# Deterioration of Rock Art Painting at unfinished obelisk quarry in Aswan

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**Abstract:** The famous unfinished obelisk quarry, southeast of Aswan is a unique source of large granite monuments. The area of the northern obelisk quarry has been recently excavated and renovated by Supreme Council of Antiquities, a huge mounds of rubble, sand and granite powder cleared to reveal many unknown granite objects, unfinished statues and several quarry tools. After the workers cleaning the sand and dirt from the quarry walls, they found that the quarry faces covered with striking scenes. The first feature, a group of Ostriches, different in body size walking in the desert with red ochre. The second feature fishes swimming in water have fins and use gills for breathing underwater and several boats or cargo boats with black ochre. Moreover, a large obelisk with red ochre present between the swimming fishes distinctly different in body size. The present paper is an attempt to elucidate the weathering, geological and structural characteristics of granite rocks. This paper also aims to identify and understand the causes and mechanisms of deterioration of the wall paintings in the unfinished obelisk quarry. Exposure to wind, rain, fluctuation of temperature, groundwater, seepage, moisture, biological growth and encrustation, all contribute to the deterioration of the rock art in the quarry. Salt effloresces, granular disintegration and the enlargement of existing granite pores and cracks close to the rock surface, facilitate and accelerating the rate of weathering. Unfortunately, even slow rates of weathering can lead to unacceptable deterioration of rock paintings, as the painting layer on the granite surface are friable and cannot persist on a disaggregating or flaking granite surfaces. Several samples has been examined by petrographic microscope, X- ray diffraction analysis (XRD) and scanning electron microscope (SEM) showed that the products of the highly weathered pink granite are dominated by kaolinite, iron oxides, calcite and muscovite.

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**Key words** Rock painting, granite weathering, unfinished obelisk quarry, red painting, black painting

## 1. Introduction:

The unfinished obelisk quarry is located in the southern part of Aswan, less than one Kilometer east of the road to the High Dam. It is an ancient quarry where wedge – holes made by the ancient quarrymen. They are can be seen beside remains of a huge, undetached block of granite (unfinished obelisk) 41.75 meters long and 4.2 meters wide at its broader end Fig. (1-A). The early peak of granite quarrying was reached during the old kingdom, when 45.000 cubic meters of stone were removed from the quarries of Aswan (Roder, 1965). The granite rocks are generally not homogenous in mineralogical composition. The unfinished obelisk quarry in Aswan contains excellent granite rocks which are hard, compact and free from many foreign xenoliths (Ball 1907). They acquire beautiful colours ranging from pink to worm red and dark red (Barthoux 1922; Hume 1935; Gindy 1974; Meneisy *et al.*, 1979). The Aswan monumental granite is dissected by large, extensive and widely spaced joints with a distance separating the joints reaching about 5 meters. It was selected by the ancient Egyptians as a sole source of the larger obelisks and many ornamental structures from the ancient time (Gindy 1956). Egyptian rock art is known in many sites in upper Egypt, Nubian Nile valley, Eastern and Western desert. Rock art is a term normally applied to paintings and engravings on natural rock surface (Coulson & Camphell, 2001).Walls of unfinished obelisk quarry were covered with striking scenes. A group of Ostriches, different in body size walking in the desert with red pigment Fig. (1-B). In Fig. (1-C) there is a scene of fishes swimming in water. Several boats with black pigment Fig. (1-D). The rock art of unfinished obelisk quarry made of two pigments red and black.

Cause of rock paintings deterioration has been argued (Bradley *et al.*, 2002). The weathering of the rock surface is rather than alteration of rock paintings, through a variety of mechanisms, (Van Rijssen, 1987).The degree of adhesion of a painting to the rock surface will depend on the nature of the rock, pigment, its binder and the method of application (Batchelor, 1990; Loubser, 1991). Dry pigments and those applied as a past are easily peeled off and deteriorate rapidly, whereas those that are more fluid are able to infiltrate deeper into the rock making them more resilient (Loubser, 1991). The disintegration of granite rocks in Aswan region seems to belong two periods other than present. The products of what seem to be the earliest period of disintegration are found at the contact of coarse red granite with the base of the overlying Nubian sandstone. They form a zone of what Ball designates as "broken - down granite, a kaolinic mass with quartz grains". The second period is manifested in a tendency toward deep, granular disintegration massively affecting the coarse red granite at a level which is approximately that of the Aswan Reservoir when full. This disintegration is best seen on the island of El Hesa (Barton, 1916). Weathering processes are influenced by endogenetic and exogenetic factors, whereby endogenetic factors are related to the structure and composition of the rock itself, and exogenetic factors include climate and vegetation. The mechanisms which contribute to the deterioration of granite can be grouped into three separate categories: mechanical, chemical and biological (Small and Clark, 1982; Viles, 1995).

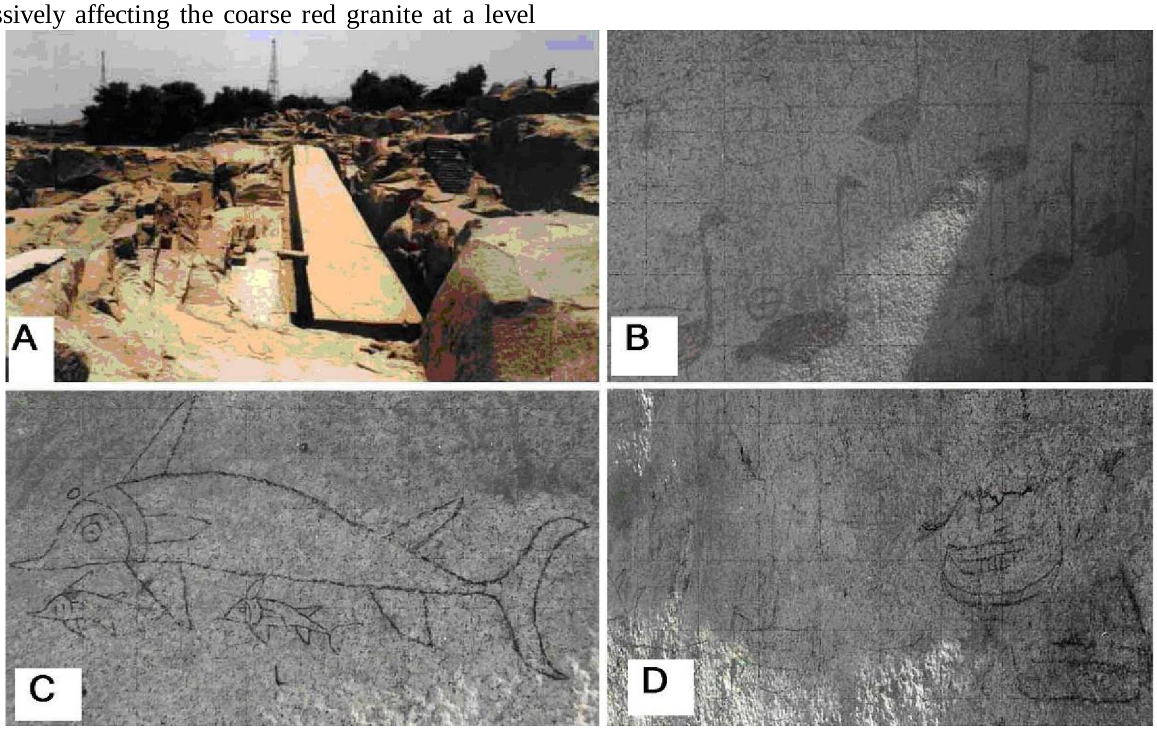


**Fig. (1A): The famous unfinished obelisk at the obelisk quarry in Aswan. (B) Group of Ostriches, different in body size walking in the desert with red pigment. (C) Fishes swimming in water. (D) Boats with black pigment.**

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The change of temperature in Egypt especially in the southern places affects these granite rocks very much in a way that leads to a disintegration of grain intergrowth forces and separation of some of these grains (Helmi, 1985). A more probable cause of this type of degradation is the infiltration of soluble salts into the rock pores and crystallization of the salts there in. Voute (1963) ascribed the damage within the granite of Aswan to soluble salts. Also, Edmond *et al.* (1979) considered the process of weathering of igneous rock as a combination of hydrolysis reaction and acid attack by $CO_2$ – charged rain and groundwater. The changes produced by weathering in fresh rocks are governed by thermodynamic laws and can be ascribed to partial or complete decomposition of both major and minor chemical elements (Carrol, 1970). Chemical weathering of rocks is one of the major processes that modify the earth's surface contributing to the geochemical cycling of elements. (Casellato *et al.*, 2000) argue that conservation intervention can be more appropriate when ''...quantitative physico-chemical properties of the object are sufficiently known" as this helps elucidate the modification the object has undergone as a result of ''...the action of time, weather and human beings." Once we better understand the chemical composition so we may better understand the performance properties of the pigments (Hao and Iqbal, 1997)

**2. Materials and Methods:**

Samples of the granite rocks, altered granite surfaces, and consolidate granite flakes were studied by Polarizing microscopy (PLM), scanning electron microscope SEM-EDX and X-ray diffraction (XRD) to find their mineral composition, morphological features and alteration products of granite rocks and paintings in the obelisk quarry.

**3. Results and Discussion:**

**Field observation**

During a field visit, a complete survey carried out by field observation, visual inspection at the unfinished obelisk quarry explained many different deterioration factors are affecting on granite rocks and paintings in the obelisk quarry as solar radiation, structural changes, moisture, ground and underground water leading to fracturing, crumbling, discoloration and exfoliation of rock surfaces (Meiklejohn, 1995). There are many deterioration aspects Fig. 2(A-E) as underground water appeared during the recent excavation, cracking, loosing and detachment of some rock art details due to internal pressures and intensive strains (as a result of salt crystals and thermophysical action) and brown, yellow and black colors due to inappropriate previous treatment represented in consolidation processes with a solution of paraloid B-72 in acetone solvent.

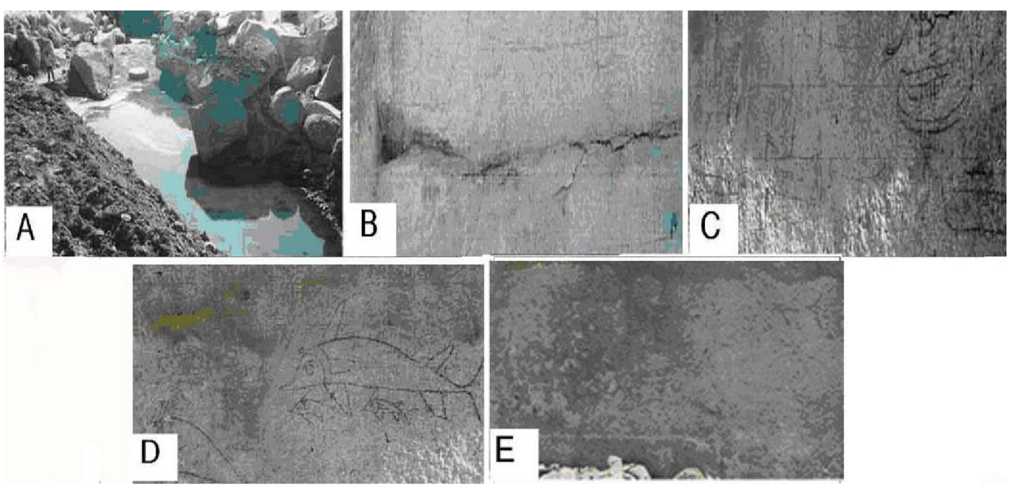


**Fig.(2) Deterioration aspects of unfinished obelisk quarry.(A) Underground water during the recent excavation. (B) Cracking, loosing and detachment of some rock art details due to internal pressures and intensive strains. (C, D, E) Brown, yellow and black colors due to inappropriate previous treatment**

**Polarizing Microscope (PL)**

The examination of the granite samples thin section under polarized light microscope displayed that the granite rock composed mainly of alkali feldspars, quartz, plagioclase and biotite, together with variable amounts of hornblende. Zircon, iron oxides, sphene and apatite are accessory minerals. Microcline appeared as subhedral to anhedral crystals, characterised by cross hatch twinning. It is slightly kaolinitized, commonly replaced by sericite, calcite and muscovite shreds. It commonly encloses fine quartz crystals replaced with biotite flakes and hornblende relics that pass into microcline crystal which causes instability of the microcline crystals Fig.(3-A). Microcline perthite forms subhedral to anhedral phoenocrystals with irregular boundary, slightly turbid, mostly cracked, completely altered and highly sericitized and kaolinitzed which make them more prone to deterioration by natural rock weathering processes Fig.(3-B). It encloses subrounded quartz crystals and relics of altered plagioclase. Irregular granules and fine dust of iron oxides concentrated along the cleavage planes. Perthite is of the vein flame and patchy types Quartz forms interlocking anhedral crystals filling the interstices between the feldspars. These crystals are highly intensely strained, cracked and exhibit wavy extinction. It is enclosed commonly in alkali feldspars, plagioclase and biotite and the calcite veinlets dissecting the quartz crystals as a result of alteration processes Fig. (3-C). The existence of calcite is essential in understanding the nature of chemical weathering of the granite rocks.

Plagioclase occurs as subhedral to anhedral crystals, turbid, cracked, slightly kaolinitzed. In Fig. (3-D) plagioclase commonly stained by hematite dust and enclosed with iron oxides granules, epidote, sericite, kaolinite. Iron oxides are commonly concentrated along the borders and cleavage planes**.** Some weathered plagioclase crystal stained by hematite dust and gives brown pigmentation due to the intensive alteration. Numerous points of sericite, epidote and scaly or tiny muscovite flakes (secondary minerals) disseminated throughout the highly weathered plagioclase as a result of mineral transformation through the alteration processes. Sometimes the weathered plagioclase crystal replaced by calcite veins (Keller 1976) Fg.(3-E), intensely strained where the twin lamellar are bent, microfaulted and occasionally absent. Biotite occurs as subheral to anhedral flakes of brown colour and strongly pleochroic from straw yellow to dark brown. Commonly biotite flakes altered along cleavage planes to sphene, epidote and brown iron oxides. It is frequently enclosed irregular granules of iron oxides Fig. (3-F). The alteration products of mafic minerals such as biotite and hornblende are hematite, supplies the typical reddish and chocolate brown colours of altered granite rocks.

Hornblende forms anhedral crystals of green colour and strong pleochroism form pale green to dark green or olive, green. It is frequently replaced by anhedral biotite flakes dispersed within it. Numerous It encloses irregular granules of iron oxides and hematite dust concentrated at the cleavage planes.

Epidot occurs as subhedral crystal and commonly associated with biotite and plagioclase crystals as shown in Fig.(3-D). Sphene forms subhedral to anhedral crystals with rhombic outline and commonly associated with hornblende and biotite.

Keller (1976) stated that the micropitting of feldspar, probably as a result of dissolution of feldspar crystals (transformation minerals) and the early stage of kaolinization. Weathering processes that are possibly to be active at these borders consist of salt crystallization, hydration and dehydration of minerals, salts hydration and dehydration of clay minerals

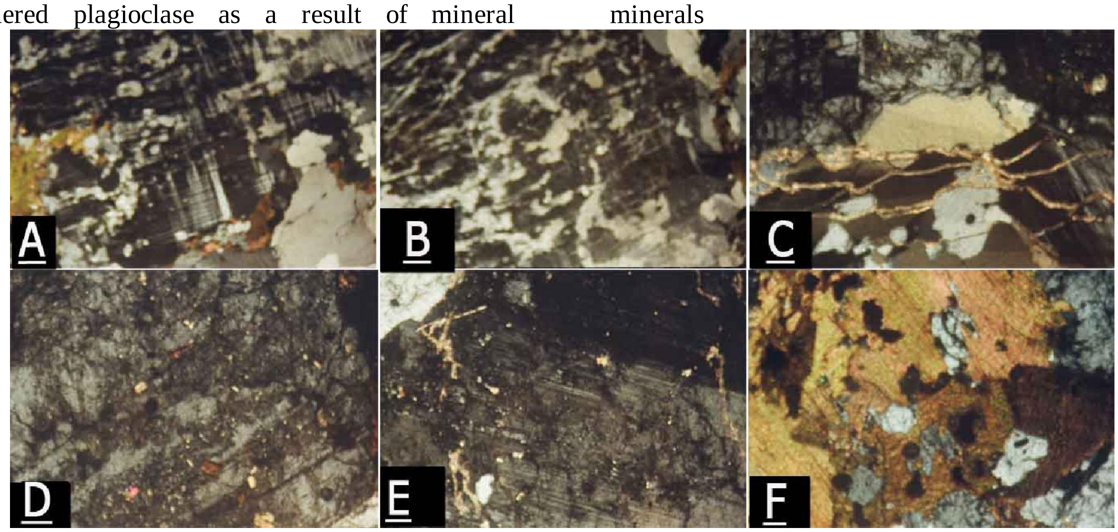


**Fig.(3): The examination of the granite samples thin section under cross polarised microscope.(A) Microcline crystal slightly sericitized, encloses fine quartz crystals and replaced with hornblende and biotite flakes. (B) Microcline perthite turbid, mostly cracked, completely altered. (C) Calcite veinlets dissecting the quartz crystals. (D) Plagioclase enclosed with iron oxides granules, epidote and sericite and (E) replaced by calcite veins. (F) Biotite flakes altered and enclosed irregular granules of iron oxides.**

**Scanning electron microscope (SEM)**

Scanning electron microscope examination micrographs of external deteriorated granite surfaces from the unfinished obelisk quarry showing that the weathered granite surfaces is porous, has many salt crystals, pits, black spots and scales as a result of physical and chemical alteration Fig. (4-A).

Formation of sheeting structure and the enlargement of existing granite cleavages close to the surface of granite, facilitate an increasingly dynamic moisture regime which leads to accelerate the rate of deterioration. Macro and micro cracks and incipient joints present lines of weakness along which individual mineral crystals or particles may disintegrate and exfoliation may occur as shown in Fig. (4-B).

The SEM micrographs showing that the typical degradation forms in granite rock consist of fissures, sheets and scales of several sizes. Paraloid - B72 is able to penetrate through these fissures and sheets where it builds up some adhering bridges between the fracture walls and sheeting structure. One of the most important weathering process at the unfinished obelisk quarry is the salt efflorescence's which cover the tope surface of paintings rock and growth of salt crystals within the porous and microcracks of the granite rocks (Hugget, 2003) Fig. (4-C). Halite crystals are usually occurs in cubic form, produce a kind of vuggy pockets Fig. (4-D). Moreover, epsomite crystals commonly occur as rhombic shape as a result of pollution, ground and underground water Fig. (4-E). The salt crystals precipitate in the porous and microcracks can exert stress and readily cause mineral breakdown. The final results is either crumbling of the thin surface layer or forming a blister and exfoliation on the surface of rock art. The hydration of salts within pores and cracks develops sufficient stress to cause extensive sapling and flaking. Weathering is very intense along fractures and the spatial variation of weathering is connected with the structure and texture of granitic rocks (Ritter *et al.* 1995). Kaolinite was identified by SEM micrographs from crystal habit (forming booklets) as a result of feldspar alteration by hydrolysis process Fig. (4-F). In addition, SEM micrographs revealing that there are large islands on the treated surfaces surrounded by rims and sometimes the rims disappear but the island area are still visible as a result of inappropriate solvent used for Paraloid-B72 film preparation Fig. (4-G). On the otherside, the treated granite samples revealed that the surface of rock art have a high density distribution of Paraloid-B72, relatively with smooth surface and sometimes with slightly rippled surface, the pores at the surface relatively are completely filled with Paraloid-B72 Fig.(4-H).

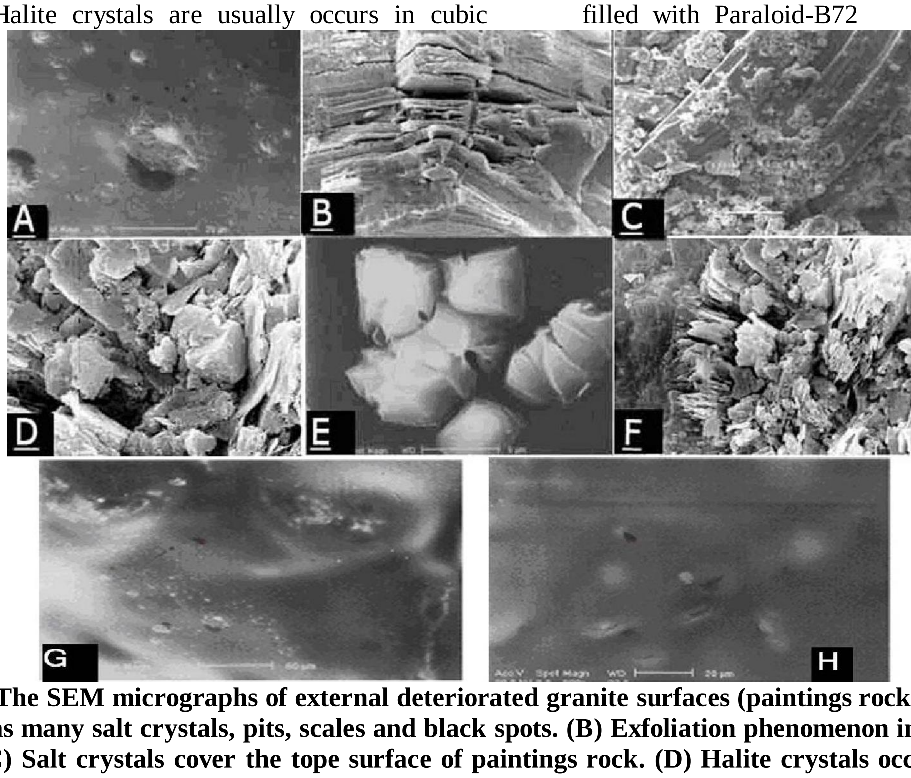


**Fig.(4) The SEM micrographs of external deteriorated granite surfaces (paintings rock). (A) Granite surface has many salt crystals, pits, scales and black spots. (B) Exfoliation phenomenon in the granite surfaces. (C) Salt crystals cover the tope surface of paintings rock. (D) Halite crystals occur in cubic form. (E) Epsomite crystals occur in rhombic shape. (F) Kaolinite booklets due to alteration of feldspars. (G) Large islands surrounded by rims on the treated granite surfaces as a result of inappropriate solvent. (H) The distribution of Paraloid-B72on granite surfaces, relatively with smooth surface and sometimes slightly rippled surface.**

**X– Ray Diffraction analysis (XRD)**

Three samples taken from damage surfaces collected from rock art site have been examined by X-ray diffraction analysis (XRD) at the Scientific Mobark City to find their mineralogical characteristics and the alteration products of pigments and granite rocks. Pigment paints lie directly on the granite rocks and that paintings is exposed to solar radiation, therefore there will be thermal differences between the pigments and the granite rock due to differential and thermal properties. Moreover, changes in environmental conditions of moisture and temperature are suggested to effect the stability of pigments of rock art. Accordingly, pigments are easily washed away or simply fade through natural weathering (Fleisher *et al.*, 2005).

**Table (1): Results of X – ray diffraction analysis**

| Sample No. | Material type | Sample site | Composition |
|---|---|---|---|
| 1 | Altered granite surface | Obelisk quarry wall | Quartz – Microcline – Albite – Epsomite – Epidote -Bayerite- |
| 2 | Red pigment | Paintings rock in obelisk quarry | Hematite - Quartz – Microcline – Albite |
| 3 | Black pigment | Paintings rock in obelisk quarry | Graphite – Nontronite – Iron oxide |

The results of the study ( Table 1 ) have shown that the altered granite sample from the obelisk quarry wall consists of quartz ( $SiO_2$ ), microcline ( K AL $Si_3O_8$ ), albite ( Na AL $Si_3O_8$ ), epidote $Ca_2$ $Fe_3$ $AL_2O$ $Si_2O_7$ $SiO_4$ (OH), bayerite $AL(OH)_3$, wustite FeO and epsomite Mg $SO_4$. 7 $H_2O$.

In addition XRD data of red pigment obtained by scraping the surface of paintings rock indicated that the red pigment consists of hematite ( $Fe_2O_3$ ), quartz ($SiO_2$ ), microcline (K AL $Si_3O_8$ ) and albite ( Na AL $Si_3O_8$ ), while the black pigment from the paintings rock consisted essentially of graphite ( C ), nantronite ( Fe, AL ) $Si_2O_5$ and iron oxides.

**Table ( 2 ) Results of ( EDX ) Energy Dispersive X-Ray analysis of the altered granite rocks from obelisk quarry.**

| Mineral composition | Al | Si | K | Ca | Ti | Mg | Fe | Na |
|---|---|---|---|---|---|---|---|---|
| **Sample of granite** | 16.7 | 46.4 | 7.3 | 1.3 | 2.6 | 1.2 | 24.5 | 0.9 |

EDX analysis of altered granite from obelisk quarry commonly consisted of Si, Al, K, Ca, Fe, Mg, Ti, and Na. The chemical composition of the altered granite sample relatively enriched in Fe, Ca, K and Al while Si is markedly depleted.

**4. Conclusion:**

Generally, the unfinished obelisk quarry is an archaeological quarry. The area of the northern unfinished obelisk quarry has been recently excavated and cleaning from sand, rubble and granite powder. The quarry has a very interesting paintings rock. The paintings and granite rocks in the unfinished obelisk quarry at Aswan are constantly exposed to many deterioration factors. The weathered granite surfaces were examined by polarizing microscope (PL), scanning electron microscope (SEM), EDX and X-ray diffraction (XRD) analysis. Some painting suffered a total loss of the painting thin layers and in others there is only loss of small parts of the painting layer.

The salt crystallization such as epsomite and halite crystals can cause a significantly degraded by intensive mechanical stresses which produced many tiny fissures, greatly increase the porosity and detachment many scale from the granite surface.

Polarizing microscope examination revealed that the weathered plagioclase crystals dissected along the cleavage planes and boundaries, frequently filled with iron oxides, epidote, sercite and clay minerals. The X-ray diffraction analysis revealed that the red pigment is hematite beside other minerals such as quartz, microcline and albite. The black pigment is carbon compound such as soot, ground charcoal or burnt animal bones.

Field observation and scanning electron microscope revealed that the cleaning and consolidating techniques were not appropriate. A granite rock needs to " breathe " or remain permeable to water vapor and liquid in order to avoid any build up of moisture ( shear stress ) at the interface between the treated zone and the untreated stone below (Fleisher *et al.*, 2005). Granite rock is not uniformly absorptive and it better to apply lower concentration and then coating repeat. SEM micrographs revealed that the Paraloid-B72 film is relatively smooth surface but in some areas show slightly rippled surface. Also, SEM photographs showing large islands surrounded by a rim and sometimes the rims disappeared but the island area is still visible. The island areas, rough and rippled surface is attributed to the inappropriate solvent which used for film preparation. The altered granite sample enriched in iron oxides, from oxidation weathering of mafic minerals as reflected from the petrographic studied and XRD and EDX analysis. This may suggest extensive invasion of water and exposure to oxidizing.

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