المؤتمر الدولي الثاني
التنمية المستدامة للمجتمعات بالوطن العربي
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Highlights on the Deterioration of Rock Art at Unfinished Obelisk Quarry in Aswan-Egypt

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Abstract:

1. The unfinished obelisk quarry in Aswan is one of the most important archeological sites in Egypt. This site contains very important rock art panels (paintings and inscriptions) which give the site further importance and are concerned with the activities of the quarry. Rock art panels at this site are subject to different kinds of physical, chemical and biological deterioration as a consequence of their exposure to the direct action of aggressive atmospheric agents (extreme temperature, wind, chemical weathering ,salts pressure and the rising water table from the canal at the site) and anthropogenic deterioration factors so; they suffer from different deterioration phenomena such as exfoliation, granular disintegration, detachment, salt crystallization, aesthetic disfigurement and chemical alterations. For this purpose, the chemical, physical and structural characterization were performed by means of Polarizing Microscope (PM), Scanning Electron Microscope (SEM) attached with EDX, X-Ray Diffraction (XRD), Infrared analysis (I.R) and microbiological study. The results have shown that these panels suffer from many crystallized salts such as sodium chloride and calcium sulfate (anhydrite or gypsum) and alteration of feldspars to clay minerals.

Key words:

Rock art, rock inscription, unfinished obelisk, Aswan, granite, deterioration, vandalism, physical enhancement.

1. Introduction

Rock art is a term normally applied to paintings and engravings on natural rock surfaces (1). The unfinished obelisk lies in the northern granite quarries at Aswan **(Fig.1a,b,c)** and this quarry is a site of tremendous importance, being one of the most impressive quarries in the world and a monument over ancient Egyptian technology, yet not completely understood (2). It derives its name from the fact that a colossal obelisk (dating to the eighteen dynasty, the reign of Hatshepsut or Thutmose III) was abandoned at an advanced stage in the process of extraction due to faults or cracks in the stone (3).This site not only supplied the Ancient Egyptians with raw materials to erect their temples, tombs, colossi and obelisks **(Fig.2(a)**) all over the history but also contains very important rock art panels (paintings and inscriptions) which give the site further importance and are concerned with the activities of the quarry and had a direct relationship to the life in the quarry in the ancient times. The results of the excavations carried out by the Supreme Council of Antiquities, Aswan office in 2002 provide that, many new discoveries such as quarry tools, different techniques of stone extraction, unfinished objects and the most famous is discovering rock art panels, all these rock art panels located above granitic bedrock face extends for about 45 meters. (4,5) divided rock art in the site generally to the follow images; A group of dolphins or fishes? In different sizes **(Fig.2 (b))** although most Egyptologists identified that figures represent dolphins. Hawss; considered them kind of fish called Thamus, well known and still to be found in Lake Nasser. A group of ostriches, standing persons holding sticks **(Fig.2(c,d))** obelisks and boats; the standing obelisks in different levels and sizes while some of these boats appear to be carrying obelisks or large blocks of granite ,Bes (the dwarf deity) depicted to protect and entertain the workers during the hard work in the quarry, geometric figures, group of work level lines and hieratic dates; both are method of calculating daily excavation and related to the ancient Egyptian calendar. In addition to the previous rock paintings, the quarry contains rock engravings represented in the inscription of Thutmose III, which containing the royal decree to cutting obelisks from the quarry in year 25 of Thutmose's reign, and scratch marks are related to the ancient Egyptian calendar.

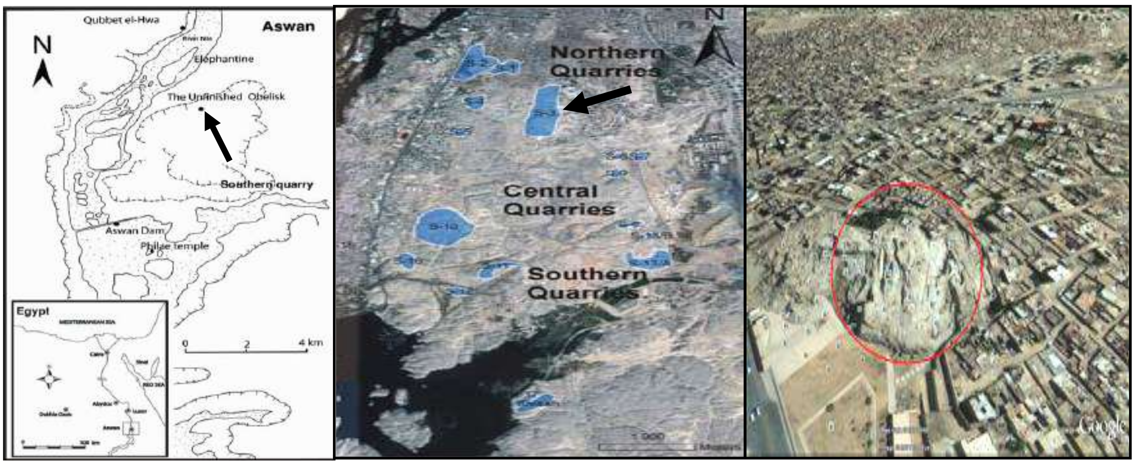


Fig.1(a) Map of Aswan area and unfinished obelisk quarry. (b) Satellite image from Google Earth of granite quarries at Aswan. (c) Unfinished obelisk quarry from Google Earth.

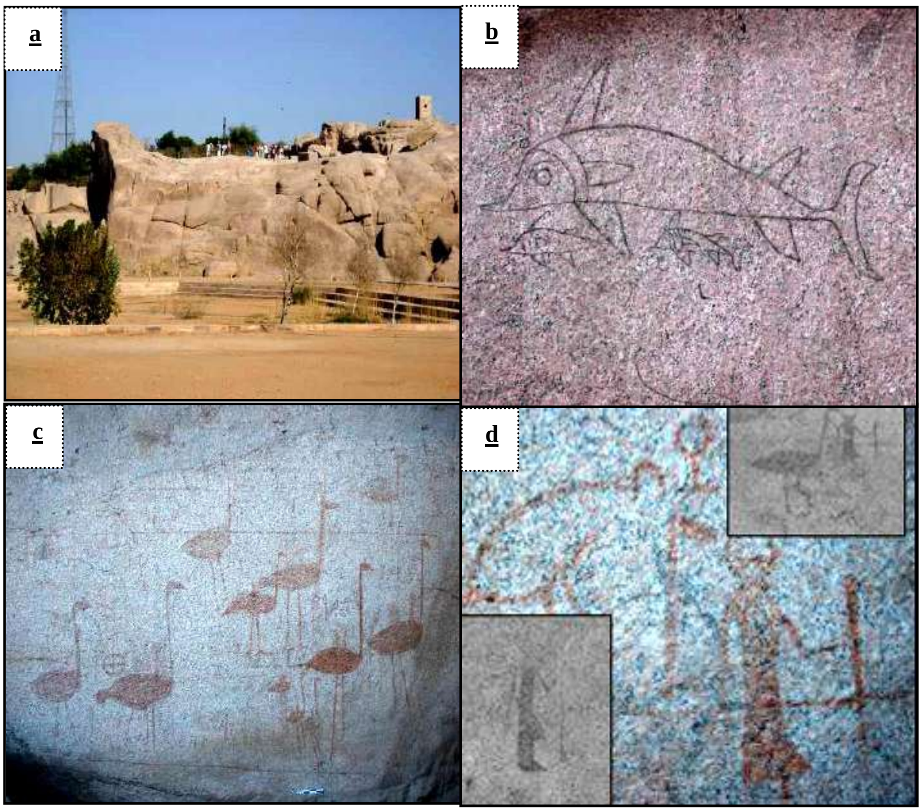


Fig. 2 (a) View of unfinished obelisk quarry at Aswan. (b) Dolphins or fishes with black pigment. (c) A group of ostriches with red pigment. (d) A standing persons holding sticks with red pigment.

1.1. Conservation State:

Rock art panels at unfinished obelisk had been exposed to either burial, aerial (exogentic) environments and endogenetic factors, whereas endogenetic related to the physical, mechanical, and chemical properties of the rock itself, and exogentic factors include environmental agents such as wind, sunlight, temperature, moisture, rain vegetation, biotic, human being agents, in addition to the rising ground water table from the canal at the site **(Fig.3 (a-f))** which helps the water and moisture to penetrate along the vertical, horizontal fractures and cracks in granitic bedrock and caused severe damage for rock art such as; Salt efflorescence, growing the vegetation and higher plants, furthermore anthropogenic deterioration factors play an important role in the deterioration of rock art through application of some substances to increase photographic contrast between the scenes and rock substrate (surface) during the documentation process, which is called the physical enhancement (6) some of these materials include the use of water and chalk, both of them have been used for documenting the rock art at unfinished obelisk quarry and they caused a serious damage, fading the rock surfaces and destroying the radiocarbon dating.

Another factor of anthropogenic deterioration is that, quick discovery and sudden exposure for rock art panels during excavations from burial to aerial environment, both have a different conditions and caused the deterioration resulted in environmental shock. The quick discovery caused quick dryness for panels from moisture and its water content, causing the fading of the paintings and salt crystallization forms such as efflorescence...etc**.** The third anthropogenic deterioration factor represented in using inappropriate treatment with a solution of Paraloid B 72 for consolidation the support of rock art (wetted granite) directly after its discovery from burial environment (7).

All the previous conditions lead to a lot of deterioration forms of rock art at unfinished obelisk quarry in Aswan **(Fig.4 (a-d))** such as exfoliation, granular disintegration, detachment, salt crystallization, aesthetic disfigurement and chemical alterations. Aesthetic disfigurement through deposit minerals on the surface that may cover the art and appearance of white and grey or black areas or rain channels on rock art panels due to rains or runoff water (8) which also dissolves soluble pigments, causing paintings to fade (9) more than that this water can also dissolve minerals and precipitate salts on or near the surface (10). These salts contribute to the weathering of rock art through thermal expansion, hydration and crystallization pressures (11) in the form of detachment scales of superficial stratum of rock art as a result of sub florescence, that is the most dangerous kind of salt crystallizations (12) salts could be lead to loss of some rock paintings details due to quick evaporation of saline solutions with aid of sand-blasting by wind.

Granite has a low thermal conductivity (13). Barton, 1916 noted that the temperature of the granite surface in Aswan reached near to 80º C during the summer (14), that led to weathering processes through thermal shock and thermal stress fatigue, through repetition on a diurnal or seasonal scale, this caused the granular disintegration or the production of new fractures in the support of rock art (15,16).

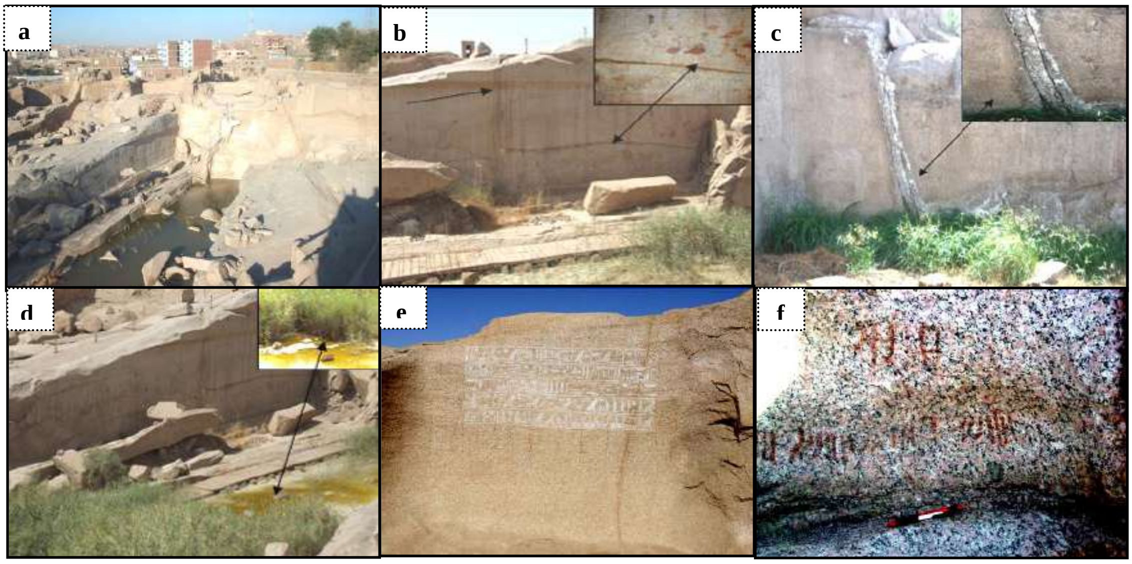


Fig.3 Deterioration factors affecting rock art at unfinished obelisk quarry:
(a) Rising of ground water table. (b) Vertical and horizontal fracture in the panels.
(c) Salts efflorescence. (d) The vegetation and higher plants.
(e) Wrong documentation using chalk. (f) Inappropriate treatment using Paraloid B 72.

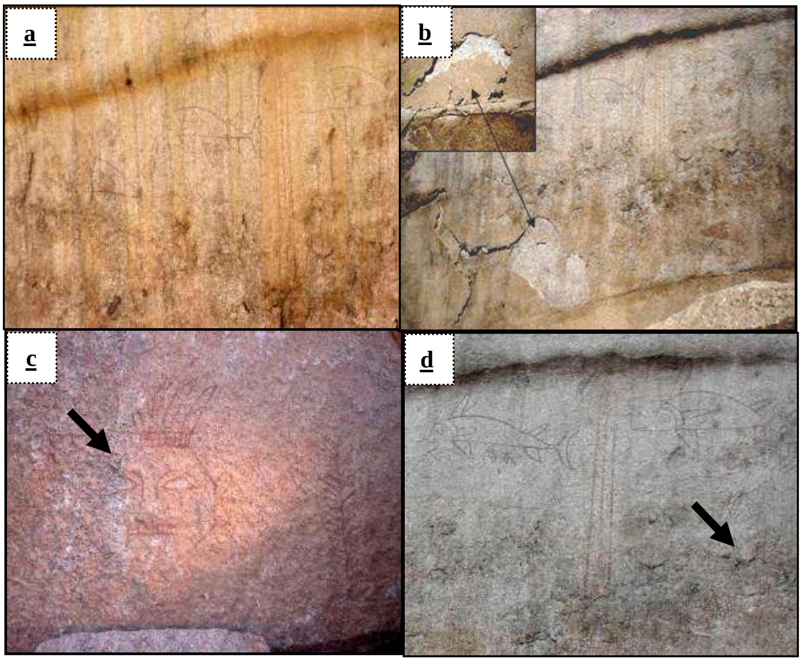


Fig.4 Deterioration forms of rock art at unfinished obelisk quarry at Aswan:
(a) White and black areas due to rains. (b) Detachment of thin outer layer of rock art support.
(c) Loss of some rock paintings details. (d) Granular disintegration and aesthetic disfigurement..

2. Materials and Methods

Some weathered samples of granite and paintings flakes from rock art surfaces at unfinished obelisk quarry were studied by scientific methods; Polarizing Microscope (PM) Scanning Electron Microscope attached with Energy dispersive X-ray analysis (SEM-EDX), X-ray diffraction (XRD) to identifying their mineralogical, chemical components, alteration features and deteioration products, in addation to deteriming the painting media. Biodeterioration study also carried out to define microorganisms classes found in the samples.

3. Results :

3.1. Polarizing Microscope (PM) Study:

Petrographic study for some weathered samples of rock art support revealed that, the granite rock is granular texture and consists of quartz, potash feldspar, plagioclase feldspar, with minor amounts of biotite, hornblende and (iron oxides). Biotite and hornblende represent the coloured minerals in the rock; they occur as minor constituents of the rock. Biotite occurs as subhedral to anhedral flakes and show wavy extinction **(Fig.5(a)),** and the alteration of some biotite to iron oxide (hematite) which stained the rock with brownish colour, the samples contained both zircon and hornblende crystals **(Fig.5(b))**.The samples exhibit alteration of the biotite to clay minerals (green chlorite) **(Fig.5(c))**. Quartz occurs as fine to coarse (0.4-1.5 mm diameters) and forms interlocking anhedral crystals filling the interstices between feldspars. It is mostly fresh; however, some of the quartz grains contained wide fractures as a result of mechanical stress. Marginal corrosion as a result of chemical solutions has been observed in some of the quartz grains. Sometimes the biotite altered to sericite, while albite crystals contained many cracks **(Fig.5 (d))**. Some of accessory minerals like allanite present in some samples, feldspars are represented by plagioclase, microcline and microcline perthite. The plagioclase is highly weathered to clay minerals and largely replaced by very fine particles of sericite appearing pale grey **(Fig.5 (e))**. Potash feldspar is represented by microcline, which occurs as fine to coarse subhedral to anhedral crystals; characterized by cross hatching twinning, sometimes occurs as elongated crystals as a result of mechanical strain or stress, with marginal corrosion **(Fig.5(f))**.Large grain of microcline is strongly altered to kaolinite as a result of chemical weathering **(Fig.5(g))**. Microcline perthite occurs as subhedral to anhedral crystals, mostly cracked **(Fig.5(h))**.

3.2. Scanning Electron Microscope (SEM) investigation:

Scanning Electron Microscope (SEM) examination of some weathered sample of granite has revealed that; the major deterioration for rock art represented in abundance of soluble salts in addition to a high degree of weathering for the rock as follows; different microcracks which have long and narrow sharp ended cracks, in addition to transgranular and intergranular fractures which caused the disintegration and decohesion among the mineral grains **(Fig.6 (a)).** Cavities and vugs are very large and deep inside stone structure and lead to increasing the porosity causing the granite become permeable and accelerate the rate of deterioration **(Fig.6 (b))**. A widespread coating of different salts is the major weathering feature such as halite and varied phases of gypsum. Halite crystal usually occurs in cubic form, produce a kind of vuggy pockets **(Fig.6(c))**, while gypsum phases occur in cluster and distributed in the cavities and vugs and penetrate towards inside **(Fig.6 (d))**. Extensive penetration of fungal hyphae inside the stone structure, which caused pitting or alveolar weathering inside feldspars and biotite grains **(Fig.6 (e-f))**.

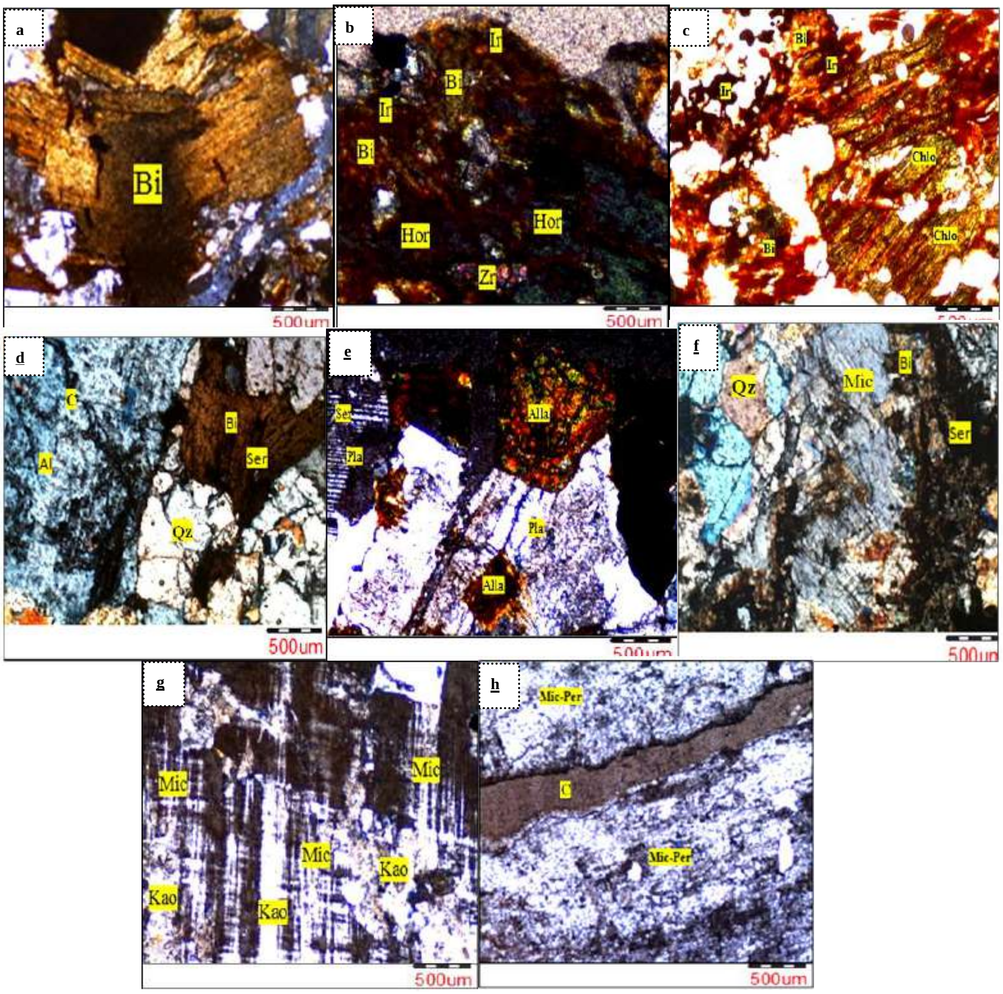


Fig. 5 The examination of granite samples under polarizing microscope:
(a) Wavy extinction in biotite crystal.(b) Hornblende, zircon and biotite grain altered to iron oxide.
(c) Biotite altered to iron oxide and chlorite. (d) Biotite altered to sericite and albite contains crack.
(e) Allanite and plagioclase altered to sericite. (f) Quartz, microcline and biotite grain altered to sericite.
(g) Microcline cross hatching twining altered to kaolinite. (h) Microcline perthite contains crack.

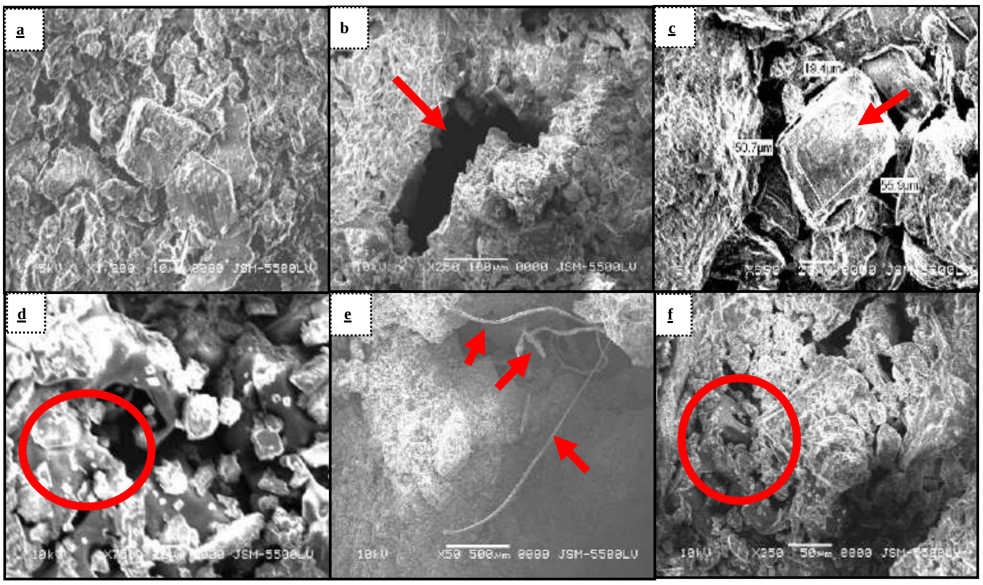


Fig.6 The SEM micrographs of weathered granite samples from rock art support:
(a) Disintegration and decoheshionof granite grains. (b) Large, deep cavities inside stone structure.
(c) Cubic crystal of sodium chloride. (d) Crystals of anhydrite and gypsum.
(e) Fungal hyphate inside stone structure. (f) Weathered feldspars with clay minerals.

3.3. X-Ray Diffraction Analysis (XRD):

X-ray diffraction results of granite samples **(Fig.7 (a-d) &Table.(1))** have identified, the presence of quartz SiO_2 as major mineral in most of the samples, while the minor minerals are represented by feldspars(albite,$NaAlSi_3O_8$) and microcline, $KAlSi_3O_8$)biotite,$K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$, Anhydrite,$CaSO_4$, calcite, $CaCO_3$ and halite (NaCl) were represented in weathered samples.

3.4. Energy dispersive X- ray analysis (EDX):

The results of EDX analysis of granite samples **(Fig. 8(a-d) and Table(2))** have indicated that, the granite samples contain high iron (Fe), high concentration of calcium (Ca), high sulfate (S), a presence of Na and Cl, In addition to the high amount of potassium (K) and Aluminum (Al) and low ratio of Ti.

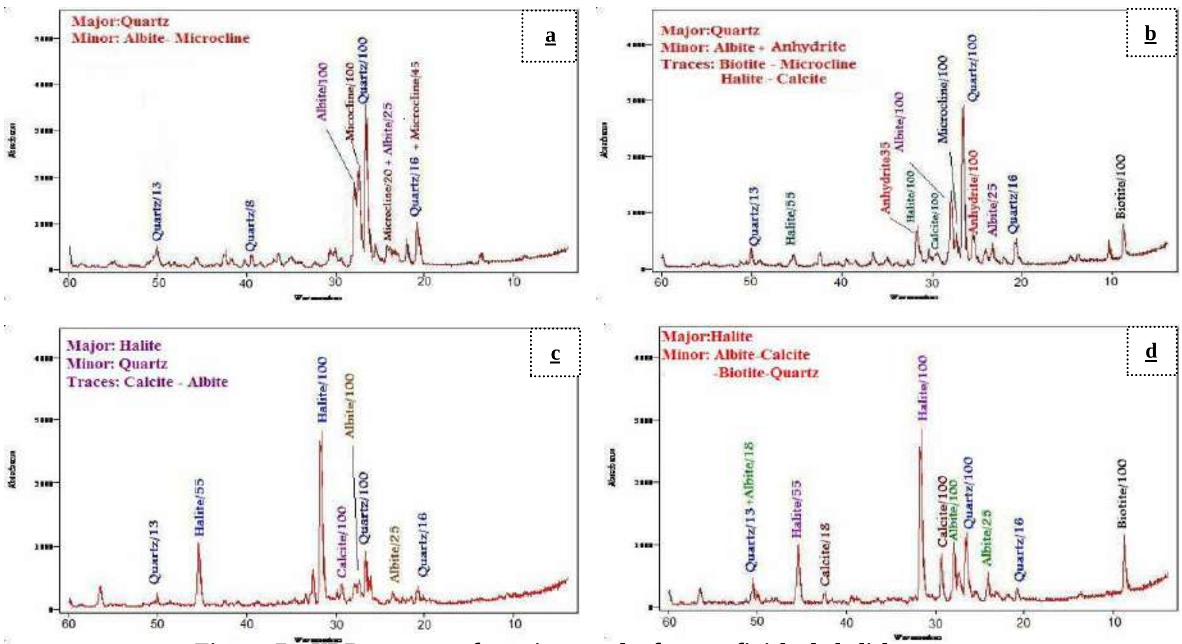


Figure. 7 XRD patterns of granite samples from unfinished obelisk quarry.

Table.1 XRD patterns of granite samples from rock art at unfinished obelisk quarry.

Samples No	Chemical Components		
	Major	Minor	Traces
A-	Quartz	Albite & Anhydrite.	Biotite, Microcline, Halite & Calcite.
B-	Quartz	Albite & Microcline.	-
C-	Halite	Quartz	Albite & Calcite.
D-	Halite	Albite, Calcite, Biotite & Quartz.	-

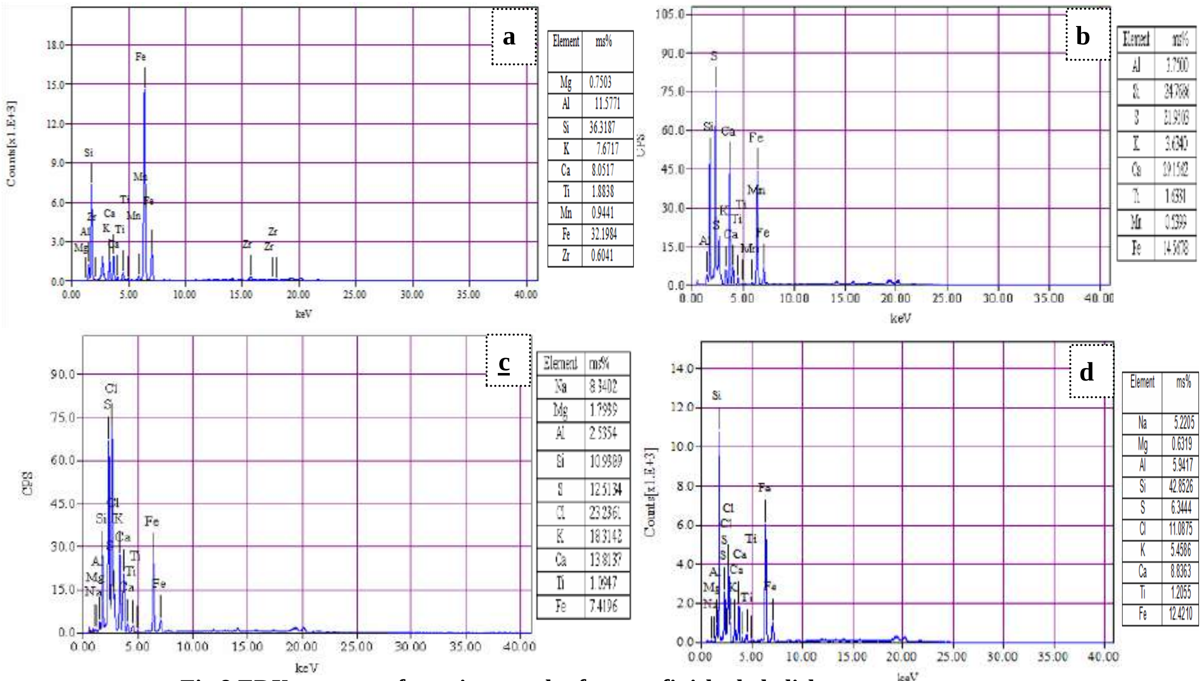


Fig.8 EDX patterns of granite samples from unfinished obelisk quarry.

Table.2 EDX patterns of granite samples from unfinished obelisk quarry.

Chemical Component	Sample NO			
Percent %	A	B	C	D
Si	36.3187	24.7686	10.9389	42.8526
K	7.6717	3.6340	18.3142	5.4586
Mn	0.9441	0.5399	——	——
Mg	0.7503	——	1.7939	0.6319
Zr	0.6041	——	——	——
Ti	1.8838	1.6331	1.0947	1.2055
Fe	32.1984	14.5678	7.4196	12.4210
Ca	8.0517	29.1562	13.8137	8.8363
Na	——	——	8.3402	5.2205
Cl	——	——	23.2361	11.0875
S	——	21.9503	12.5134	6.3444
Al	11.5771	3.7500	2.5354	5.9417

3.5. <u>Infra red analysis (I.R):</u>

I.R spectra of black and red pigments from the rock art on granitic bedrock at unfinished obelisk quarry show absorption bands at the following wave numbers: λ3546, 3409,3200,1625, 1618,1384, 1381,1092,1030 and 1024 as shown in **(Fig.(9) and table(3)).** By comparison study with, glue albumen, egg-yellow and Arabic gum I.R. stander shows that, the medium which was used in studied rock art was Arabic gum. According to (Ahmed, S.A. &Abbas, H.K., 2011) the previous pigments consisted of hematite (Fe_2O_3) as red pigment and carbon (c), as black pigment.

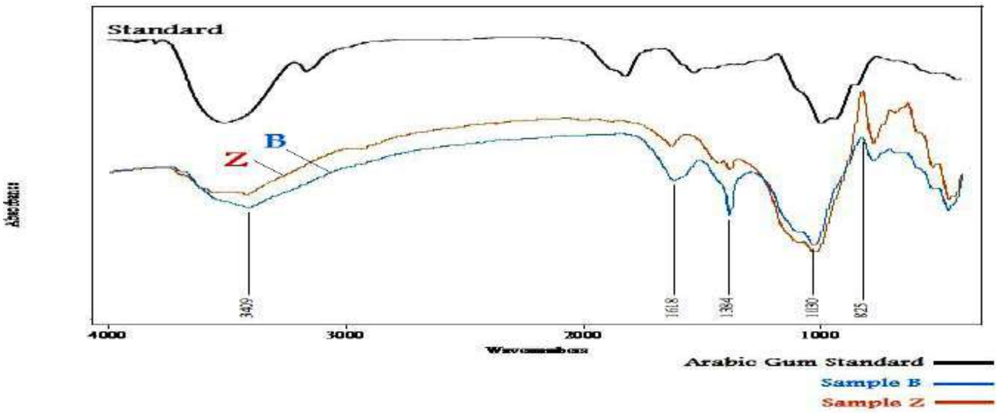


Fig.9 I.R spectra of black and red pigments from rock art at unfinished obelisk quarry.

Table 3 FTIR results of rock art pigments medium from unfinished obelisk quarry.

Wave Number			Functional Groups
Sample B Black pigment	Sample Z Red pigment	Arabic Gum	
3409	3546 -3413	3600 – 3200 cm^{-1}	O–H Stretching band
1618	1625	1650 cm	O–H Bending band
1384	1381	1480 – 1300 cm^{-1}	C– H Bending band
1030	1092–1024	1300 – 900 cm^{-1}	C–O Stretching bands

3.6. Isolation and identification microorganisms:

Microbiological analyses revealed the presence of bacteria and fungi at average contamination levels **(Fig.10 (a-h) and Table (4))**. For the isolation of fungi, plate count method was used, the plates contained Czapek's agar medium (17).The same method was used for the isolation of bacteria,by using nutrient agar medium (NA) (18).The Isolated fungi were identified at least to the genus level depending on their morphological characteristics using light microscopes according to (19). The fungal strains isolated from the weathered granite belong to the genera; *Aspergillus niger, Aspergillus flavus, Alternaria alternate, Paecilomyces carneus, and Cladosporum uredinicola*, Also *Gram positive- sporing form of Bacillus sp., Bacillus insolitus, Bacillus alcalophilus*, bacteria were identified.

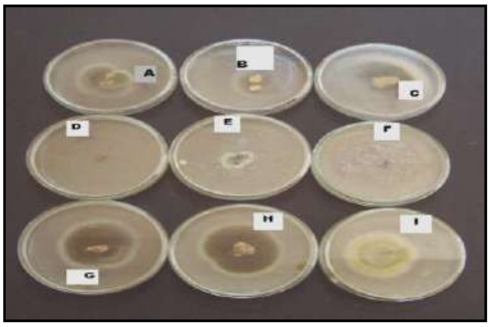
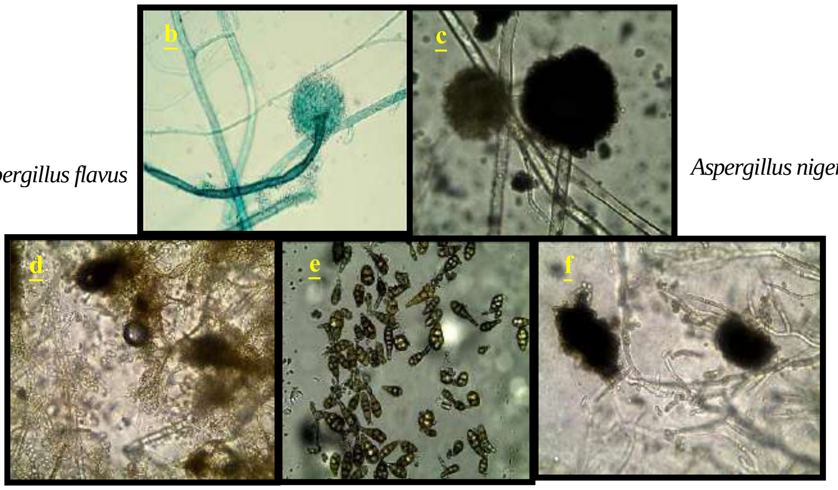


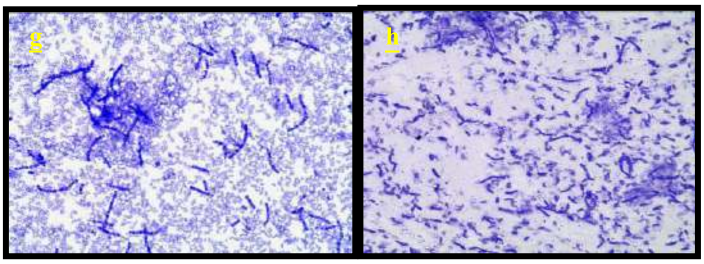
Fig.10 (a) Petrie dishes of bio-colonization.



Aspergillus flavus *Aspergillus niger*

Paecilomyces carneus *Alternaria alternate* *Cladosporium uredinicola*

Fig.10 (b-f) Fungi isolated from rock art panels at unfinished obelisk quarry.



Bacillus insolitus *Bacillus alcalophilus*

Fig.10 (g-h) Bacteria isolated from rock art panels at unfinished obelisk quarry.

Table 4 Microorganisms species isolated from rock art supports from unfinished obelisk quarry.

Sample No	Fungi	Bacteria
1-	*Asperigellus Flavus, Asperigellus Niger & Paecilomyces carneus .*	*Bacillus insolitus*
2-	*Alternaria alternata , Cladosporium uredinicola , Asperigellus Niger & Asperigellus Flavus .*	*Bacillus alcalophilus*

4. Discussion:

The famous unfinished obelisk quarry in Aswan is one of the most important archeological sites, in ancient Egypt it was a source for supplying ancient Egyptian with the raw materials of granite for the establishment their civilization. Rock art at unfinished obelisk quarry carried out on granite surfaces by two previous techniques (paintings and engravings or inscriptions). The rock paintings made of two natural pigments red and black with paintings media (Arabic gum).

The rock art at unfinished obelisk quarry suffers from several deterioration factors; physical, chemical ,biological and anthropogenic. Anthropogenic deterioration factors include the preparation method of granite surfaces (polishing or smoothing with a" grinding stone" which leads to variation and difference in its physical properties such as the perceived texture, color and gloss (20) and also generates structural stresses in the rock(21), in the same manner, the nature, the mineral composition, the binder and the method of application of the pigments, all have an impact upon pigment response to deterioration factors in the ambient environment.

Liquid pigments are able to penetrate deeper inside the rock, hence they are more resistant to deterioration if compared with dry pigments and those applied as a paste easily peeled off (22), in addition to application the physical enhancement process on rock inscriptions using water and chalk.

Before the previous mentioned factors; the quick discovery during excavations and sudden exposure of rock art panels from burial to aerial environment caused immediate destruction or deterioration after the discovery due to environmental shock and consolidation of rock art later by inappropriate treatment with a solution of Paraloid B 72 in acetone solvent, all the previous measures caused deterioration aspects of rock art such as; fading, peeled off paintings and salt crystallization forms.

Generally, the soil of Aswan area is known to be saline this suggests that, rock art panels buried for thousands of years will eventually become salinized through salt-transporting ground water since the construction of the first dam on the Nile and the High Dam near Aswan .The ancient canal at unfinished quarry represents the main factor of deterioration rock art in the site, as a source of water and saline solutions which lead to the destruction of rock art panels and motivate growing vegetation and higher plants (23, 24, 25) that also could cause some accelerated weathering to rock art in situ. Inhabitants (population) mass around the site promoted the quantity and variety of observable stone deterioration; seepage and leakage water, rising ground water table, visual disfigurement, air pollution that, threaten the rock art in situ. The deterioration phenomena of rock art at unfinished obelisk quarry in Aswan are varied such as; exfoliation, granular disintegration, scaling, cracks, fractures, salt crystallization (efflorescence, sub-florescence), discoloration, in addition to fading, flaking and loss of paintings**.**

Petrographic Studies have revealed that; the deterioration of granite was subject to both physical and chemical weathering as follows; both orthoclase and microcline are slightly or strongly altered to kaolinite and sericite. This feature is cleared by the fissures and cracks that are invading the rock, most of biotite and quartz grains make the wavy extinction clear as a result of mechanical stress. Some biotite altered to chlorite or iron oxides as a result of chemical solutions and the liberation of iron oxides which stained the rock with a brownish color. Moreover some quartz grains contained cracks may be due to the preparation process of rock art surfaces by grinding stones.

SEM Studies have revealed that; the deterioration of granite showed that the collapse of the internal structure of the stone disintegration and decoheshion between grains as a result of many crystallized salts especially halite, gypsum and anhydrite which exhibit macro and microcracks, fissures and pits inside the internal structure of rock, furthermore alteration of feldspars to clay minerals and the growth hayphae of biodeterioration within the stone's pores.

XRD Studies have revealed that; the granitic support of rock art consists of quartz, microcline, albite, biotite as main components in addition to calcite as secondary mineral, some samples also contained anhydrite and halite salts. Feldspars minerals and biotite are main components in granite rocks; anhydrite is assumed to be the result of transformation of the gypsum, which caused the surface layer detachment. Also in this case, both of anhydrite and gypsum mostly may have been associated with seepage water from ancient canal or air pollution. Some authors have specifically postulated that these crusts are formed by combination of sulfates from air pollution and Ca from feldspars (26,27). X-ray diffraction patterns also revealed that weathered granite samples contained a high mount of aggressive salt, sodium chloride NaCl due to soluble salts from soil in consequence of direct contact and adjacency between granitic bedrock (rock art support) and the water from the ancient canal recently discovered at site and the ancient egyptian used it to facilitate the transportation granite blocks from the quarry to the Nile (28).

EDX Studies have revealed that; the support is highly weathered by deterioration factors as follow; high iron (Fe) content due to alteration process of iron oxides; convert ferrous-iron to ferric iron (29) which cause coloration of granite with brown, beige to red colors. A high concentration of calcium (Ca) may be attributed to calcite, originated from decomposition of feldspars. The relatively high sulfate (S) and (Ca) contents in the samples may be attributed to the crystallization of calcium sulphate salts (anhydrite and gypsum). (Na) ions perhaps attributed to sodic or plagioclase feldspars components in granite, furthermore the high concentration of chlorine (Cl) and sodium (Na) in the samples suggested that the degradation of granite was also due to the crystallization of sodium chloride NaCl. On the other hand the results of EDX also revealed that the decrease of silica (Si) content in granite samples and this loss is due to alteration process. In addition to the high amount of potassium (K) and Aluminum (Al) respectively attributed to feldspars content of the rock and the presence of titanium (Ti) and potassium (K) correlated with the content of alumina or alteration processes.

Bio-deterioration Studies have revealed that; the isolated fungi and bacteria from the granitic rock art were of these species: **Fungi** such as**;** *Aspergillus Niger*, *Aspergillus flavus*, *Alternaria alternata*, *Paecilomyces carneus* and *Cladosporium uredinicola***, bacteria** such as; *Bacillus alcalophilus* and *Bacillus insolitus*. these genera of microorganisms were cleared by SEM, and their growing correlated with environmental factors and presence of feldspars in granite as a source of nutrients for them (30) also they play aggressive role in physical and chemical weathering of rock art through they contribute to acid dissolution, oxidation, chelation by organic acids or other substances produced by the fungi (31) and physical fracturing induced by root hyphae.

FTIR Studies have revealed that; the medium which was used in rock paintings on the granitic bedrock at the unfinished obelisk quarry was Arabic gum.

5. Suggestions and Recommendations:

- Re-design development schemes for population mass adjacent to the unfinished obelisk site to minimize their impact upon the archaeological site or move it away.
- Completion the archaeological excavations in the site via systematic methods.
- Re-habitation of rock art site through design site management contains foot paths or walkways, (boardwalks), guidance signs, informative signs, low fencing to guide visitors over a site and barriers around the panels as protective procedures.
- Legislation should forbid the inappropriate methods in archaeological documentation of rock art by application physical enhancement process using water, chalk and other substances.
- Recording methodologies should use non-destructive techniques which don't cause damage to rock art being recorded.
- Before conservation procedures of rock art sites, it's necessary to assess the current condition, the risks from humans, natural causes, the environmental pollution and the adjacent setting.

- First, before the conservation works begin, it is necessary to prevent the contact with groundwater from the ancient canal and keeping water out of the rock art through change the waterway in the canal or design a pipeline system or using covered drainage.
- Removing and cleaning vegetation and higher plants in the site mechanically and chemically by using chemical pesticides.
- Consolidation the weak granitic panels with ethyl silicate; Estel 1000 15% in white sprit by suitable mean pipette, brushing or Injection (32).
- Removal soluble salts by suitable poultices cleaning with protective layer of long fiber tissue paper (Japanese or hemp) for protecting water sensitive pigments in rock paintings.
- Dry biological colonization's must be removed from the rock support by dry brushing then applying chemical treatment with suitable pesticides to forbid the microorganisms growth in the future.
- Monitoring the site to observe any re-colonization, if this occurs in any substantial way, then repetition of treatment may be required.
- Applying water diversion system through opening natural drainage lines or drainage channels using sand, cement and the rock on the roof of granitic bedrock for allowing the water to run off far away from the panels.
- Applying dripline technique using appropriate silicone water repellent on vertical panels to prevent them from direct water erosion (flow) by rains effects.
- Redirecting water emanating from cracks or fissures through using silicone building sealant to fill narrow cracks or fissures, while large ones must be filled with Schlarge foam product then silicone sealant applying (33).

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