wavy extinction as a result of deformations (Fig.6a). Also, biotite it altered to green colour chlorite along cracks and cleavage planes (Fig. 6b, c). Hornblende is represented by euhedral to subhedral hornblende shows pale brown to mildgreen pleochroism. Cracks are common in hornblende grain with presence internal grains filled with secondary quartz (fig 7a). Hornoblend partly altered to pale green iron oxides (Fig.7b) and chlorite (Fig.7a).

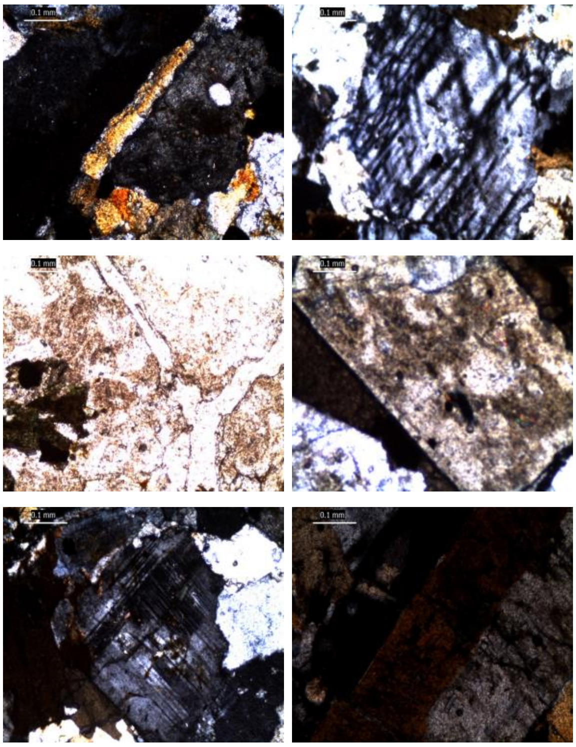

Figure 5 Petrographic view of Plagioclase grains in diorite at Mut temple a- plagioclase altered to sericite with presence veinlet of silica; b- cross hatching twining in potash feldspar; c- plagioclase crystal contain cracks cross-shaped (y) ppl; d- euhedral grains of plagioclase shows cloudy polysynthetic twinning which altered to kaolinite and sericite; e- orthogonal twinning in plagioclase which exposed to alteration; f- rectangular crystal of plagioclase has carlsbad and albite twinning altered to kaolinite.

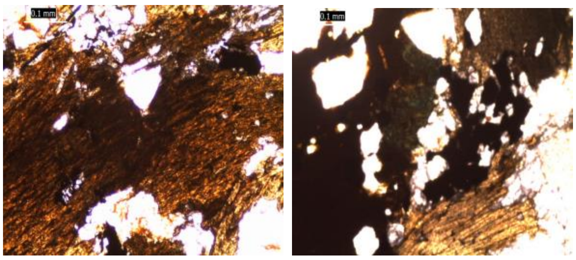

Figure 6 Petrographic view of biotite grains a- Wavy extinction in biotite in ppl.; b- biotite grain altered to green chlorite and dark iron oxide.

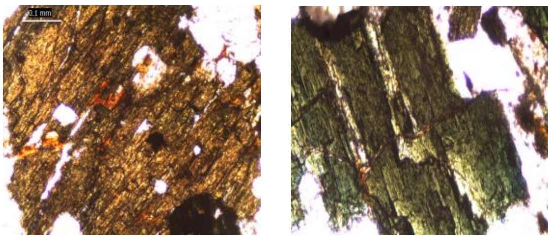

Figure 7 Petrographic view of hornblende grains a- coarse grain of hornblende contains multiple forms cracks and filled with secondary quartz; b- Course grain of hornblende altered to green chlorite along cracks.

3.3 Scanning Electron Microscope (SEM) results

Scanning Electron Microscope (SEM) revealed obliteration of the characterized igneous textures, fractures in the minerals, the volume and distribution of the pores. SEM micrograph revealed the intra-crystal microcracks within feldspar and quartz, such cracks contributed to increase porosity causing the diorite become permeable. The SEM studies show that, the major deterioration cause of the diorite in Mut temple is the abundance of soluble salts in the rock. Various crystalline forma of halite and gypsum such as prismatic and needles halite and accicular and platy were noticed on weathered diorite. In addition to, exfoliation and micro pitting appears clearly. SEM micrographs showed the biodeteriorated stone surface beneath the microbiota, Extensive penetration of fungal hyphae inside the stone were clearly established in some samples as shown in (fig.8).

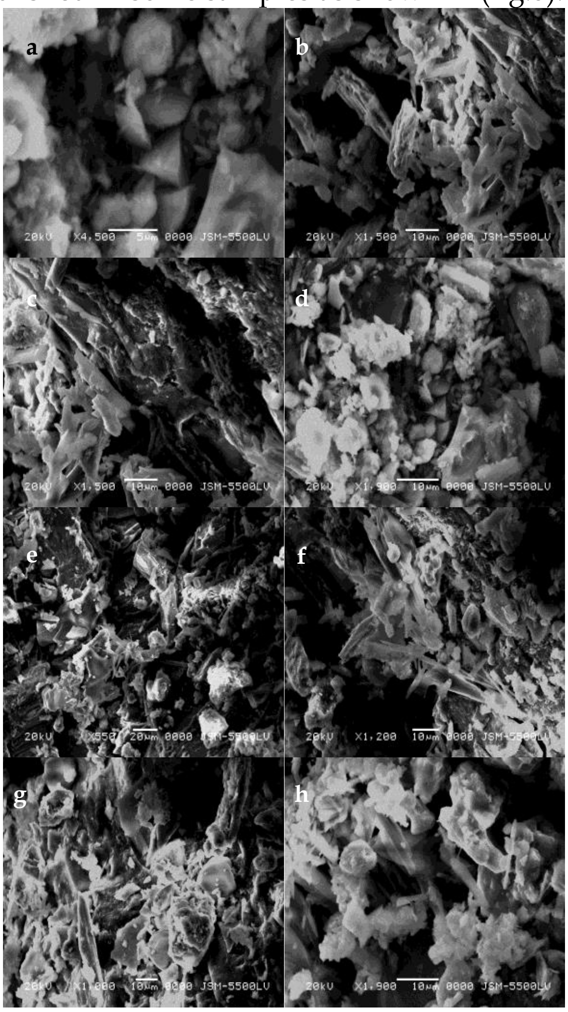

Figure 8 SEM photomicrographs of the diorite samples a,b- deformation of internal structure of diorite; c- micro exfoliation and pitting; d- disintegration; e,f- sodium chloride crystals; g,h - crystal of gypsum.

3.4 Major and traces elements (EDX)

Diorite samples have been analyzed for major and selected trace elements by EDX (Tab. 1, Fig.7). The results of EDX indicate a high silicate and high ferromagnetic mineral content characteristic of a diorite, a high concentration of calcium (Ca) may be attributed to calcite. A high concentration of sulfate (S) may be attributed to the crystallization of gypsum salts. The high amount of potassium (K) and Aluminum (Al) attributed to feldspar content of the rock. The high concentration of sodium (Na) perhaps attributed to sodic or plagioclase feldspar, or the high concentration of chlorine (Cl) and sodium (Na) attributed to the crystallization of halite salt on the statues. This excess of Na, Cl in the samples suggested that degradation of diorite was due to NaCl. The presence of Ti, P concentration characteristic of Egyptian rocks, (Said R., 1962).

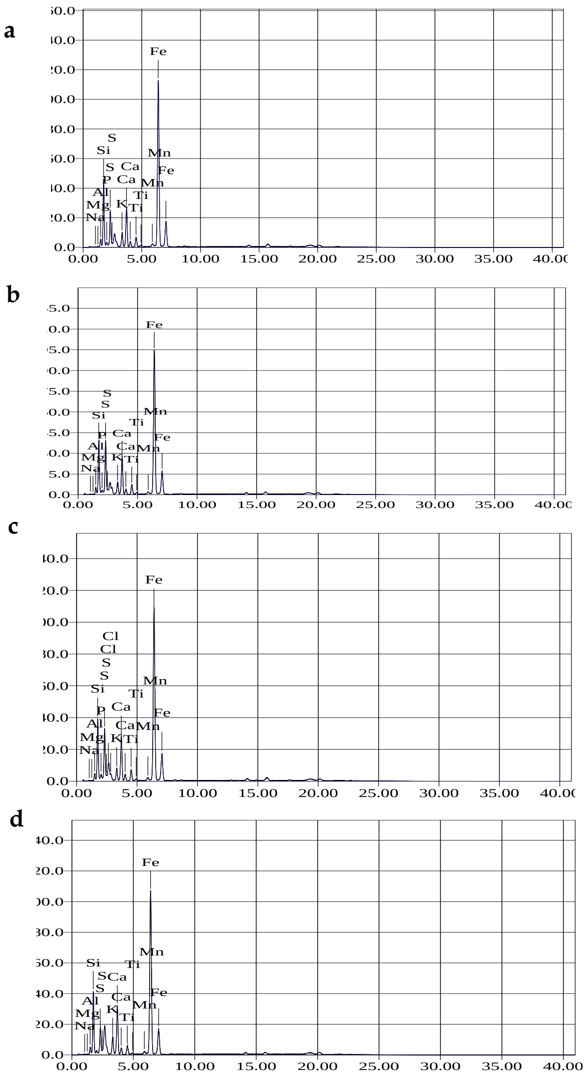

Figure 9 EDX pattern of diorite samples from Mut temple.

Table 1 EDX results of diorite samples from Mut temple

Elements	**Diorite samples**			
	D1	D2	D3	D4
Na	4.11	6.72	5.41	5.58
Mg	1.45	1.50	1.27	2.25
Al	6.18	5.66	5.22	5.73
Si	26.18	22.63	21.53	24.83
P	1.19	0.92	1.40	-------
S	7.33	11.23	9.16	5.24
K	5.46	4.96	4.43	6.24
Ca	13.29	13.47	14.14	15.59
Ti	2.72	2.93	2.85	2.47
Mn	1.03	0.92	1.07	1.10
Fe	31.02	28.96	30.28	30.93
Cl	------	------	3.17	------
total	99.96	99.9	99.93	99.96

3.5 Light Optical Microscopes (LOM) Study

Examination of diorite samples by optical microscope reveals, the samples suffer from several deterioration of its structural coherence. Granular disintegration fractures was detected clearly. Exfoliation, crustification and cracks were also detected. Image showed a black superficial crust covered the grains. Pitting, voids and hollows were noticeable clearly. The observations revealed significant presence of muscovite clearly.

3.6 Chemical studies of groundwater

Chemical analysis and Atomic Absorption Spectroscopy (AAS) methods were performed to identify the soluble salts in the water sample from the sacred lake 'Isheru' affecting the diorite statues at the Mut temple and to evaluate their different components "cations and anions" the investigations results (Fig.10) showed that the water sample is rich in sodium (Na^+), chloride (Cl^-) and sulphates (SO_4^{2-}). This reflected in the hypothetical salts combination of the scared lake water sample, where the dissolved minerals are Selvite KCl(23.31%), HaliteNaCl(36.13%) and Anhydrite $CaSO_4$ (40.56%). The pH (8.2) and the Electric conductivity (14.54) indicate the higher content of the total dissolved solids where the calculated total dissolved solids (TDS) is 6139 mg/l.

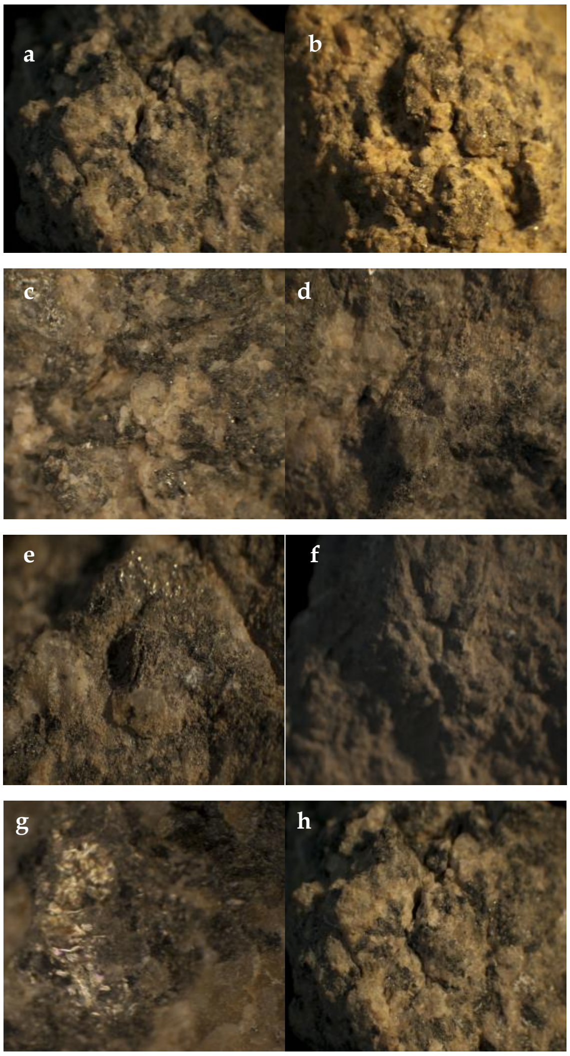

Figure 10 micrographs of investigated samples by LOM (4X) Granular disintegration, fractured, cracks, Exfoliation, cracks, voids, concentrated layer of dirt and mica noticed clearly.

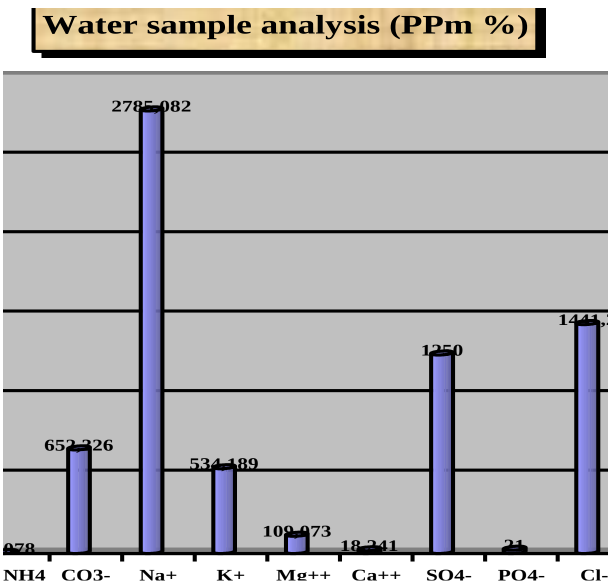

Figure 11 the chemical analysis results of groundwater from Sacred Lake at Mut temple

3.7 Isolation, identification and enumeration of microorganisms

Microbiological analyses revealed the presence of bacteria and fungi at average contamination levels (Table 3). The Isolated fungi were identified at least to the genus level depending on their morphological characteristics on different culture media using light microscopes according to (Domsch et al 1980). The fungal strains isolated from the weathered diorite belonged to the genera, *Aspergillus niger*, *Aspergillus flavus*, *Alternaria alternate*, *Fusarium sp.*, *Penicillium sp*), *Mucor sp*. Also *Gram positive Bacillus sp.*, of bacteria were identified.

Table 3 various types of microbiological growths found over diorite statues at Mut temple.

Sample	Fungi (CFU/g)	Bacteria (CFU/g)	Microorganisms	
			Bacteria	Fungus
1	11×10^3	80×10^3	*Gram positive Bacilli sp.*	*Aspergillus niger, Aspergillus flavus, Mucor sp.*
3	9×10^3	6×10^3	*Gram positive Bacilli sp.*	*Aspergillus flavus, Alternaria alternate*
5	6×10^3	40	*Gram positive Bacilli sp.*	*Aspergillus flavus, Fusarium sp., Penicillium sp.*

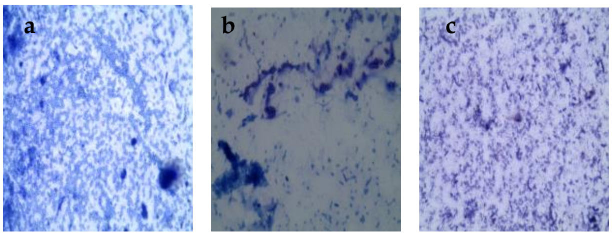

Figure 12 Cyanobacteria isolated from diorite statues at Mut temple

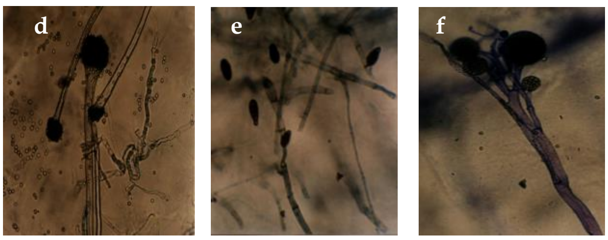

Figure 13 Fungi isolated from diorite statues at Mut a- *Aspergillus flavus*; b- *Alternaria alternate*; c- *Mucor sp.*

4. DISCUSSION

The sacred lake called the Isheru represents the main source of water in the Mut temple and is one of the most arid saline lakes. Samples from the lake water were analyzed for comparison with other samples from the Mut statues to see how much the lake water had affected them. The chemical analysis showed that the water sample is rich in sodium (Na^+), chloride (Cl^-), potassium (K^+), magnesium (Mg^{2+}), nitrate (NO^{3-}) and calcium (Ca^{++}) ions. The water also has a high content of sulphates (SO_4^{2-}), Carbonate (CO_3^{--}), phosphate (PO_4^{--}) and Ammonia (N-NH_4). The XRF analysis of the diorite samples showed similar results and the presence of the same salts in addition to a high percentage of Cl and Na, which are contained in halite. The samples also showed a saturation state with both calcium (Ca), magnesium (Mg) and phosphate (P). This phenomenon is related to the effect of the lake groundwater. This excess of chloride ions, sulphates, nitrate and carbonates suggested that degradation of the diorite statues. The presence of halite, sulphates and carbonates in the diorite samples is derived from the lake or the soil of the temple. Generally, the soil of Egypt is known to be saline. This suggests that statues buried for thousands of years will eventually become salinized through salt-transporting ground water or through rare rains percolating through the earth. Since the construction of the first dam on the Nile and the High Dam near Aswan (1965). Irrigation has greatly increased the salt content of soil and monuments at Karnak. Upon excavation of the diorite, the absorbed water gradually evaporated and the salts present crystallized. Pressures on the micropores of the rock, due to the crystallization of the salts, would have likely caused its deterioration (McFarlanek J., et al 1983). Scanning electron microscope (SEM) results confirm that a major deterioration is the abundance of soluble salts in the rock. SEM micrographs revealed the salt deposits on the statues surface causes several alterations such cracks contributed to increased porosity causing the diorite to become permeable and losses of cohesion between grains. The microcracks and intergranular cracks had developed into channels hence creating permeability for ingress of pollutants in gaseous and aqueous form. Various crystalline forms of halite and gypsum, such as needles crystal of halite and acicular and platy of gypsum were found in the weathered diorite. The samples show a high incidence of rust colored iron staining. XRF, XRD and some of the rust colored staining were seen in the thin section. Mobilization of Fe from minerals within the stone, such as biotite, may also be a source of the ferric Fe^{2+}which during the weathering process goes to the more mobile ferrous^{3+} (Jones, M.S et al 1996). The rate and extent of degradation of Sekhmet diorite statues depends also on the weathering of individual minerals within its matrix. The study proved that, the feldspar, plagioclase and mica minerals in diorite were partially sericitised and completely altered crystal. The petrographic study appeared plagioclase very cloudy due to replacement by fine grained clay minerals such as sericite [$K_2Al_4Si_6O_{20}$ (OH_4)] and kaolinite [$Al_4Si_4O_{10}$ (OH_8)]. The degradation and alteration of plagioclase in diorite may proceed by one or more mechanisms, including the leaching of cations from the silica lattice by hydrogen ion activity on its surface or to depths greater than one or two unit cells. The leaching of silica, which in turn renders the rock more porous is another suspected mechanism of igneous rock weathering, (McFarlanek J. et al 1983). Biotite and hornblende was found in all samples altered to green chlorite. Biotite undergoes volume changes when it alters to chlorite, in addition clay minerals are hydrophilic and react to varying humidities by expansion and contraction. The activation of chlorite clay layers may destabilize the grains and cause decay. The weathering process altering biotite to chlorite involves loss of K, Na, Ti, OH and Si. The XRF data shows a loss of K and Ti.

LOM investigated showed a thick layer of dust covered the surface of the rock. Generally the accumulate of dirt coating the surfaces of monuments lead to degradation of the stone surface as result of the reaction between the dirt and the stone surface which affect the statues visibility and its aesthetic value (Eric, D., Price, C.A. 2010).

The biological investigation proved that diorite statues in the studied object are exposed to the attack of microorganisms, also SEM micrograph revealed some microflora inside the pits at the diorite samples from the Mut temple. The biological investigation of the genera isolated from the diorite samples that were derived from the forte of Sekhmet statues revealed that the fungal flora *Aspergillus flavus* represents the dominant fungi isolates from the collating samples. *Aspergillus niger* was detected upon the other statues. The fungal flora *Alternaria alternate* has been detected also, while the fungal flora *phoma sp., Fusarium sp.,* and *Penicillium sp.* were detected in the isolates taken from the diorite statues. In addition to, *Gram positive Bacillus sp.*, of bacteria were identified. Recent research has demonstrated that microorganisms can accelerate elemental release from geologic materials, either directly through the acquisition of limiting nutrients required for biomass synthesis; e.g., P and Fe (Bennett P. 2001) or indirectly through the release of exoproducts that lower pH, complex cations, and/or change mineral saturation states (Liermann L. 2000). Other work has shown that microbial activities can inhibit elemental release by facilitating development of an amorphous leached layer (Benzerara et al., 2004, 2005), promoting adsorption of polysaccharides onto mineral surfaces (Welch et al., 1999) and releasing ferric iron that interacts with surface sites (Santelli et al., 2001).

Mechanical degradation of statues was suggested to occur upon their excavation In addition, it is highly probably that microfractures caused by crystallization of soluble salts during burial; i.e. in dry periods between rains, accelerates the destruction of the mineral structure.

5. CONSERVATION - SUGGESTION AND RECOMMENDATION

The previous study clarifies that the diorite statues at Mut temple had been exposed to aggressive deterioration factors. Therefore, the statues need to carry out different treatments and conservation processes, 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 because any efforts that taken to protect the statues when water levels surge is worthwhile. The important problem is the raised groundwater level due to increased irrigation. This can be solved in various ways, but probably the most sustainable solution is to change or improve the irrigation management in the area; restricting crop types.
- The present irrigation flood system should be changed to new systems such as sprinkler and drop methods to reduce groundwater recharge.
- Continuous monitoring of physical parameters e.g. pH, Electrical Conductivity, as a clue of changes in groundwater chemistry to trace the source of recharge water as well as pollutants.
- The present study shows the increased of concentration of ions (especially Na^+, Cl^- and SO_4^{-2}) in some low-lying areas in flood plains regions include Mut temple area due to the lack of agricultural drainage in newly reclaimed lands next to some other factors, such as lack of a sewage system in the majority of rural areas and the intensive use of agricultural fertilizers.
- Construction of a sewage network in the temple area and the surroundings villages with a continuous care and detection of leakage in the drainage networks.
- Demolition all modern buildings (a few houses) near the site to preserving the historical environment, cultural and heritage values in addition to integrated preservation to the site.
- Completing excavation to discover all the buried statues. Careful observation of burial environments could save many dioritic statues from rapid degradation. In the case of obviously damp soils, the statues should be immediately protected from evaporation.
- Reconstruction mud bricks wall enclosing the site that will be capable of excluding the animals which are damaging the site, with maintenance of the aesthetics and integrity of the site.
- Cleaning and removing of vegetation should be carried out to reduce the negative impacts by trees, plants, shrubs roots for all archeological remains at the site by mechanical removal for roots and rhizomes and chemical removal by using chemical pesti-

cides as pesticide Glyphosate pesticide or Fuluazifop-p-butyl 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.in the context of other parameters-depth of penetration, stability of surface appearance, and retention of porosity (Klaus J.H, et al 1988).

- After Preventive Conservation, conservation interventions have to be individually planned and Consolidation, other conservation treatments must as always only be performed after thoroughly testing all procedures, recalling the often friable nature of these unique statues and avoid further damages.
- During field observation, highly areas have been detected. Here emergency measures should be carried out immediately in order to prevent the loss of original material. 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.66 diluted at 5% in acetone by spray methods is the best consolidant material to apply in this environment.
- 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 et al 2003). Chemical cleaning can be done to remove what mechanical cleaning failed to remove from stains and dirt by using organic solvents, the best results will obtained with mixture of ethyl alcohol, acetone, toluene and trichloroethylene.
- 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 statues and its inscription 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. A mixture of clay and paper fiber produces an absorbent and plastic mixture that is often favored by conservators of stone sculpture. (Aneta et al 2010).
- 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 diorite statues using Silane (The alkoxysilanes, or "silanes" for short, have undoubtedly been the most widely used stone consolidants over the past twenty years. Two compounds, in particular, have been dominant: methyltrimethoxysilane (MTMOS) and tetraethoxysilane (TEOS). The silanes are hydrolyzed by water to form silanols, which then polymerize in a condensation reaction to give a silicone polymer) (Price, C.A. 1996) which aims to eliminate or reduce capillary absorption of water in driving rain and enhance durability of the stone. Laboratory research and experimental field work suggest that siloxanes, silanes and other alkoxysilanes consolidants are promising for treatment of diorite because of penetrating into the stone substrate slightly, increasing in compressive strength, modulus of rupture, and abrasion resistance. These improvements seem remarkable, given the relatively small amount of consolidant deposited.
- 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; diorite crushing under 5mm, dark sand, Wacker VB132+ Ac-

ryloid B.72 is the best one for weather diorite (Bader, N. 2011).

- Re-jointing and linking of the broken statues can be done by using stainless steel bars, Araldite 1092 and the same mortars and then complete the missing gaps and spaces with the same components.
- After conservation steps, all statues should be set on mastabas, further the possibility to waterproof the mastaba will be made all the more necessary by prevent intermittent rising and lowering of the water table.
- The display area at the temple of Mut should be completed roofing to protect the statues.
- Preparing the site with restricting access, signs, low guidance fencing or barriers, walkways etc.
- Periodical monitoring with regular measurements (moisture, groundwater table, temperature, air pollution…etc.) will be more effective and help to observe any seriously impacting or damaging at the site.

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