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The Environment Deterioration Impact on the Granite Rock Art Relief of Seti I in Aswan, Egypt

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Abstract

Aswan is famous for Granite rock art reliefs. Seti I granite rock art relief is one of the most important of them. This granite rock art relief suffers from weakness, fragility, fragmentation and peeling because of many deterioration factors, especially environmental deterioration impacts, such as desert climate with high temperature, residential areas with cafes and shops, and air pollution from exhausts and Kima factory. They can cause chemical weathering. Scientific investigations and analyzes were conducted on this rock art relief such as USB microscope, Polarized (PM) investigation, scanning electron microscope investigation with X-ray energy dispersal unit (EDX) and X-ray diffraction (XRD) analysis to determine the nature and the degree of deterioration, as well as the chemical and mineral composition of the rock and its natural, chemical and mechanical properties. A treatment suggestion to this granite rock art relief has been done.

Keywords

Granite Rock Art Relief, Seti I, XRD, EDX, Deterioration, High Temperature, Air Pollution, Chemical Weathering

1. Introduction

Aswan has received the attention of the great kings of Egypt since the beginning of history, due to its unique location and distinguished products [1]. The ancient Egyptians obtained gold from the lands south of Aswan "Nubia" [2]. The land of Nubia was called in historical periods "Tasti", which means the land of the bow [3]. Aswan quarries are the main source of granite in Egypt [4], since the era of the old Kingdom [5]. Granite comes in third place in terms of its use in the Egyptian civilization (after limestone and sandstone) [6]. The granite rocks taken from Aswan were called syenite [7]. Aswan city is located in the far south of Egypt (**Figure 1**). It is located in the sub-tropical region, at latitude 24˚06' and longitude 32˚54'. Therefore, the city of Aswan is characterized by high temperature and severe dryness, as it is considered within the desert region, as the temperature in this region ranges between 30˚C - 50˚C during the day in summer, which has a minimum value at night in winter, so temperatures in winter reach about 24˚:10˚C [8]. The relief is from King Seti I that is one of the great kings of the nineteenth dynasty (1279-1212 B.C). He is the father of the great pharaoh Ramses II [9], where his name appears in the relief (Men Maat Ra) as in **Figure 2**.

The Current Status of the Granite Rock Art Relief

This relief is located about 100 m to the north of the site of the unfinished Obelisk (**Figure 3**). This relief is not fenced, and there is no minimum degree of protection for it, as it is open to the main street from the east and to houses from the west, north and south. The environmental changes surrounding the area have a significant impact on the deterioration of the relief. Temperature ranges over acceptable ranges which may lead to accelerated deterioration [10]. Continuous changes in temperature play a large role in the processes of deterioration to the rock relief [11]. Granite as an igneous rock is characterized by heterogeneity and variance in mineral composition [12]. In addition to the absence of pores, the temperature circulates very slowly between the different layers of granite, so the surface layers of it are affected exclusively by the sun temperature during the day, so they expand; then these layers soon shrink as a result of the cold night, the repeating of this case consequences exfoliation [13], fragmentation [14], fissures [15], scaling, and brittleness of the surface layer [16] (**Figures 4-6**). This relief is found alone in a residential area with cafes and shops, also on a lively street that connects the city, so it is crowded with transportation and pedestrians (**Figures 7-9**). In front of this relief, there is a sewage sink in which Aswan City Council cars are disposed of (**Figure 10**), which leads to frequent vibrations that lead to mechanical damage such as falling loose and semi-separated crusts. Right of the relief there is a garbage dump (**Figure 11**), which is often burned in this place and the resulting smoke and pollution on the relief (**Figure 12**). There are also, bad habits of the residents such as throwing, burning waste and pouring water next to the relief (**Figure 13**, **Figure 14**). This relief is located in an area crowded with cars and not far from Kima Factory, where air pollution gases abound, so the chemical weathering could be happening, which depends on the presence of water [17] pollution gases and soluble and insoluble solids [18], which decomposes the mineral components of granite, such as feldspar, which decomposes into clay minerals [19]. Researches on the Seti I granite rock art relief are rare so; this research aims to study this rock art relief and its deterioration to pay close attention to more researches.

Figure 1. Map of Egypt shows Aswan location is in the south of Egypt.

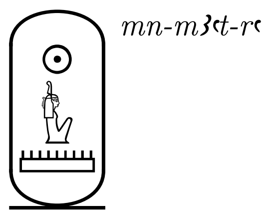

Figure 2. The s name of King Seti I.

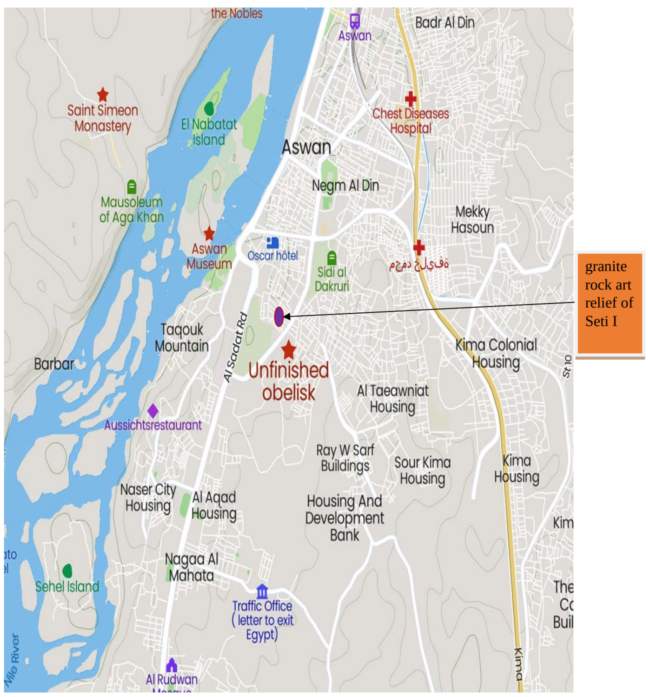

Figure 3. Map of Aswan shows the location of granite rock art relief of Seti I near to the unfinished obelisk and Kima factory.

Figure 4. Corrosion, loss, gaps, and Peel off the text hieroglyphic.

Figure 5. Corrosion, loss, gaps, and Peel off the text hieroglyphic.

Figure 6. Name of the king suffers from Exfoliation and fragmentation.

Figure 7. Cars close to relief.

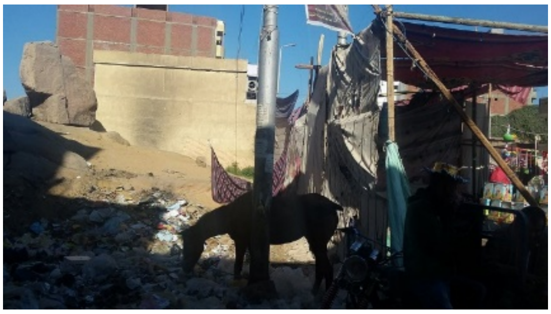

Figure 8. Animals and rubbish beside relief.

Figure 9. Crowd beside relief.

Figure 10. A sewage sinks beside relief.

Figure 11. Rubbish prank.

Figure 12. Calcifications covering relief.

Figure 13. Waste on relief and pouring water.

Figure 14. Effects of burning backgrounds.

2. Materials and Methods

2.1. Materials

Samples were collected from the granite quarry and prepared for study by laboratory investigations and analyses.

2.2. Methods

Laboratory investigations and analyzes were achieved to identify the physical properties, chemical and Mineral composition [20], morphological features, and modifications of the samples. Investigation with the USB microscope was achieved using HC630 USB measurement camera, Sensor: CMOS 1/1.8, Resolution: 6.3 MP, Frame rate: 30FPS. Investigation with polarization microscopy (PM) was carried out using polarizing microscope (Olympus BX50, Japan) associated with computer software imaging system. Investigation with scanning electron microscopy (SEM) and analyzes with (EDX) were achieved using SEM Microscope Model JEOL JSM 5400 LV: EDX Link ISIS - Oxford Detector High Vacuum. Analyzes with X-ray diffraction (XRD) were carried out using X-ray model X' Pert Pro Phillips MPD PW 3050/60 X-ray diffractometer. It is provided with a proportional digital counter and Nickel-filtered Cu - kα radiation at 40 kv and 30 mA, over an interval (0˚ - 50˚) at a scanning speed of 2/min in the XRD lab of the HBRC. The investigations by (PM), (SEM) and the analyzes (EDX) and (XRD) carried out in the National Research Center of Housing and Building, Raw Building Materials and Processing Technology Research Institute in Cairo.

3. Results

3.1. Investigation with USB Microscope

Through field Observations and investigation with the USB microscope, weakness, fragility, fragmentation and peeling of the surface layer were observed, as well as the occurrence of deep cracks (**Figure 15**, **Figure 16**).

3.2. Polarizing Microscope (PM) Results

Three samples were prepared in cross section to investigate with a polarizing microscope, the results were as follows:

Figure 15. Erosion and peeling of the surface layers.

Figure 16. Weakness, fragility, fragmentation and cracks.

1) The first sample shows the presence of quartz grains, most of them are coarse-grains in different sizes and shapes and slightly altered racked cross-hatched microcline (**Figure 17**). In another part of the sample shows the presence of large crystal of string perthite and some cracks (**Figure 18**). In another part of the sample shows the presence of the main mineralogical composition of the studied altered granite such as some plagioclase altered to epidote, some quartz, som microcline, some feldspars are altered to clays and presence of opaque were also noticed and some cracks (**Figure 19**).

2) The second sample shows the presence of plagioclase, some quartz, some microcline, and some cracks (**Figure 20**). In another part of the sample shows the presence of congated biotite crystal surrounded by opaque and most biotite are altered to serecite (**Figure 21**). In another part of the sample shows the presence of some quartz, some microcline, and some biotite (**Figure 22**).

3) The third sample shows the presence of some quartz and some biotite (**Figure 23**). In another part of the sample shows the presence of the plagioclase altered to epidote (**Figure 24**).

3.3. Scanning Electron Microscopy (SEM) Results

Three samples of granite from the site were examined using scanning electron microscope, the results were as follows:

1) The first sample was examined under a scanning electron microscope: The sample suffers from physicochemical weathering, as there are many spread of gaps and cracks impurities in the sample at a magnification force (2000×), as in **Figure 25**, as well as fragmentation and distortion of mineral crystals at a magnification force (4000×) as in **Figure 26**.

2) The second sample was examined under a scanning electron microscope: The sample suffers from fissures, foliation, and separations, at a magnification

force (1000×), as in **Figure 27**, in the magnification force (2000×) shows the sample suffers from foliation, separation, and crystal deformation of the minerals composition from the physicochemical weathering), as in **Figure 28**.

3) The third sample was examined under a scanning electron microscope: The sample suffers from cracks, separations, grains disintegration and incoherence at a magnification of 4000, as in **Figure 29**, in the magnification of 8000 shows the sample suffers from Diffusion of gaps, cracks, deformation of grains, mineral decomposition and disintegration, as in **Figure 30**.

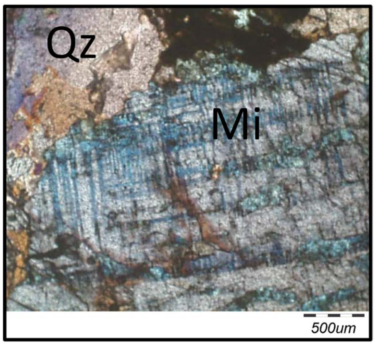

Figure 17. Photomicrograph shows quartz (Qz) coarse-grains and slightly altered microcline (Mi).

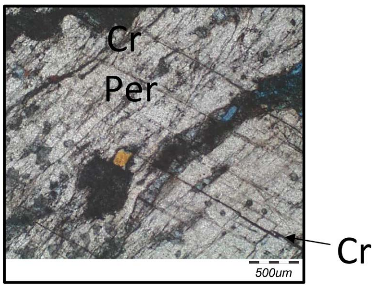

Figure 18. Photomicrograph shows large crystal of string perthite (per) and Cracks (cr).

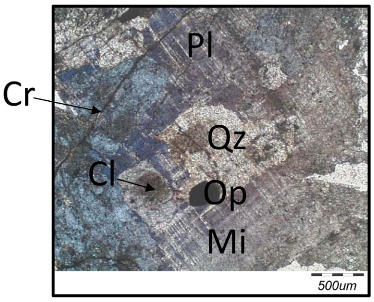

Figure 19. Photomicrograph shows some plagioclase (pl) altered to epidote, some cracks, som quartz, some microcline, some feldspars are altered to clays (cl) and presence of opaque (op).

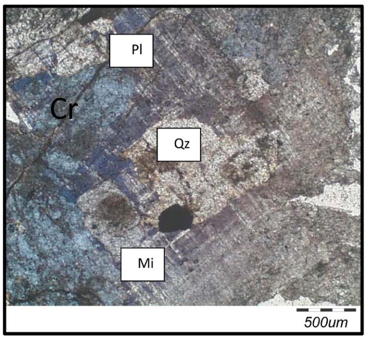

Figure 20. Plagioclase, quartz, microcline, and some cracks.

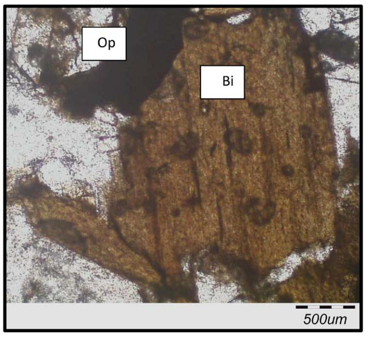

Figure 21. Biotite (bi) crystal surrounded by opaque.

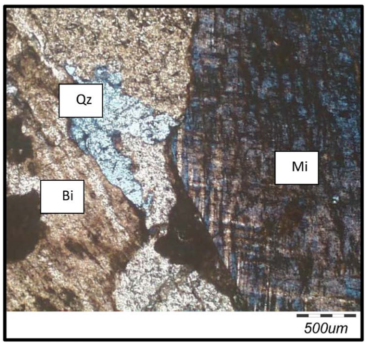

Figure 22. Some quartz, some microcline, and some biotite.

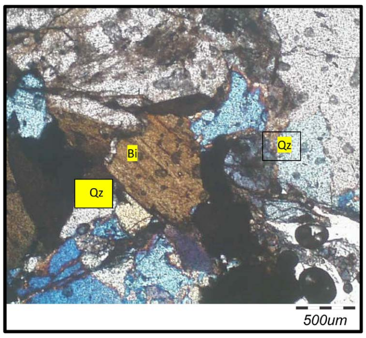

Figure 23. Some quartz and some biotite.

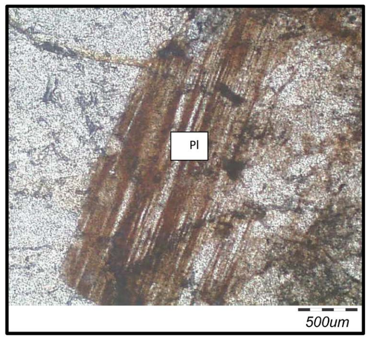

Figure 24. Some plagioclase.

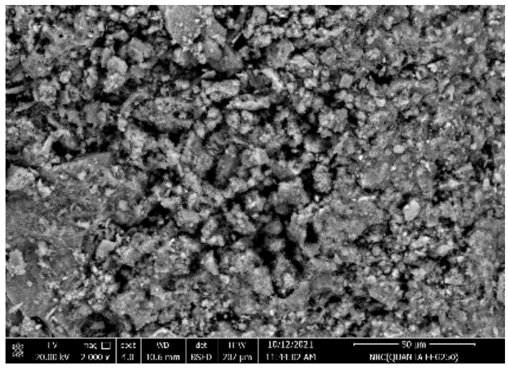

Figure 25. Gaps and cracks, 2000×.

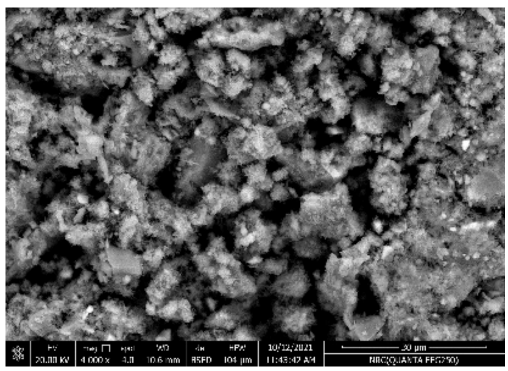

Figure 26. Fragmentation, 4000×.

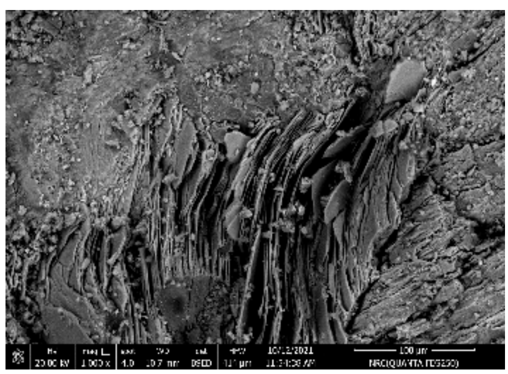

Figure 27. Fissures, foliation, cracks and separations, 1000×.

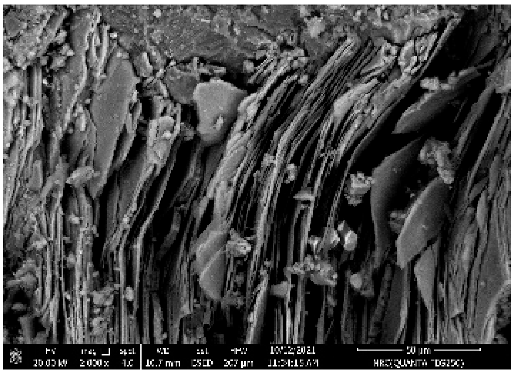

Figure 28. Crystal deformation, 2000×.

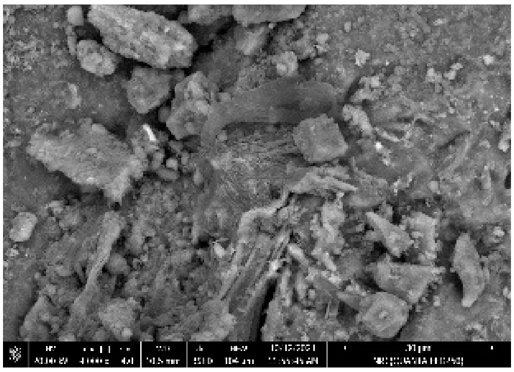

Figure 29. Disintegration and incoherence, gaps and cracks 4000×.

Figure 30. Deformation and disintegration 8000×.

3.4. Analyzed by a Scanning Electron Microscope Equipped with an EDX Unit

1) The first sample was analyzed by a scanning electron microscope equipped with an EDX unit, and the results of the analysis were as in Figure 31. It proved the presence of potassium oxide, sodium oxide, aluminum oxide, silicon dioxide, calcium oxide, iron oxide, sulfur dioxide and chlorine.

2) The second sample was analyzed by a scanning electron microscope equipped with an EDX unit, and the results of the analysis were as in Figure 32, it proved the presence of sodium oxide, magnesium oxide, aluminum oxide, silicon dio-

xide, potassium oxide, calcium oxide, titanium oxide, sulfur dioxide and iron oxide.

3) The third sample was analyzed by a scanning electron microscope equipped with an EDX unit, and the results of the analysis were as in Figure 33, it proved the presence of sodium oxide, magnesium oxide, aluminum oxide, silicon dioxide, potassium oxide, calcium oxide, chlorine and iron oxide.

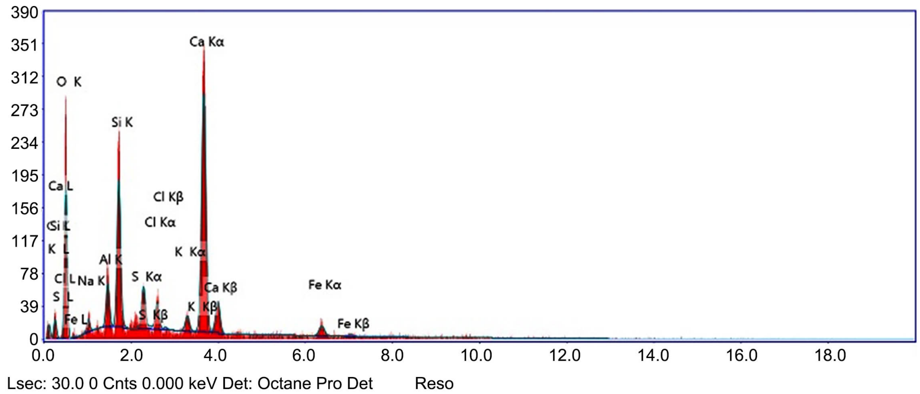

Figure 31. Potassium oxide, sodium oxide, aluminum oxide, silicon dioxide, calcium oxide, iron oxide, sulfur dioxide and chlorine.

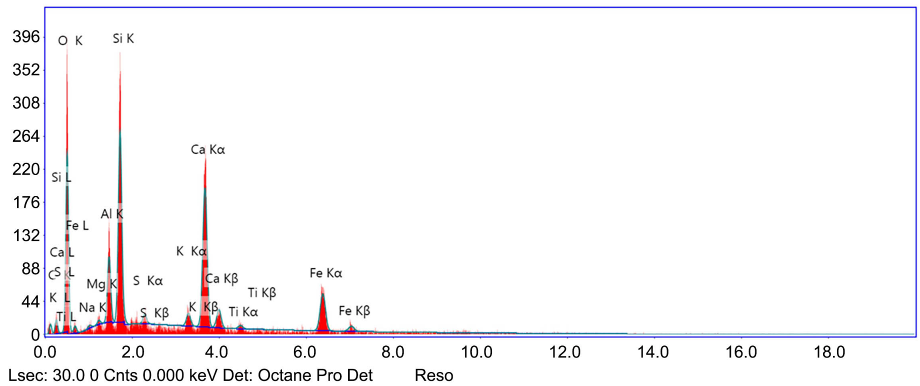

Figure 32. Sodium oxide, magnesium oxide, aluminum oxide, silicon dioxide, potassium oxide, calcium oxide, titanium oxide, sulfur dioxide and iron oxide.

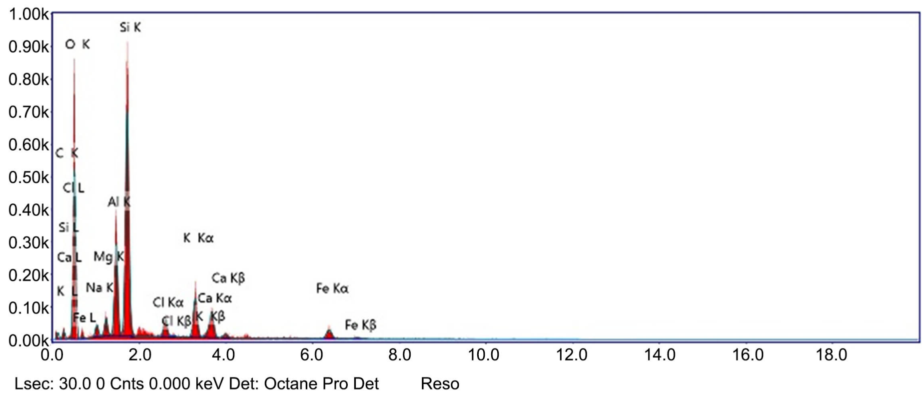

Figure 33. Sodium oxide, magnesium oxide, aluminum oxide, silicon dioxide, potassium oxide, calcium oxide, chlorine and iron oxide.

3.5. XRD Results

1) Sample 1: According to XRD analysis, as in Figure 34, the first sample are Quartz SiO_2, Albite (NaCa) $(AlSiO_{8})$, Microcline $KAlSi_3O_8$, and Biotite $K_2(FeMgTi)(AlSiO_{20})(OH)_4$, as in Table 1.

2) Sample 2: According to XRD analyses, as in Figure 35, the second sample are Quartz SiO_2, Microcline $K_2O \cdot Al_2O_3 \cdot 6SiO_2$, Rutile TiO_2, Albite $Na(AlSi_3O_8)$ and Illite $KAl_2(Si_3AlO_{10})(OH)_2$, as in Table 2.

3) Sample 3: According to XRD analyses, as in Figure 36, the third sample are Quartz SiO_2, Microcline $K_2O \cdot Al_2O_{3.6}SiO_2$, and Albite Na $(AlSi_3O_8)$, as in Table 3.

4) Sample 4: According to XRD analyses, as in Figure 37, the forth sample are Quartz SiO_2, Microcline $K_2O \cdot Al_2O_{3.6}SiO_2$, Albite $Na(AlSi_3O_8)$, and Illite $KAl_2(Si_3AlO_{10})(OH)_2$, as in Table 4.

Table 1. Sample 1 XRD results.

Sample no. 1	Mineral	Relative %	Card number
1	Quartz SiO_2	50.4	(5 - 0490)
2	Microcline $KAlSi_3O_8$	22.2	(01 - 0705)
3	Albite $(NaCa)(AlSiO_8)$	20.6	(02 - 0739)
4	Biotite $K_2(FeMgTi)(AlSiO_{20})(OH)_4$	6.8	(04 - 0144)

Table 2. Sample 2 XRD results.

Sample no. 2	Mineral	Relative %	Card number
1	Quartz SiO_2	50.2	(5 - 0490)
2	Microcline $KAlSi_3O_8$	20.9	(01 - 0705)
3	Rutile TiO_2	20.1	(21 - 1272)
4	Albite $Na(AlSi_3O_8)$	5.8	(02 - 0739)
5	Illite $KAl_2(Si_3AlO_{10})(OH)_2$	3.0	(25 - 0001)

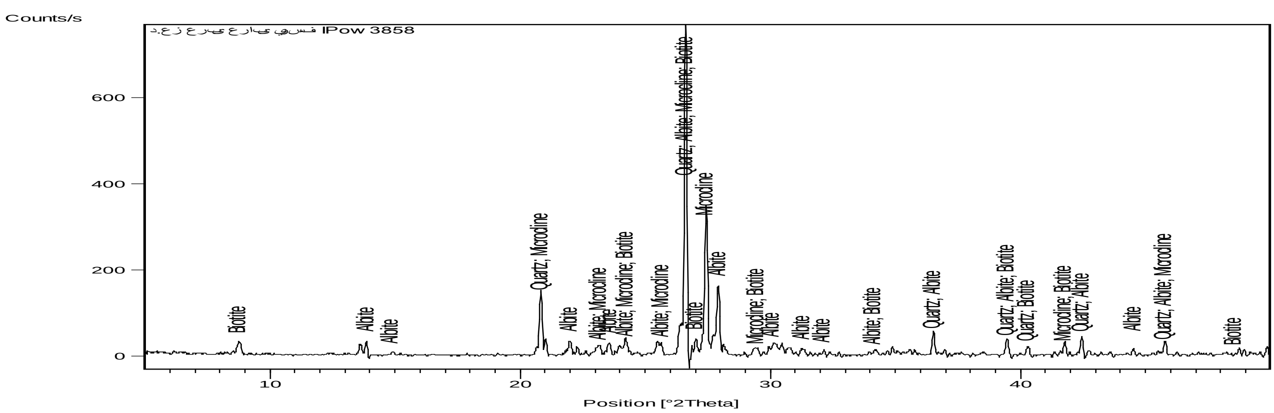

Figure 34. Quartz, Albite, Microcline, and Biotite.

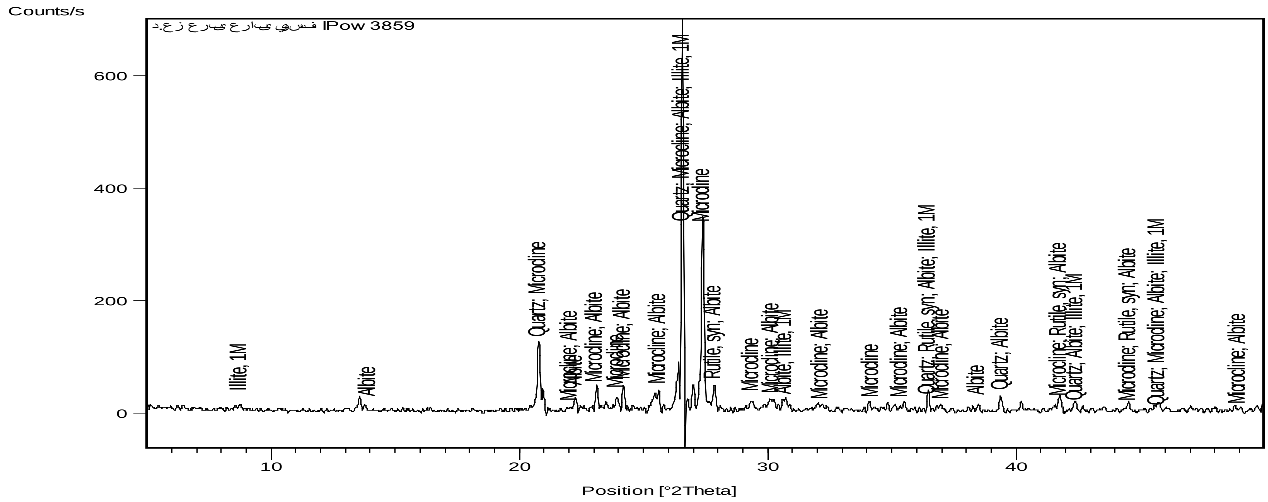

Figure 35. Quartz, Microcline, Rutile, Albite, and Illite.

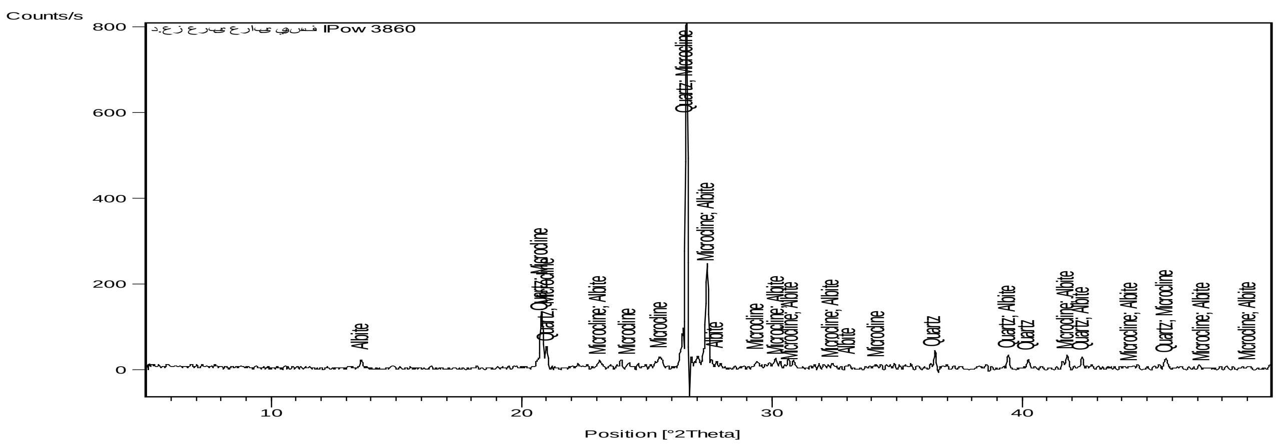

Figure 36. Quartz, Microcline, and Albite.

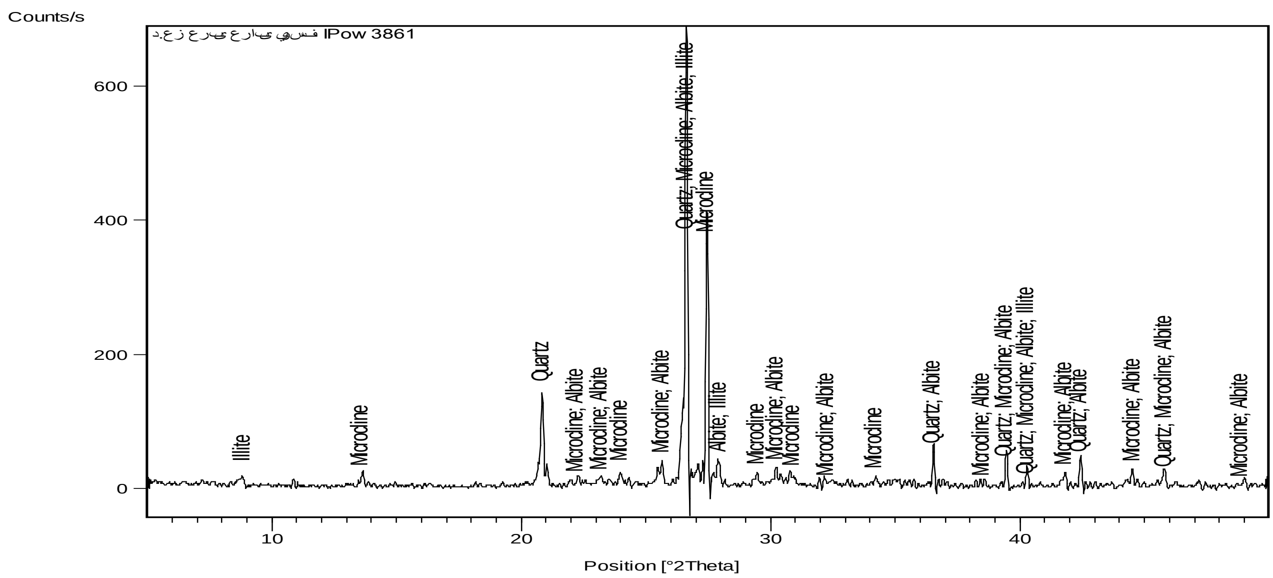

Figure 37. Quartz, Microcline, Albite, and Illite.

Table 3. Sample 3 XRD results.

Sample no. 3	Mineral	Relative %	Card number
1	Quartz SiO_2	62.5	(5 - 0490)
2	Microcline $KAlSi_3O_8$	33.6	(01 - 0705)
3	Albite $Na(AlSi_3O_8)$	3.9	(02 - 0739)

Table 4. Sample 4 XRD results.

Sample no. 4	Mineral	Relative %	Card number
1	Quartz SiO_2	36.6	(5 - 0490)
2	Microcline $KAlSi_3O_8$	35.4	(01 - 0705)
3	Albite $Na(Al\ Si_3O_8)$	23.3	(02 - 0739)
4	Illite $KAl_2(Si_3AlO_{10})(OH)_2$	4.7	(25 - 0001)

4. Results Discussion

The USB microscope investigations show the weakness, fragility, fragmentation and peeling of the surface layers. Chemical weathering due to the pollution of the granite rock art relief area with pollution gases and water, decomposed the mineral components of the granite, especially for native elements [21] [22]. Heavy traffic on roads, landfills and industries is the source of atmospheric pollution worldwide [23]. Chemical decomposition always occurs for rock formations close to gases and water, which they are often the surface layers [24], as in the relief, subject of the study. New minerals are produced as a result of the effect of granite chemical weathering [25]. Orthoclase feldspar decomposes into silica, potassium salts KX and clay minerals [26]. Plagioclase feldspar decomposes to sodium NaX and calcium salts CaX, which decomposes to hydrated aluminum silicate $Al_2Si_3\ nH_2O$, while potassium oxides K_2O, sodium Na_2O and calcium CaO are soluble in the form of carbonates and chlorides [27]. From the study of representative samples of Aswan granite rocks, a geochemical study showed that these rocks contain a high percentage of potassium and sodium minerals, ferrous oxide FeO and ferric oxide Fe_3O_4, but they are poor in the percentage of aluminum oxides Al_2O_3 and magnesium oxide MgO. From the study of some feldspar crystals, it became clear that the plagioclase surrounding the potassium feldspar crystals is rich in calcium, and it also became clear that the crystallization temperature of these rocks in Aswan ranges between 500˚C: 600˚C at a pressure of 5 kilobars [28] [29]. By studying the amphibole mineral $[7(Mg{\cdot}Fe)2(Si_4O_{11}(OH)]$ it was found that it is represented in the iron-rich hornblende mineral. It characterized by a high percentage of Fe^+, which ranges between 0.84:0.89, and a low percentage of aluminum and titanium. The hornblende explains the metamorphic genesis of this mineral [30]. It is a strong relationship between the properties of archaeological materials and the surrounding environmental conditions and deterioration phenomena [31]. As well as the occurrence of deep cracks due to the large and continuous change in temperature [32]. The petrography study confirmed: that the studied samples consisted mainly of quartz, alkali feldspars (microcline) and plagioclase while microcline greater than plagioclase. The studied sample contains more than 20%, microcline about 70% while plagioclase, biotite and some opaque represented the other percentage. It can be also noticed that most biotite is altered to sericite. On the other hand, some plagioclase is altered to clay minerals represented by dark brown patches that appeared within lamellar twining of plagioclase crystals. Minor within some crystals are associated also with some major cracks that cuts through some parts of the main texture. It can be also noticed that the main texture of the studied sample is ophitic and perthitic. The examined using the scanning electron microscope showed the spread of gaps, cracks, fragmentation, grains disintegration and incoherence, impurities, and distortion and deformation of mineral crystals, also suffers from fissures, foliation, and separations from the physicochemical weathering, which is consistent with the results of polarized microscopy. The analysis by a scanning electron microscope equipped with an EDX unit proved the presence of potassium oxide, sodium oxide, aluminum oxide, silicon dioxide, calcium oxide, iron oxide, magnesium oxide, titanium oxide, sulfur dioxide and chlorine. The analysis by XRD found Quartz SiO_2, Albite $(NaCa)(AlSiO_{8})$, Microcline $KAlSi_3O_8$, Biotite $K_2(FeMgTi)(AlSiO_{20})(OH)_4$, Rutile TiO_2, and Illite. The high percentage of albite and alite in the samples confirm the chemical decomposition of some granite into clay minerals, which is consistent with the results of EDX.

5. The Suggest Treatment and Conservation Plan

1) The most important step, before starting the restoration and conservation work, a fence must be made surrounding the relief to protect it and prevent it from infringement.

2) Full registration of the relief using the modern devices and methods.

3) More archaeological study of the relief.

4) Consolidation of loose and separated parts of the relief.

5) The relief should be cleaned from soot and foreign things using mechanical cleaning with brushes of various sizes [33], also some wooden and metal brushes can be used to remove some hard surface plankton that are strongly adhesive to the surface, after being wetted with water mixed with ethyl alcohol [34].

6) Filling the cracks.

6. Conclusions

The research reached important results in identifying the mineral composition and the nature of the texture of the rock granite relief of Seti I in Aswan. This granite relief suffers from the impact of environmental degradation. The surface layers suffer from weakness, fragility, fragmentation, peeling, and decompose the mineral components because of the chemical weathering, with the high percentage of clay minerals. The analysis proved the presence of Quartz, Microcline, Albite, Illite.

Based on these results, a treatment and conservation proposal was made.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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